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Idaho National Engineering Laboratory

Alternatives to Reduce Corrosion of Carbon Steel Storage Drums

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Lockheed Idaho Technologies Company

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ABSTRACT

The major tasks of this research were (a) pollution prevention opportunity assessments on the overpacking operations for failed or corroded drums, (b) research on existing container corrosion data, (c) investigation of the storage environment of the new Resource Conservation and Recovery Act Type II storage modules, (d) identification of waste streams that demonstrate deleterious corrosion affects on drum storage life, and (e) corrosion test cell program development.

Overpacking is an expensive process that consumes not only time and materials to perform the overpacking, but also requires 50% more storage and disposal space, and even more in management costs. It has been estimated that 10% (2,400) of the drums from the air support building will have to be overpacked and up to 50% (50,000) of the drums from the earthen covered storage will have to be overpacked. Pollution prevention opportunity assessments performed showed potential a cost saving of $110 million. Pollution prevention evaluations performed on the pollution prevention opportunity assessment and Idaho National Engineering Laboratory drum inventory data projected a potential savings of $800 million.

The new Resource Conservation and Recovery Act Type II storage modules constructed for the storage of the transuranic waste and transuranic mixed-waste drums were found to have a problem with excessive condensation generation. A mass and heat transfer computer model of the dew point temperature within Building 628 was written. The model showed that during a 4-day period in February 1995, 44 hours of condensation would occur.

Twenty-one waste streams from five U.S. Department of Energy (DOE) sites within the DOE Complex were identified to demonstrate a deleterious effect to steel storage drums. The major components of these waste streams include acids, salts, and solvent liquids, sludges, and still bottoms. The solvent-based waste streams typically had the shortest time to failure: 0.5 to 2 years.

The results of this research support the position that pollution prevention evaluations at the front end of a project or process will reduce pollution on the back end.

CONTENTS

FIGURES

ACRONYMS

ASB-1/ASB-2	Air Support Buildings 1 and 2
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
DRU	Drum Refurbishment Unit
HROI	High Return of Investment
INEL	Idaho National Engineering Laboratory
MWSF	Mixed Waste Storage Facility
P^2	pollution prevention
PPOA	pollution prevention opportunity assessment
RCRA	Resource Conservation and Recovery Act
RWMC	Radioactive Waste Management Complex
SSCS	Sort, Segregation, and Compaction System
SWB	standard waste box
SWEPP	Stored Waste Examination Pilot Project
TRU	transuranic waste
TRU-M	transuranic mixed-waste
VOC	volatile organic compound
WMin	Waste Minimization
WIPP	Waste Isolation Pilot Plant

Alternatives to Reduce Corrosion of Carbon Steel Storage Drums

1. INTRODUCTION

This engineering study was prepared as an integral part of the Idaho National Engineering Laboratory (INEL) Waste Minimization (WMin) and pollution prevention (P^2) program for the U.S. Department of Energy (DOE) Office of Environmental Restoration and Waste Management. This was study was managed by Lockheed Idaho Technologies Company under U.S. Department of Energy Idaho Operations Office (DOE-ID) Contract DE AC07 94ID13223.

This engineering study was initiated in response to a request for proposals by EM-334 under their Special Projects Program within the DOE WMin/P^2 Program. The drivers for the WMin/P^2 Program include DOE Orders 5400.1 and 5400.3.

The focus of this research is to reduce the amount of waste generation at the INEL by reducing corrosion or the impact of corrosion on storage containers.

1.1 Purpose and Scope

The purpose of this research was to approach the drum corrosion problems from a WMin/P^2 point of view. The corrosion problem can be divided into two parts: what is causing the corrosion and impact of overpacking the corroded containers. The overpacking of drum generates 50% void volume, and the overpacking of 12,000 drums will generate an additional 1,254 m^3 of extra volume to dispose of.

There are approximately 150,000 55-gal, painted steel, drums containing hazardous and radioactive waste stored on the INEL. There are two major sites on the INEL for the storage of these drums. The Mixed Waste Storage Facility (MWSF) stores about 1,000 drums of mixed waste and the Radioactive Waste Management Complex (RWMC) stores about 140,000 drums of transuranic (TRU) waste and TRU-mixed (TRU-M) waste drums; an aerial view of the RWMC is shown in Figure 1. These containers are in various stages of deterioration ranging from new condition to detectible leaks. When a drum fails in service or is no longer considered safe for waste storage, the drum is overpacked. At the RWMC there are two typical overpack containers, (a) a 83-gal steel drum, and (b) a standard waste box (SWB). A 83-gal drum holds one 55-gal drum while a SWB holds four 55-gal drums. There are several negative consequences associated with the overpacking of 55-gal drums of radioactive and hazardous wastes. These include:

- A 50% increase (from 55-gal to 83-gal) of disposable volume (the void volume increase with a SWB is also about 50%)
- A loss of the limited storage/disposal space
- More storage/disposal facilities needed to store the overpacks

Figure 1. Photograph of the Radioactive Waste Management Complex.

- Increase of disposal costs (disposal is based on the final container size not the amount of waste)
- Cost for the overpack drum
- Labor to perform the overpack
- Subsequent assay inspection of waste at great costs
- Extra drum tracking and management costs.

There are other consequences of overpacking into 83-gal drums that are unique to the RWMC:

- There is no existing method for shipping 83-gal drums to WIPP
- There is no disposal facility that will take 83-gal drums of TRU waste
- The 83-gal drums will have to be opened and the 55-gal drum retrieved before shipping or disposal
- When a 55-gal drum is overpacked, it is not being made "road ready" for future Waste Isolation Pilot Plant (WIPP) disposal
- There is no facility or equipment at the RWMC to open the overpack drum.

There are occasions that overpacking is the only alterative, but this report will show that there are alternatives to the current "end-all" approach of overpacking.

This study used standard science and engineering techniques along with tools used by P^2, to focus on both the treatment of corrosion symptoms on drums and the cause of the corrosion on drums. The goal of the research was to evaluate the drum management methods of overpacking the drums and to determine what can be done to solve the rusting of the drums. To reach these goals, the following strategy was used, (a) perform pollution prevention opportunity assessment (PPOA) on the overpacking operations when failed or corroded drums are overpacked, (b) research the RWMC existing container corrosion data, (c) investigate the corrosive environment of the new Resource Conservation and Recovery Act (RCRA) Type II storage modules at the RWMC, (d) identify waste streams that demonstrate deleterious or preferential corrosion effects on drum storage life, and (e) develop a corrosion test cell and testing program.

The research is limited primarily to storage at the RWMC and MWSF for the above strategies except for item d listed above. Item d, "Identification of waste steams that demonstrate deleterious or preferential corrosion effects on drum storage life" was expanded to include all DOE storage sites and facilities who would respond to a questionnaire. The item d was a milestone report submitted in June 1995.

1.2 Background

The event that started the corrosion studies was the failure of several drums from internal corrosion at the MWSF. Several low-level mixed waste drums containing nitric acid solution, which had been used to remove contaminated mercury residues, are stored at the MWSF. The generator of the waste attempted to solidify the sludge, but the sludge de-watered during storage.[1] At the water level inside of the drum, the synergism of the waste stream components were optimum for pin hole corrosion. In time, corrosion pin holes penetrated the drum wall and blistered the exterior paint. If the paint blister were scrapped off, liquid would begin to ooze out of the pin hole. Over the last few years, all drums of this waste stream have been overpacked into 83-gal polyethylene (poly) drums.

As a result of the pin hole corrosion problem, the INEL Container Integrity Committee was consulted. After meeting with the committee and hearing about the corrosion problems of the 140,000 drums at the RWMC, it was obvious that the drum management process at the RWMC had a high potential for WMin/P^2 opportunities.

The idea for this research began with some initial calculations on the number of overpack containers, cost to overpack, and the loss of disposal space, and the discovery of tremendous savings in disposal space and overpacking costs were the driving force to perform this research. The PPOA on the overpack operations projected a potential cost savings of $105 million, and other P^2 evaluations of other potential cost savings were over $800 million, these potential savings were higher than originally estimated.

Figure 2 shows an at-risk drum of radioactive waste stored at the RWMC. It has failed the inspection criteria for excessive rust and it has been set aside as a drum "to be overpacked" (note: the "OP" label in the figure). It has been estimated that there will be 12,000 of these "OP" drums identified over the next 6 years as the drums at the RWMC are moved from the covered and protected storage areas into the new RCRA Type II storage modules.[2]

Figure 2. Photograph of OP drum.

2. METHODOLOGY

This project employed a systems engineering approach. The systems engineering elements used were (a) identify the function, (b) requirements identification for each deliverable, (c) task architecture, and (d) identification of measurables and tests. The systems engineering approach forces the project engineers to focus on functions, requirements, methodologies, and a method to test the results. The systems engineering plan is outlined in Figure 3.

This research was divided into nine deliverables or tasks:

- Four PPOAs: one PPOA on the overpacking of wastes and one on the clean-up of breached drums at both the RWMC and the MWSF
- Existing Corrosion Data Evaluation
- Research Environmental Forces in RCRA Type II Storage Modules
- Report on Findings
- Corrosive Waste Streams Identification
- Test Cell Design
- Collect Test Drums
- Test Cell Specimens Design
- Final Report.

2.1 Task 1: Pollution Prevention Opportunity Assessments

Four PPOAs were scheduled to be performed for this project: two for the RWMC and two for the MWSF. At each of these facilities, one PPOA was to assess the process of overpacking the at risk drums and one PPOA was to look at the process of cleaning-up breached drums. The PPOA format used was the new software program developed by the P^2 Unit at the INEL. The software was developed about the same time these PPOAs were started. In fact, the PPOAs on the overpack operations at the RWMC and MWSF were an unofficial beta test of the software. Because of the complexity of the processes, the software was revised several times over eight months until it reflected what needed to be assessed. There were actually three PPOAs performed to more fully assess the overpacking operations. Two at the RWMC and one at the MWSF. The software was functional and the results of the PPOAs pointed directly to several P^2 opportunities and issues. The PPOAs also provided the data to assist in developing further P^2 cost saving evaluations.

SYSTEMS ENGINEERING PLAN FOR 1ST YEAR OF THE CORROSION, MATERIAL OPTIMIZATION AND REFURBISHMENT STUDIES FOR HAZARDOUS AND RADIOACTIVE WASTE 55-GALLON STEEL STORAGE DRUMS

Level 1

FUNCTIONS	REQUIREMENTS	ARCHITECTURE	TEST	REFERENCE
Reduce drum corrosion waste	Eliminate overpacking	Drum refurbishment Unit	Report /design/ build prototype system	

Level 2

FUNCTION	REQUIREMENT	ARCHITECTURE	TEST	REFERENCES
Perform PPOA (overpack)	Complete per the P2 Unit format and check list.	PPOA software package and hard copy.	Report signed by supervisor	
Perform PPOA (clean-up)	Complete per the P2 Unit format and check list	PPOA software package and hard copy.	Report signed by supervisor	
Identify waste streams	List INELwaste streams related to drum over pack and clean up.	Electronic chart and hard copy	Compare with current waste min. plan	
Characterize rust	Identify rust patterns and types present on INEL metal storage drums and compare with standards.	Electronic chart and hard copy	Independent technical review of report	
Investigate RCRA module environment	Audit modules, identify and list rust enhancing characteristics	Field survey and audit report	Approved by G. Beitel	
Investigate drum storage configuration	Audit stacking arays, identify and list rust enhancing characteristics	Field survey and audit report	Approved by G. Beitel	
Investigate drum storage pallets	Audit and investigate pallet materials, identify and list rust enhancing characteristics	Field survey and audit report	List/Report	

Figure 3. Systems Engineering Plan.

Identify waste streams deleterious to steel drums	Identify INEL overpacked drums, compare drum failure to wastes streams. Internal vs external rust	Electronic chart and hard copy	List/Report
Design test cell	Identify standard tests for corrosion coupons. Itemize the test plan and schedule.	Report	Drawing/Report
Level 3			
Identify test coupons types	List material, coupon sizes and coupon numbers per standardized tests	Electronic chart and hard copy	List/Report
Describe coupon testing program	List tests and environments per standardized tests	Electronic chart and hard copy	List/Report
Describe coupon test set-up	Prepare DOP for testing	Word processor and hard copy	Approved procedure

Figure 3. (continued).

2.2 Task 2: Quantify Existing Corrosion Data

The initial goal of this task was to characterize the rust patterns within the storage environment at the RWMC. Drums have been stored at the RWMC for 30 years, and a data bank of rust patterns relative to the storage environment have been established for those drums stored in manned entry facilities. The drums stored under earthen storage are not visible and can not be characterized. The drums stored above ground in the Air Support Buildings (ASBs) 1 and 2 at the RWMC are being moved to meet the State of Idaho Consent Order. Since the drums are being moved, they are readily available for visual inspection. About half of the available drums for inspection or rust characterization have been moved into the new RCRA Type II storage modules and the rusty or at risk drums have been separated and segregated from the non-rusty drums.

2.3 Task 3: Research Environmental Forces in RCRA Type II Storage Modules

The drums at the RWMC have been stored in two conditions: covered storage and in the ASBs. The 1970's drums were placed under earthen storage. The drums were stacked tightly together into groups called cells on an asphalt pad. Boxes were stacked around the drums to corral the drums. Then a plywood and plastic barrier or tarp was placed over the drums before covering with dirt. There are about 100,000 drums currently stored in this manner. The ASB-1 and ASB-2 have stored about 40,000 drums. Air Support Building-1 stored about 5,000 drums and ASB-2 about 35,000. However, these buildings are currently being emptied of their drums. A consent order from the State of Idaho requires all drums be moved into new RCRA Type II storage modules for storage.

The ASBs kept the weather off of the drums, but the environmental conditions were not ideal for a corrosion free environment. In the winter and spring months, the dew point temperatures of the outside air, forced into the building for support, was high enough that condensation or dew would condense on the drums. The condensation would turn to frost on the drums when the temperature of the drums was below freezing and to free water when not freezing. Water running down the outside of the drums causing rust streaks. See Figure 4 for an example of streaking.

In concert with these environmental conditions, the drums were stacked on fire retardant treated plywood. Studies, reports, and articles have been written which propose that the fire retardant plywood enhanced the corrosion of the steel. However, other studies have concluded that the retardant is not corrosive. Nevertheless, there is a dominate rust band typically at the bottom of the drum. It is possible that the plywood soaks up[3] the water of condensation (described above) and rusts the bottom edge of the drum. Subsequently, the water would wick-up through the rust onto the drum and further enhance the corrosion. See Figures 5a and 5b for rust patterns along the bottom edge of the storage drums.

As a result of the State of Idaho Consent Order to move the drums to the RCRA Type II storage modules, seven new modules are in various stages of construction. Each module is 150 ft wide and 240 ft long and were designed to hold about 19,000 drums. The drums are stacked into two rows of drums within a building. Typically the stacks consists of 440 drums: 4 drums wide, 5 drums high and 22 drums long.

Figure 4. Photos of streaking.

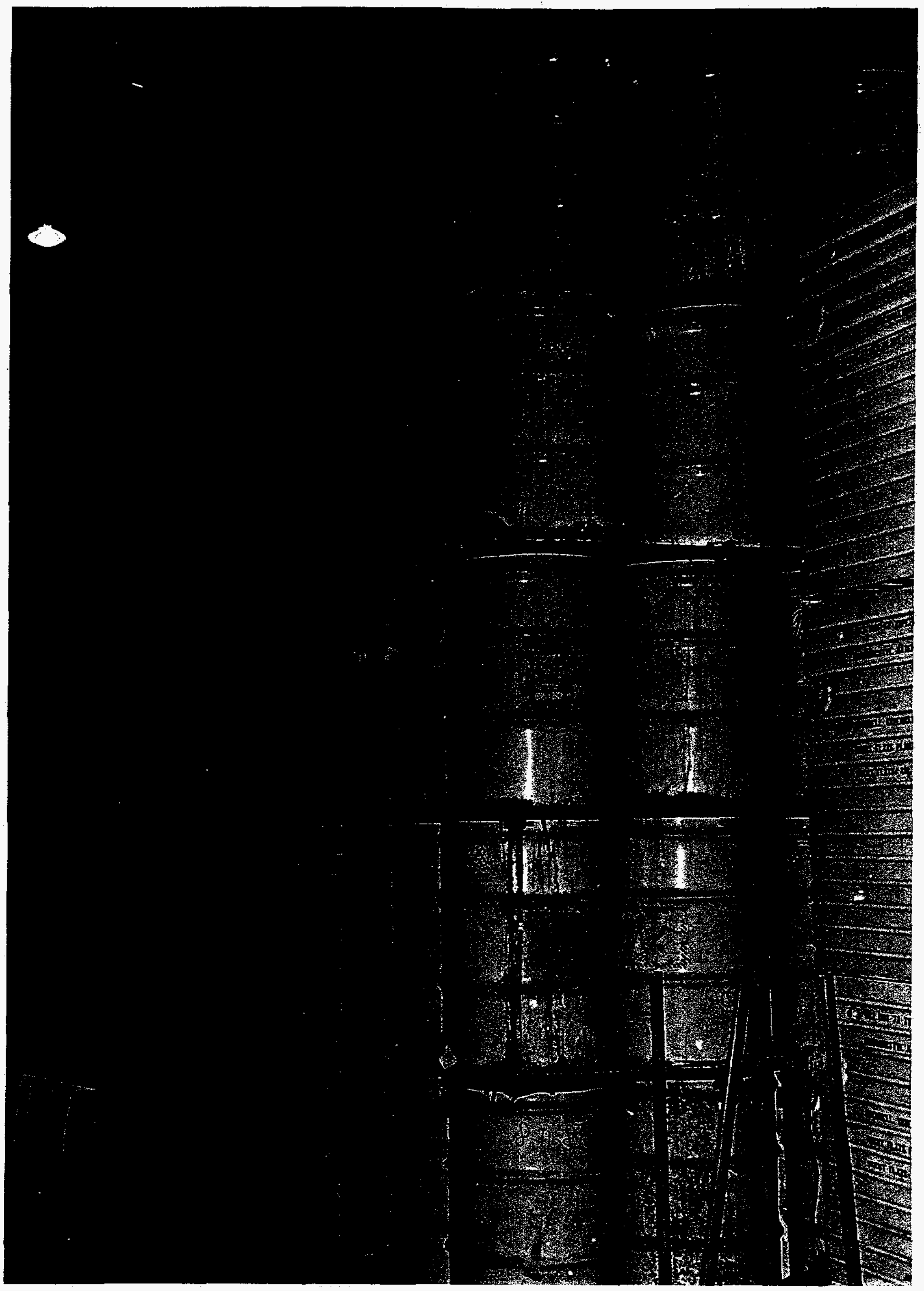


Figure 5a. Photo of drum stack with bottom edge rust patterns in ASB-II.

Figure 5b. Photo of close up of bottom ring rust pattern.

The objective of this sub-task was to research the environmental elements or forces in RCRA Type II storage modules. It was proposed that an assessment of the building be performed to determine if there were any obvious or not so obvious physical or intrinsic factors that would lead to accelerated corrosion of the steel drums. This investigation assessed the first completed module, Building 628, which was about 70% full of drums at the time of the assessment (March 1995). The assessment was subdivided into the following parts:

- Plan the activity
- Develop an check sheet
- Select the assessment team
- Conduct site visits.

The checklist provided focus and direction of the team members as they performed their walk-through of Building 628. The checklist had six objectives:

Objective 1 Evaluate the stacking configuration of the drums for any corrosion problems.

Objective 2 Visually examine the pallets and spacers to identify any possible drum corrosion problem.

Objective 3 Evaluate the storage buildings (RCRA storage module) to identify any possible drum corrosion problem arising from the building structure.

Objective 4 Evaluate the stacking configuration of the drums within the modules to identify any possible drum corrosion problem caused from the stacking array.

Objective 5 Propose means to extend the life of old drums.

Objective 6 Propose means to extend the life of the new overpack drums.

The assessment team consisted of four metallurgists and engineers. The whole assessment process was review by the Stored Waste Examination Pilot Project (SWEPP) project manager before the initial visit occurred.

The initial site visit was on February 28, 1995. The tour consisted of a brief visit to various sites at the RWMC to familiarize the team with the history and operations of the facility. Finally the ASB-2 and Building 628 were visited. One week later on March 3, 1995, the team again visited the ASB-2 and Building 628.

2.4 Task 4: RCRA Type II Storage Module Assessment

The salient parts of the assessment are included in the results section of this report. After the assessment team completed their visits, it was apparent that there was a condensation problem in

Building 628. Because no definitive data was available on the drum dew point temperature, it was decided that a computer model be made to determine the dew point conditions.

2.5 Task 5: Identify Waste Streams Deleterious or Corrosive to 55-gal Steel Storage Drums

This task was a milestone report and it was issued in June 1995.

Initially the Integrated Data Base for 1992[4] was consulted to identify sites in addition to the INEL with large inventories of drums. The following list of DOE Sites, laboratories, and/or contractors was identified.

- Battelle Pacific Northwest Laboratory
- Fernald Environmental Restoration Management Company
- Los Alamos National Laboratory
- Mound Plant
- Nevada Test Site
- Oak Ridge National Laboratory
- Rocky Flats Plant
- Westinghouse Hanford Company
- Savannah River Site
- West Valley Demonstration Project.

A telephone search was then conducted to find a contact person having data on waste streams that preferentially corrode 55-gallon steel drums. A contact list was compiled and a survey was sent out to each person on the list. The survey contained the following documents:

- An introductory letter about the study
- Background and instructions of the study and instructions determining which waste containers need to be addressed
- A waste stream corrosion work sheet along with instructions for completing the work sheet
- An example work sheet to be used as a guide.

Each person was contacted one week after the surveys were mailed; this was done to ensure that each person on the contact list received the survey or to ascertain if the survey had been passed down to someone else to complete. If someone other than our initial contact was given the survey, the contact list was updated.

Salient parts of the findings are included in the results section of this report.

2.6 Task 6: Design Test Cell

The scope of this task was expanded and accelerated beyond the "design" stage because (a) the funding for the second year of this special project was canceled, and (b) the assessment team suggested an "in-the-stack" test cell for this task be implemented. Because this "in-the-stack" test cell goes beyond the scope of the first year of the project, by assimilating the elemental steps of task 7 "Collect Test Drums," and task 8, "Design Test Cell Specimens," into the implementation and installation of an "in-the-stack" test cell.

2.6.1 Background on the Design of Test Cell

The surface condition of many of the storage drums located in the ASBs and those retrieved from the covered storage are in various stages of deterioration (rust or corrosion). By observation of the drums, it is evident that some elements within these two storage environments (the moisture condensation and fire retardant treated plywood) are deleterious to the storage life of 55-gal steel drums. The assessment of newly constructed storage modules showed that the new buildings exhibit similar corrosive environments to the prior storage facilities (free standing water on the floor). Therefore the assessment team proposed that an "in-the-stack" test cell be installed to determine conditions the drums are exposed to.

This "in-the-stack" corrosion test cell will measure both the meteorological conditions (temperature and humidity) and the corrosion rate of the drums within one of the drum stacks of the RCRA Type II modules. The dew point temperatures at the drum stack are calculated from the meteorological data. The corrosion rate of a drum within a stack will be a function of the following three factors: (a) ambient and surface temperature, (b) relative humidity, and stacking configuration.

The assessment team suggested that an "in-the-stack" corrosion test cell would be the best method to obtain the needed data. Before the corrosion rate of the drums can be predicted, the conditions that affect the drums need to be defined (i.e., what conditions are the drums experiencing, what are the synergistic effects of the drum stack and thermal mass, and what are the environmental forces and boundaries inside of a new storage module).

2.6.2 Test Period

The test will be conducted for a minimum of 12-months; however, a longer testing interval would produce a broader data base.

2.6.3 Test Objectives

The "in-the-stack" test objectives are to determine the:

- Surface (contact) temperature of five drums and a roof truss
- Surface (ambient) temperature of five drums and a roof truss
- Ambient humidity near five drums and a roof truss
- Atmospheric corrosion rate near two drums
- Surface corrosion rate of five or six drums and roof truss
- Surface corrosion rate of one drum connected to a continuous data logger
- Environmental conditions the drums are experiencing
- Gradient of the environmental conditions within a drum stack
- Effect of thermal mass of waste on corrosion rate.

2.6.4 Description of Test and Test Set-up

The test objectives will be met in the following manner.

- By using six type K thermocouples connected to a continuous data logger performing readings every 15 minutes, the surface (contact) temperature of seven drums and a roof truss will be determined
- By using six type K thermocouples connected to a continuous data logger performing readings every 15 minutes, the near surface (ambient) temperature of five drums and a roof truss will be determined
- By using humidity probes connected to a continuous data logger performing readings every 15 minutes, the ambient humidity near five drums and a roof truss will be determined
- By using electrical resistance probes that are down-loaded to a portable data logger every two weeks, the atmospheric corrosion rate near two drums will be determined
- By using electrical resistance probes that are down-loaded to a portable data logger every two weeks, the surface corrosion rate of six drums and roof truss will be determined
- By using a electrical resistance probe that is connected to a continuous data logger performing readings every 15 minutes, a real-time the surface corrosion rate of one drum will be determined

- Through the above data gathering activities, both the environmental conditions the drums are experiencing, and the gradient of the environmental conditions within a drum stack will be determined.

The test area locations throughout a drum stack are shown in Figure 6.

The equipment for this test was selected because of its compatibility with existing equipment used at the RWMC to monitor meteorological data.

2.6.5 Installation of Test Equipment

The test equipment installation consists of two parts.

1. Placing of a dummy drum within the stack. This dummy drum will provide a location to house the data logging equipment during the duration of the test. This drum has been structurally reinforced on the inside to facilitate an opening or doorway to be cut in the drum, while maintaining structural integrity. The sketch of the dummy drum shown in Figure 7 has been given a structural analysis to verify loading strength. There is no space near a stack to place a table for the data logger to set on during this test. The dummy drum will be used to house the data logging equipment and to protect it from condensation. The drum will be installed in a position near the end of the stack and on the second layer (see Figure 6 for the location of the dummy drum within the drum stack). The cables for the humidity and corrosion probes have been manufactured at the factory, therefore the dummy drum has to be an exact location for the cables to reach the data logging equipment.

2. Install the probes and thermocouples in place. Figure 6 indicates the locations of the temperature thermocouples, corrosion probes, and the relative humidity probes. Five pieces of ABS plastic pipe will be cut lengthwise to allow the wires to fit inside of the pipe, and placed into the stack to support the probes and wires in place. The pipe will rest on the roll-rings of the drums (see Figure 8a and 8b for details). The thermocouples and probes will be set into place with the ABS pipe; only the contact probes and thermocouple ends will be attached to a nearby drum surface either with epoxy adhesive or tape. The wiring strung from the ABS pipe to the dummy drum will be securely banded to the drum spacers to keep loose wires from sticking out into the drum aisle space.

Prior to placement within one of the RCRA Type II modules, all probes and equipment shall be set up in the North Holmes Laboratory to verify readiness. This mock-up and equipment check-out will de-bug the system prior to installation and reduce potential problems during installation and radiation exposure to the technicians.

2.6.6 Measurement of Test Data

The test equipment was selected to match the meteorological station equipment in place within one of the RCRA Type II modules. It is proposed that when engineers or technicians, of the Waste Storage Facility Emissions Program, down-load their data from the meteorological station,

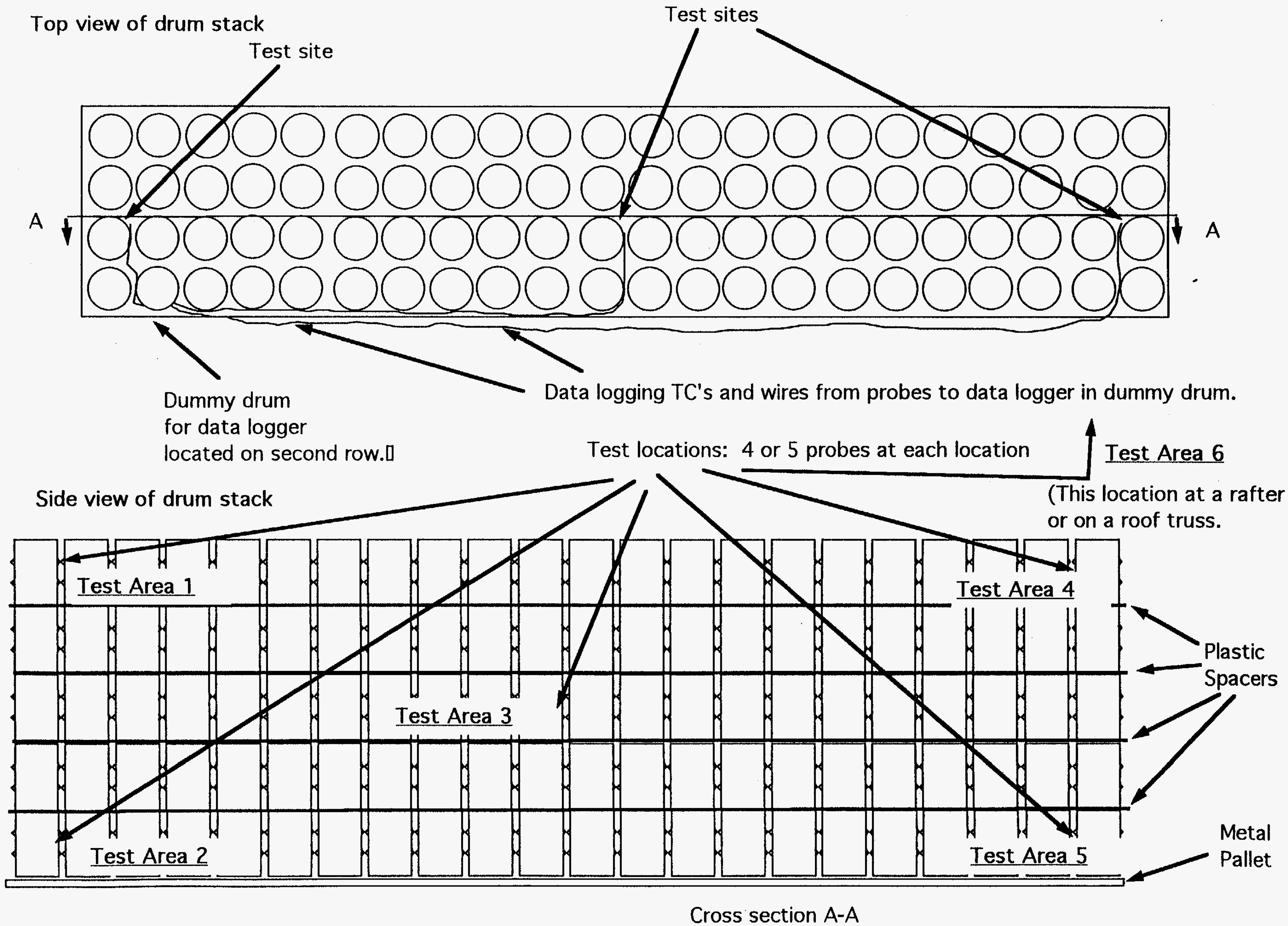
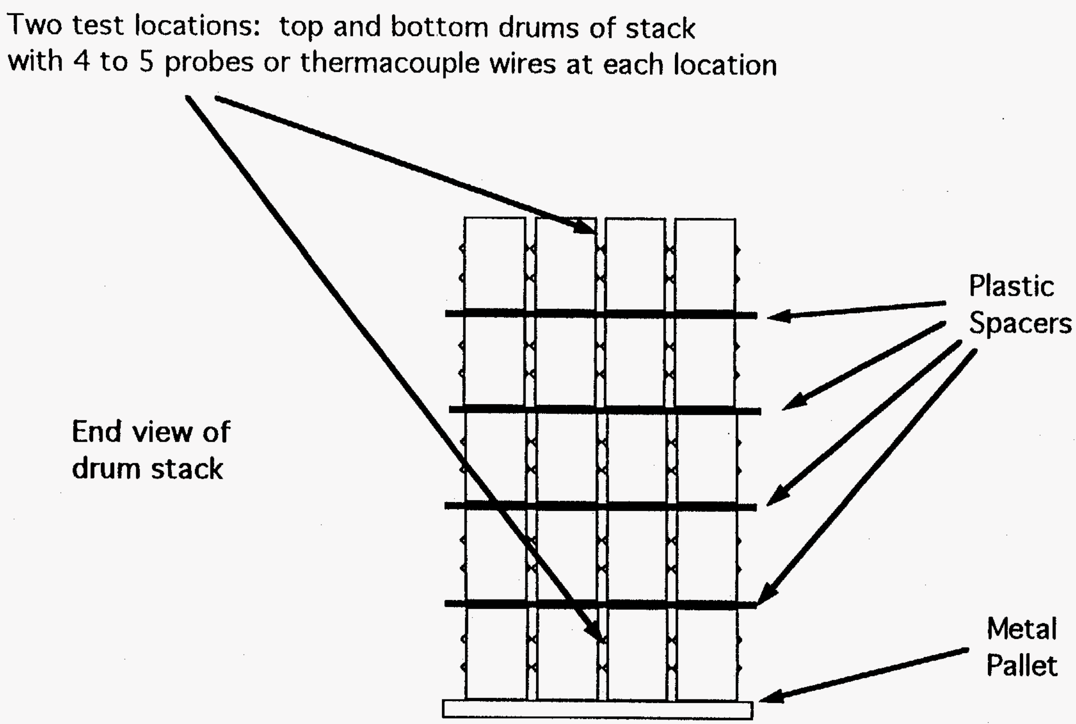


Figure 6. Test area locations.



<u>TEST DETAILS:</u>

<u>Test Area 1</u>: Test Area 1 includes contact and ambient TC's, humidity probe, contact (2) and ambient corrosion probes.

<u>Test Area 2</u>: Test Area 2 includes contact and ambient TC's, humidity probe, contact and ambient corrosion probes.

<u>Test 3-6</u>: Test Areas 3-6 includes contact and ambient TC's, humidity probe, contact corrosion probe.

Figure 6. (continued).

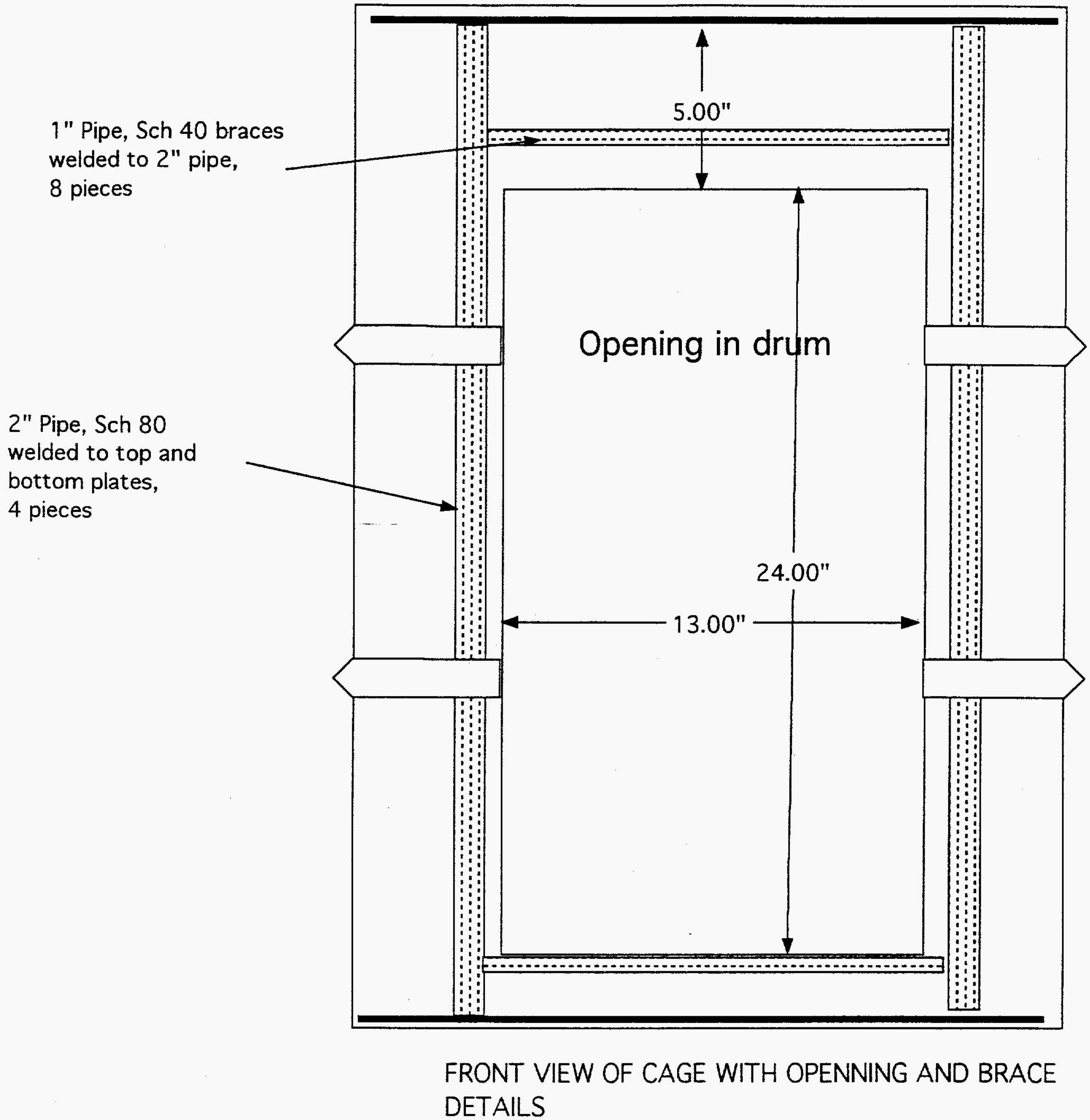
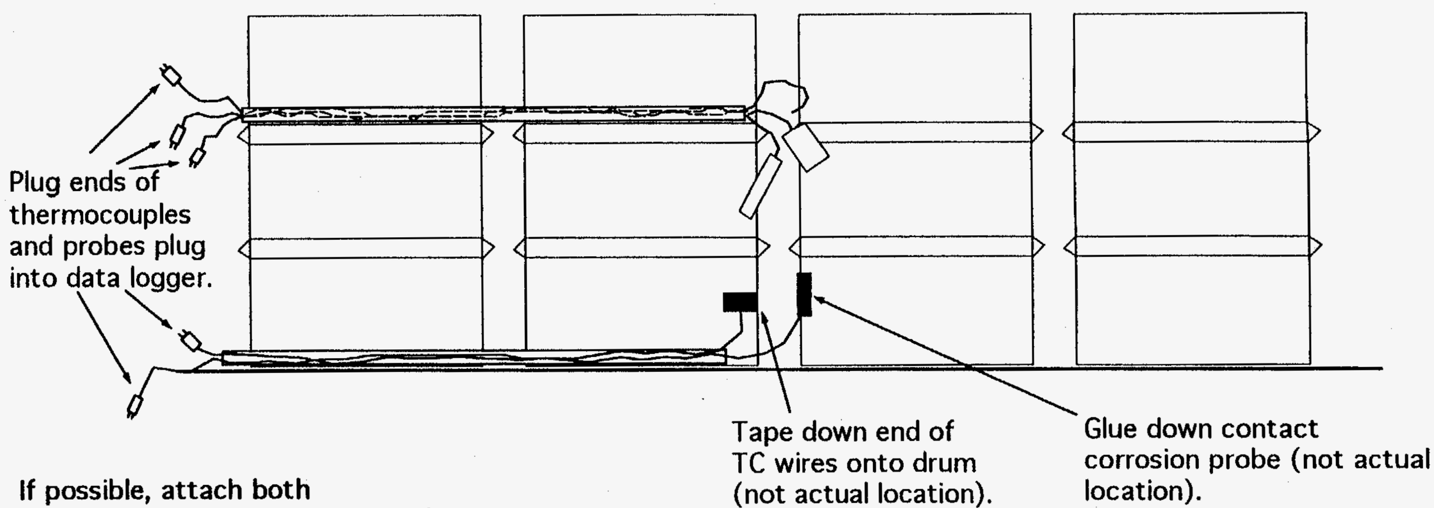
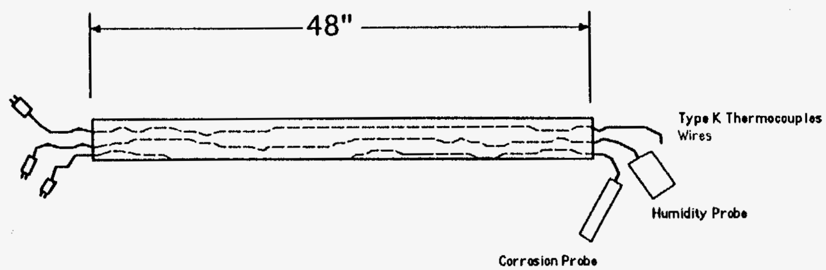


Figure 7. Dummy drum.

A side view of a typical set-up with TC wires and probes in 1" plastic piping to carry ends into the center of drum stack . If possible use one pipe for all wires, but if needed, use two as shown.



NOTE: If possible, attach both contact thermocouple and corrosion probe before stack is built up past the test area site. Otherwise, attach the wires after-the-fact and as best of location as possible.



Plastic pipe, 1" outside diameter, cut to 48" long and slit length wise with a 0.25" slot on one side only. Need 5 to 8 pieces of ABS pipe.

Figure 8a. Side view of tubing carriers and wiring details.

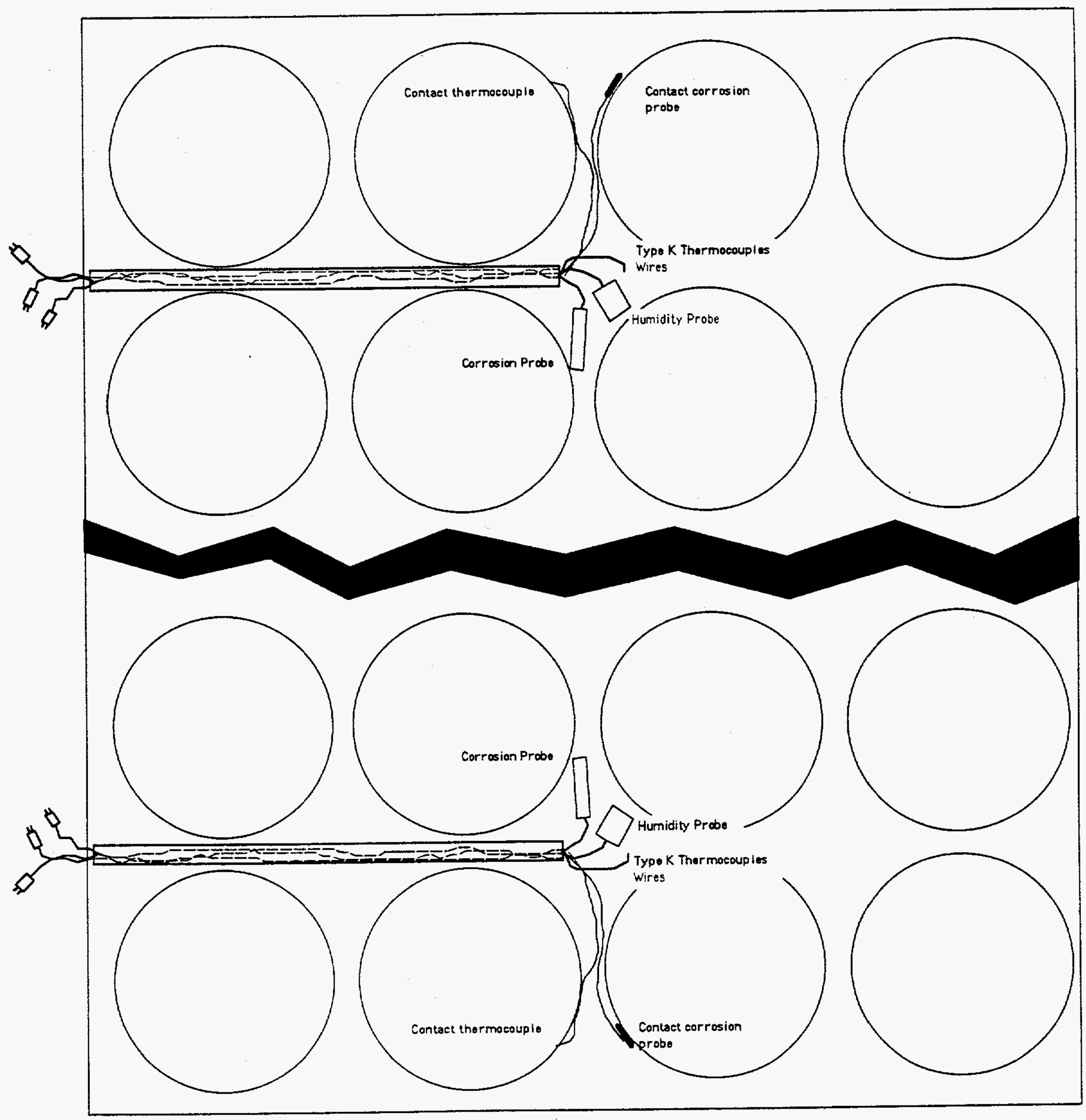


Figure 8b. Plan view of carriers and wiring details.

they can also down-load the data from the "in-the-stack" test data logger. They have a monitoring plan procedure in place that they follow, and this will also reduce the need for more people to be in the area. The data will be retrieved from them for future reporting needs.

2.6.7 Training Requirements and Radiological Safety

No additional training is required. After the initial installation the exposure time to personnel shall be minimal. Technical data, books, and manuals will be maintained at the dummy drum for reference.

2.6.8 Reporting

Reporting of the data and results shall be twice yearly.

2.6.9 Summary of Expected Results

This study will provide a baseline of information for the RWMC management and the INEL Container Integrity Program. The test is well designed, and if managed properly, could furnish fundamental data for years to come. This study shall provide:

- A proactive approach to drum management for a high profile facility
- A proactive approach to the drum corrosion and container integrity problem
- Data that characterizes the condensation and environmental effects within the new storage building
- Data that can be used to predict drum storage life
- A program that can be used for other areas of concern over corrosion (buried vaults)
- Data that will be used to validate the computer models.

This test cell has been designed and the design has been submitted to the RWMC for installation. Installation has been scheduled during December 1995.

2.6.10 Other Corrosion Monitoring

Other corrosion coupon test programs has been developed to monitor the actual corrosion of small strips of low carbon steel that closely match the drum material. There are 100 steel strips stacked in various places throughout Building 628 to measure any corrosive gradient between the stacks or within the stacks. A second test proposed cell consists of both old and new drums organized to monitor corrosive conditions. The rust on the old drums will be carefully characterized to monitor both increase of corrosion over time and the rate of corrosion. The results of steel strips test, the whole drum evaluations and the "in-the-stack" tests will provide a comprehensive approach to the corrosion problem.

2.7 Final Report

This report is the final report of the drum corrosion study.

3. RESULTS

This section will summarize the results of the deliverable:

- Four PPOAs: one PPOA on the overpacking of wastes and one on the clean-up of breached drums at both the RWMC and the MWSF
- Existing Corrosion Data Evaluation
- Research Environmental Forces in RCRA Type II Storage Modules
- Report on Findings
- Corrosive Waste Streams Identification
- Test Cell Design
- Collect Test Drums
- Test Cell Specimens Design
- Final Report

3.1 Results of the PPOAs

Three PPOAs instead of two were actually completed for the overpacking processes on the INEL. Two were for the RWMC and one for the MWSF. The "costing sheets" of the three PPOAs on the overpacking processes are included in Appendix A.

3.1.1 Overpack of Transuranic Waste

The RWMC management assumes that 1,200 drums would fail the inspection and may have to be overpacked this year (1995) and 12,000 drums are estimated to fail or be at-risk over the next 6 years. To completely assess the overpacking process, two PPOAs were performed: overpacking all of the at-risk drums with 83-gal drums and overpacking all of the at-risk drums in SWB. These two overpacking methods are typically used at the RWMC.

3.1.1.1 83-gal Overpack of TRU Waste Drums. Results of this PPOA show that:

- When a 55-gal drum is overpacked into a 83-gal drum there are 28-gal of void volume generated
- Since disposal cost for radioactive waste is based on the final container size, the 28-gal of void volume generated from the overpacking must be considered a waste
- If 1,200 drums are overpacked, 128 m^3 of void volume waste is generated

- The disposal cost of the 128 m^3 (\$48,000.00 per m^3) is \$6.1 million
- Over 6-years, the projected increased disposal cost will be \$61.0 million
- If half of the drums could be refurbished instead of overpacked, the savings would be substantial.

3.1.1.2 SWB Overpack of TRU Waste Drums. Results of this PPOA show that:

- When four 55-gal drums are overpacked into a SWB about 50% void volume is generated
- Since disposal cost for radioactive waste is based on the final container size, the void volume generated from the overpacking must be considered a waste
- If the 12,000 drums were overpacked into SWBs, the projected disposal costs will be \$105.0 million.

3.1.2 Overpack of Mixed Waste

This PPOA was performed on the overpacking process at the MWSF. The failure of drums at the MWSF averages one to two drums per year over the last several years.

3.1.2.1 83-gal Polyethylene Overpack. Results of this PPOA include:

- 28-gal of extra volume is generated with each overpack
- 28-gal is equivalent to \$6,000.00 per m^3
- Liners should be used inside of the 55-gal drums to eliminate possible internal corrosion.

3.1.3 Clean-up of Breached Drums

An evaluation was made before PPOAs were performed on the clean-up of breached drums. This evaluation discovered that there has been less than a cubic foot of rags or waste generated in the clean-up of breached drum at both facilities during the last several years. The quality assurance and inspection programs intercept the at-risk drums before failure and overpack them. Therefore, no PPOAs for clean-up of breached drums were performed at either facility.

3.1.4 Three P^2 Cost Saving Evaluations

Three P^2 cost saving evaluations were written as a result of findings generated by the PPOAs. These evaluations were written into three High Return of Investment (HROI) proposals. Three HROI proposals were written with the help of the INEL P^2 Unit and the combined cost saving potential was over \$800 million. These HROIs propose to build a (a) Drum Refurbishment Unit (DRU), (b) Waste Repackaging Unit, and (c) Sort, Segregation, and Compaction System (SSCS).

3.1.4.1 Drum Refurbishment Unit. The DRU would refurbish the TRU waste drums that are still structurally sound (>0.047-in. wall thickness), but have extensive superficial rust. The goal of the DRU is to intercept drums that have failed the inspection criteria prior to being overpacked. The rusty drum surface would first be cleaned of rust, paint, labels, and contamination. Then the drum wall would be inspected by ultrasonic inspection to verify drum wall thickness. If the thickness was determined to be >0.047-in., the drum would be coated with aluminum, zinc or plastic (studies are required to select the coating material).

There are several advantages of refurbishment:

- Save drums from overpacking
- Save disposal and storage space
- Simplifies subsequent assays and inspections
- Make TRU waste drums "road-ready" for WIPP
- Greater auditor appeal.

One major advantage of this DRU is that the DRU is not waste treatment and the Part B Permit is not required too be changed.

This HROI proposal was not accepted by the DOE-ID because the storage space at the RWMC is essentially free, there is ample space to store the overpacked drums at the RWMC, and uncertainty on the WIPP open-date.

3.1.4.2 Waste Packaging Unit. The waste packaging unit (WPU) would remove the TRU waste from the drums that had less than the required wall thickness to be WIPP road-ready. The old drum would be removed and the waste would be repackaged into a new drum. The goal of the WPU is to intercept drums that had failed the inspection criteria before being overpacked. There are several advantages of repackaging:

- Proactive approach to drum management
- Proactive approach to P^2 and WMin
- Save drums from overpacking
- Save disposal and storage space
- Simplifies subsequent assay and inspection
- Make TRU waste drum "road-ready" for WIPP
- Greater auditor appeal.

A major advantage of the WPU is that the WPU is not waste treatment, and the Part B Permit would not have to be changed to allow the RWMC to open a drum.

This HROI proposal was not accepted by the DOE-ID because the RWMC does not allow for the opening of drums. Subsequently, the RWMC environmental compliance group suggests that the HROI be submitted next year after they revise the Safety Analysis Report to allow the opening of the drums.

3.1.4.3 Sort, Segregation, and Compaction System. The SSCS could serve several purposes. The main purpose would be to compact the approximately 36,000 drums[6] of compactible waste stored at the RWMC to a 6:1 volume reduction. To avoid the criticality issue with compaction, the drum would have to be assayed first. As a drum is moved through the SWEPP operation, it is assayed. The assaying of drums is one of the steps required to meet the WIPP Waste Acceptance Criteria. An added advantage of this system would the ability to open a drum and remove free liquid between the liner and drum, to remove a container of liquid in the drum or remove an aerosol can from the waste contents. This would make the TRU waste drums WIPP road-ready; otherwise it may have to overpacked and remain forever at the RWMC.

The advantages of this system include:

- Proactive approach to P^2 and WMin
- Excellent volume reduction
- Increase the wattage levels allowable for shipment[7]
- Make TRU waste drums "road-ready" for WIPP
- Substantial savings in disposal costs.

The evaluation of the SSCS can best be shown by using the "existing" and "proposed" process flow charts developed for the HROI proposals. The projected saving over 20-years of $750 million is shown in the Figure 9a and 9b. The major disadvantage of this SSCS is that "sorting, segregating and compaction" is a treatment and the Part B Permit would be required to be changed. A drum compaction system is operating at the Rocky Flats Plant and it has gone through an extensive safety analysis review and permitting process providing clear guidance for implementation of this treatment system.

This HROI proposal was not accepted by the DOE-ID because the Part B Permit at the RWMC does not allow treatment of waste or the opening of drums. Subsequently, the RWMC environmental compliance group suggests that the HROI be submitted next year (1996) after they revise the permit to allow the opening of the drums.

3.2 Results Quantify Existing Corrosion Data

The initial goal of this task was to characterize the long term rust patterns within the storage environment at the RWMC. After the preliminary investigation into identifying rust patterns on drums as the result of the storage environment, it was discovered that the drums in the ASB-1 and ASB-2 have been

Existing Costs for 36,000 Drums of Compactable Waste

NOTE:

There are approximately 36,000 drums of compactable waste (plastics, paper and glove box gloves) stored at the RWMC. These drums will be fingerprinted, processed, and eventually sent to WIPP.

5% of the 36,000 drums (1800) will have its waste characterized and visually examined at ANL-W plus 200 more for the WIPP Characterization Program.

Drum Management and Disposal Costs

$0.29 Million for transportation to ANL-W and back

$40.0 Million for waste characterization at ANL-W

$4.0 Million to build storage modules for the drums

$4.6 Million Load TRUPACKS

$3.9 Million shipping documentation

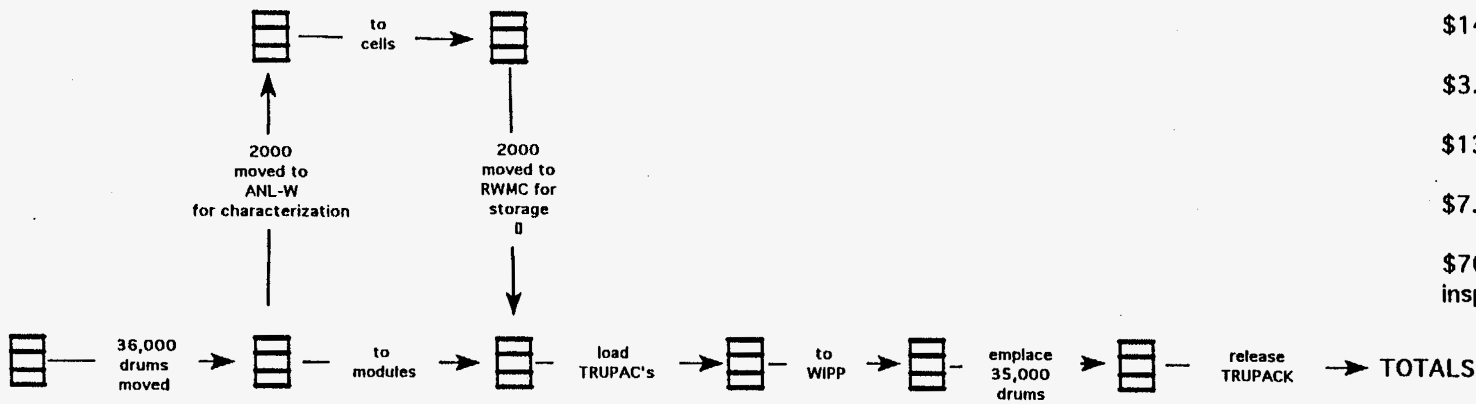
$14.4 Million shipping to WIPP

$3.2 Million to receive drums

$131.8 Million to emplace drums

$7.3 Million to release transporter

$700 Million for 20-years of drum inspection at WIPP



$909.5 Million

or $26,000.00/drum

Costing Data: Avoidable Waste Management Costs INEL-94/0205, 1995, pages C-21, D-42 and D-43

RWMC Inventory Data Base, and

$20,000.00 per drum costs at ANL-W

Figure 9a. SSCS existing flow chart

Proposed Costs for 36,000 Drums of Compactable Waste

NOTE:

An alpha box, with an attached drum compaction system, the 36,000 drums of compactable waste can be given a 6:1 reduction ratio eliminating 30,000 drums from the inventory.

The sorting and segregating of waste prior to compaction constitutes a waste code verification and characterization. This eliminates the need to send 2000 drums to ANL-W for openning.

Sorting, segregating and compacting 12 drum per day during 2 shifts, the drums can be processed in 15 years.

Other benefits include, making most of the out-of-specification waste drums WIPP "road ready", ability to examine unknown drums, and R&D activities.

Drum Management and Disposal Costs

$1.4 Million for LLW disposal

$0.125 Million for waste boxes

$4.2 Million for labor to compact waste at RWMC

$1.9 Million for glove box

$0.77 Million to Load TRUPACKS

$0.654 Million shipping documentation

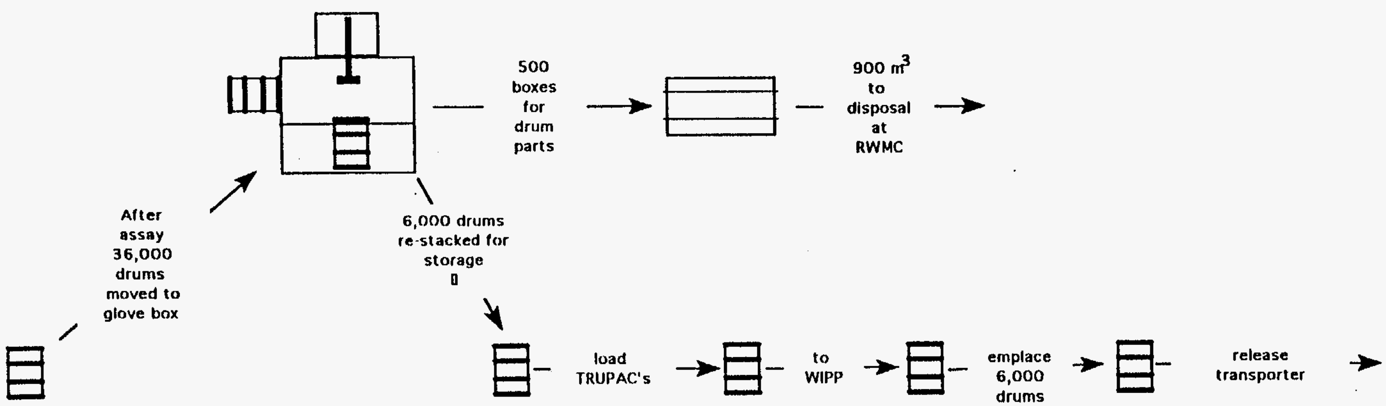
$2.4 Million shipping to WIPP

$3.1 Million to receive drums

$22.0 Million to emplace drums

$1.2 Million to release transporter

$120.0 Million for 20-years of drum inspection at WIPP



TOTALS: $157.75 Million

or $26,300.00 per drum

Costs:		
	Existing costs:	$909,500,000.00
	Proposed costs:	$157,750,000.00
	Costs saved with glove box at RWMC:	$751,750,000.00

Figure 9b. SSCS proposed flow chart.

moved several time over the last few years. Any rust patterns and corrosion data at the RWMC has been thus convoluted. Most of the drums are still under earthen storage and can not be inspected. Therefore, no definitive data was obtained.

3.3 Results of RCRA Type II Storage Module Assessment

There were two site visits to the RWMC to assess the environmental conditions with-in the first completed RCRA Type II storage module (Building 628). The first visit on February 23, 1995, was not as eventful as the visit on March 2, 1995. On the first visit to the building, two obvious items were noticed (a) rust deposits, and (b) water leaking into the building from a melting snow bank. It was evident that the drums had become wet because there were rust stain deposits between the drums and the black plastic (Zurex) pallet spacers. The water on the floor of Building 628 was obviously from the melting snow.

It should be noted here that the drums in the stacks do not have much rust on them. These drums have been given several inspections prior to placement into the Building 628. The very rusted and corroded drums have be set aside for future overpacking. However, the drums in Building 628 have been moved with forklifts and drum handlers several times. As a result of the constant moving, as seen in Figure 10, the paint from the middle section of the drum has suffered abrasion. This photograph shows a drum that has had paint scraped off of its middle section by drum handling tongs, but the top section of the drum is near new in condition. The paint used to paint drums is typically of lesser quality and is easily scraped off. This leaves shinny bare metal spots exposed on many drums. Therefore, even with a slight or casual wetting of the exposed metal on the drums, rust can readily form.

The second visit was very enlightening. The week of the second visit the weather was colder than the week before and the snow was not melting and leaking into the building. As the assessment team entered Building 628, multiple water deposits on both the floor and the plastic spacers were observed. Water was on the pallets of every drum stack and on the floor in between most of the stacks.

Figure 10. Drum handling abrasion.

3.3.1 Responses to the Objectives

The responses of the assessment team to the objectives were divided into three parts: (1) positive observations, (2) negative observations, and (3) recommendations.

3.3.1.1 Objective 1. Evaluate the stacking configuration of the drums for any corrosion problems.

Positive Observations

- The fire retardant plywood which has been known to corrode drums has been eliminated.

Negative Observations

- There was large amount of free water on the drum spacers and on the floor between the stacks. Every stack had water on the drum spacers. On one stack the upper layers were inspected and water was also present on the upper layers of one inspected stack.
- Most of the damage to the paint on the drums is from the drum handling tongs.
- There was evidence of wet and dry cycles because rust was present between the drums and pallets/spacers.

Recommendations

- Consider padding or coating the drum handling arms to reduce drum paint abrasion.
- Monitor future drum movement to assess damage with coated drum handler.
- It would be prudent to have an on going corrosion study program at the facility since actual transfer of drums to disposal may not occur for some time.
- Characterize rust from an empty drum one returned from Argonne-West, for example.
- Place corrosion coupons in Building 628 to develop qualitative corrosion data.
- Develop a drum stack monitoring system to quantify environmental conditions to which the drums are exposed.

3.3.1.2 Objective 2. Visually examine the pallets and spacers to identify any possible drum corrosion problem.

Negative Observations

- The welding on the pallets had been performed after galvanizing, but the welds were painted to resist corrosion.

Positive Observations

- Based on verbal data, the spacer material is corrosion and radiation resistant and has been used for hazardous/radioactive waste containment at others facilities.
- The new galvanized steel pallets support or keep the drums off the floor so that the drums will not contact the floor or water on the floor.
- The new spacers show a great deal of thought in development. They appear not to be a source of corrodants, allow ventilation between the drums, and they promote stack stability.

Recommendations

- Perform tests to determine if off-gassing from drum spacer material will corrode steel.

3.3.1.3 Objective 3. Evaluate the storage buildings (RCRA storage module) to identify any possible drum corrosion problem arising from the building structure.

Positive Observations

- The building intake vents have filters to reduce the dust
- There was no evidence of water dripping off the ceiling as in the air support building
- It is very proactive that the volatile organic compounds (VOCs) are being monitored within Building 628.

Negative Observations

- There was some dust on the drums. Dust can be nucleation sites for condensation or frost, and the water can be corrosive if the dust is chemically contaminated.
- There were large puddles of water underneath two of the stacks. The water had flowed into the building from snow drifts that were melting on the North side of the building. Dams had been set up to prevent the water from running under the stacks, but they were not effective.
- With water on the floor from condensation and water on the floor from melting snow, it will be hard for the weekly RCRA inspection personnel to know what is and what is not a drum leak.
- The relative humidity on the day of the second visit was 98% in Building 628. The humidity is comparable to that of the ASB. Building 628 will still have a humidity/corrosion problem until the humidity problem is addressed. This would apply to all other buildings of the same or similar design with the approximate number of drums or boxes.

Recommendations

- Consider better filters to remove more dust particles.

- Remove the snow drifts from the North side of the building so the problem of water running into the building will not occur, or put a barrier up to prevent the water from entering the building.

- Reduce the air flow in the ventilation system to reduce the moisture build-up.

- Perform some engineering evaluations to reduce the humidity such as leaving the bay door open for several hours. Then check the humidity data for that day to verify results. If these measures do not reduce the relative humidity in the building below 70% (the point at which condensation occurs), consider other measures to control relative humidity.

3.3.1.4 Objective 4. Evaluate the stacking configuration of the drums within the modules to identify any possible drum corrosion problem caused from the stacking array.

Positive Observations

- None.

Negative Observations

- None.

Recommendations

- None.

3.3.1.5 Objective 5. Do you, as a member of the assessment team, have any ideas on extending the life of old drums?

Positive Observations

- The new modules and manner of stacking (pallets, polyolefin copolymer spacers instead of plywood) are vastly superior to the ASB

- It is a good idea to move the drums as soon as possible.

Negative Observations

- Remove the drums from covered storage; because the plastic tarps on the covered storage is impermeable to water, drum corrosion will occur because the water cannot escape.

Recommendations

- Identify spots on a series of drums that have had the paint scraped off from handling. Monitor these spots over time to determine the rate and extent of future corrosion of the drums.

- Determine from the VOC monitoring group if there are any VOCs that might be deleterious to drum storage life.

- Coordinate the Building 628 VOC sampling and analysis program with the start-up of the New Waste Calcine Facility at the Idaho Chemical Processing Plant. Nitrous oxide clouds traverse the RWMC with certain weather patterns.

- Consider treating (coating) drums if an inexpensive, foolproof, and effective method can be developed.

- Determine of what type of external visible damage characterizes acceptable and rejectable drums (i.e., those subject to overpacking). This should include photographs and metallographic sampling which show gradations of acceptable to rejectable conditions. This should be followed by a statistical sampling of failed or rusty drums to help sort the drums to reduce the number of rejected drums.

- The no-defect coating requirement is probably nearly impossible to achieve or maintain given the environment of the drums. Thus, the coating must be anodic to iron under the storage conditions at the RWMC (i.e., it must corrode in preference to the steel). A zinc coating is anodic to steel.

- Put into Building 628 corrosion sample racks to determine the corrosion rate of exposed, unpainted metal. Use drum materials with and without paint and prepared in accordance with standard American Society for Testing and Materials test methods.

- Set up temperature and humidity probes to determine what environmental conditions the drums are experiencing.

- Drum inspection should have to identify drums with the minimum wall thickness consistent with the life expectancy.

- Localized corrosive attack such as pitting or crevice corrosion should be identified and evaluated. Localized attack has higher penetration rates than general corrosion.

- Perform a study to choose a humidity reduction system for the new buildings.

3.3.1.6 Objective 6. Do you, as a member of the assessment team, have any ideas on extending the life of the new overpack drums?

Positive Observations

- The drum appears to be better choice that what was used before.

Negative Observations

- None.

Recommendations

- Protect or modify the drum handling tongs for the 83-gal overpack to prevent drum handling damage.

- The coating should be subjected to a corrosion testing program to determine the coating's ability to withstand the handling and storage environment.

- The poly lining seems to have a uniform thickness and high integrity. A rigorous specification and incoming inspection program should be instituted to ensure that the lining quality does not decrease over time.

3.3.1.7 Final Recommendations. Some of the recommendations may be impossible to do because of funding, or other requirements unknown to the team. However, several of the recommendations were selected as most important and are listed below.

- Implement a stack monitoring system with temperature, relative humidity, and corrosion rate probes within a drum stack in order to understand what environmental conditions the drums are experiencing.

- Prepare a corrosion monitoring program to develop data for RCRA certification of the storage facilities that is based on the data measured with the corrosion probe and corrosion coupons.

- Look at possible drum refurbishing systems to prevent drum failure from further rusting.

- Investigate the use of polyester or polyethylene plastics to overcoat the drums.

- Perform a condensate sampling plan that would include sampling during the next calcination run at the Idaho Chemical Processing Plant.

- Perform a corrosion survey to see if there is a correlation between failure rate (excessive corrosion) and waste stream (waste code).

- Perform an analysis to determine a typical corrosion rate for drums stored on the INEL. How long can a drum be safely stored on the INEL?

- Develop a laboratory corrosion testing plan to test overpack coatings for RCRA certification and certification for use at the WIPP facility.

3.3.2 Mass and Heat Transfer Modeling Results

One of the most exciting parts of this study was the use of computer modeling. Because no definitive data was available on drum dew point temperature, a computer model was made to determine the dew point conditions within Building 628. The time period of February 22, 1995 to February 22, 1995 was used as the modeling period. This time was selected because on February 21, 1995, the scientists who perform the VOC monitoring in Building 628 noticed that there was water falling from the ceiling of

Building 628. The model was used to prove why rain occurred inside of Building 628. The temperature plots are shown in Figure 11.

The plot shows the interrelationship between five temperatures. The waste inventories consist of about 80% cemented sludges and a cemented sludge is essentially a "rock." It is obvious that the drum temperatures would not noticeably vary. The plot shows a typical temperature cycling with the inside temperatures being cooler than the outside. The part of the plot that is not intuitively obvious is the synergistic effects between the ventilation system of the building and the climatic conditions.

The ventilation system of Building 628 pulls 12,400 cubic feet per minute through the building. During the modelling period, the outside dew point temperature was higher than the inside temperature and much higher than the drum temperature. As the ventilation system pulled the warmer air into the building and onto the cooler drums, condensation occurs. The plot shows that over the four day period, about 44-hours of condensation could occur. The peak times for condensation are identified as in the afternoon, and this compares with the event reported by the VOC loggers. In essence, the new RCRA Type II storage modules are large condensers.

A note should be made here about the corrosive nature of condensation. Rain water is not as corrosive as condensation. Rain water can wash off dust[8], and it only wets exposed parts. Whereas condensation wets the whole part and the surface contamination on the drums remains in place to react with subsequent wettings.

An obvious conclusion would be to shut off the ventilation system, but that system is needed to remove the VOCs that out-gas from the drums through the carbon filters that are attached to each drum.

3.4 Results of the Study to Identify Deleterious or Corrosive Waste Streams to 55-gal Steel Storage Drums

This task was completed in June 1995 and was submitted as a milestone report. The report explained how the search for corrosive waste streams was conducted Complex wide. There were several sites that had no experience with drum failure from inside out or interior corrosion. There were also several sites that would not or could not respond to the survey, but five sites did respond and 21 waste streams were identified that demonstrated deleterious effects on 55-gal steel drums. It should be noted here that most of these failures were in drums that the waste was placed in direct contact with the interior surface of the drum. Most of the wastes stored on the INEL have been placed into a 90 mil polyethylene liner that fits into a drum. These listed failures occurred in drums without a drum liner. The charts showing these 21 waste streams is printed in Appendix B. Figure 12 shows the expected drum failure rates. Conclusions of this study included:

- Containers with corrosive waste streams fail early (within 7 years)
- Waste streams with acids require added measures to protect the steel storage drum
- Waste streams that have solvent liquids, sludge, and still bottoms should use added measures to protect the steel storage drum

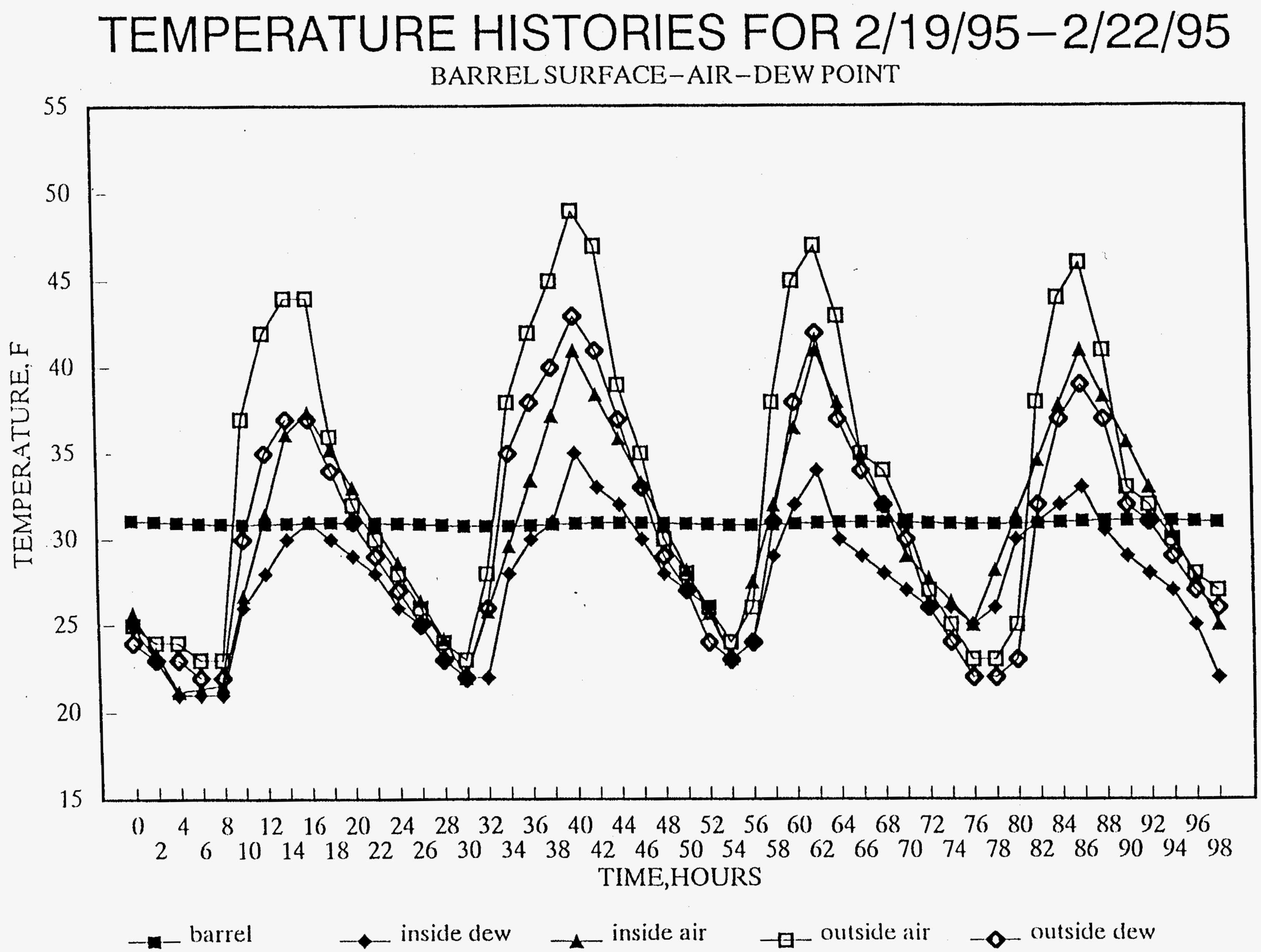
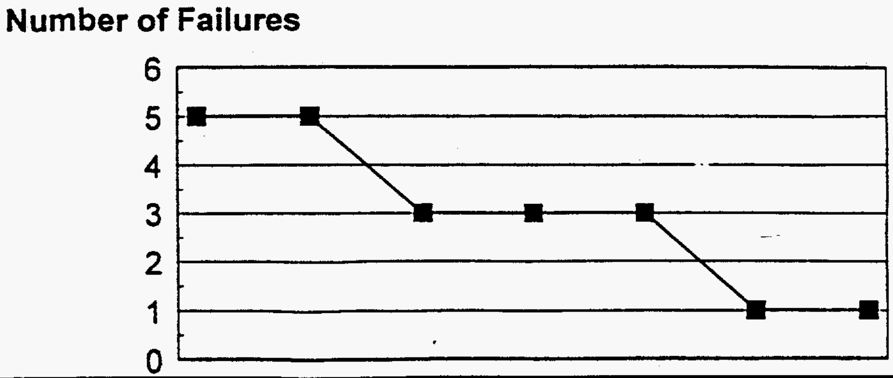


Figure 11. Temperature/dew point plots.

Drum Failures



Years in Storage	1 year	2 years	3 years	4 years	5 years	6 years	7 years
Number of Failures	5	5	3	3	3	1	1

The survey reported that 21 waste streams from seven DOE facilities caused the 55-gal steel storage drums to be overpacked or repackaged because of preferential corrosion by the waste stream componants on the drum.

Figure 12. Drum Failure Rates.

- Some recently packaged waste streams have been packaged into incompatible drums.
- The synergistic effect between the component parts of the waste and the drum are not intuitively obvious; therefore, when dealing with border-line compatibility waste streams, poly liners or drums are advisable.

3.5 Results of Test Cell

The results of the test cell are limited because it has not been installed. The equipment and parts for the test cell have been ordered, and received on site. At the RWMC, a Facility Change Form has been started to allow the test cell to be installed. Also, the operating procedure is being prepared to allow for the data logging and maintenance of the test cell. The test cell was to be installed in the second year of this project, but the second year of this special project was canceled. However, the facility will install and run the test cell. The equipment has been set-up in a INEL test facility to perform a pre-installation debugging and equipment readiness check.

The stress analysis of the dummy drum was performed and the analysis report is included in Appendix C.

3.6 Final Report

This report is the final report of the drum corrosion study.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

There are many conclusions that can be made from the research.

1. The PPOAs performed on the overpacking operation at the RWMC showed that if the estimated 12,000 at risk drums could be intercepted from overpacking the potential cost savings would be $105 million.

2. If the three HROIs could be implemented, the potential cost savings would be over $800 million.

3. Drums from the segregated and certified storage (ASBs) have about 10% rejection rate from corrosion.

4. The new RCRA Type II Storage Modules have an condensation condition.

5. The condensation on the drums can accelerate corrosion rates and increase future overpacking.

6. Containers with corrosive waste streams fail early (within 7 years).

7. The synergistic reaction between the component parts of the waste and the drum are not intuitively obvious; therefore storing border-line compatibility waste streams, poly liners in drums are advisable.

8. A corrosion test cell needs to be representative of the environment and materials being tested.

4.2 Recommendations

The thrust of this research is to generate facts that can be shared with others to give a "heads-up" on a potential P^2 cost savings. The goal of this research is to approach the corrosion problem at the drum storage facilities from a P^2 point of view to save disposal costs, conserve on storage/disposal space and overpacking expenditures. There are a plethora of recommendations that can be made from the research performed to date.

- Share this data with others for potential cost savings

- Approach other storage and disposal problems from a P^2 point of view

- Pursue building both the Drum Refurbishment Unit and the Waste Packing Unit to eliminate the 50% void volume generated from overpacking

- Maintain the "in-the-stack" monitoring system to establish a corrosion rate within the drum stack

- Pursue methods to reduce the condensation within the RCRA Type II Storage Modules

- Efforts need to be taken to keep the drums cleaner since the condensation can react with the dust to accelerate corrosion of the drums

- Extend the search to all DOE Site to find waste streams that demonstrate a deleterious effect on steel drums

- Enter salient facts of this report onto the World Wide Web or some other network.

5. REFERENCES

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4. Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW--0006-Rev. 8, October 1992, Oak Ridge National Laboratory.

5. TRUPACT-II Content Codes (TRUCON), DOE/WIPP 89-004, Rev. 5, April 1991.

6. C.J. Barnard, Internal Technical Report, "Inventory Analysis of Stored Transuranic (TRU) Waste at the Radioactive Waste Management Complex (RWMC), WM-PD-003 Rev. 1, June 30, 1993

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Appendix A

PPOAs on the Overpacking Processes

Worksheet 3

Pollution Prevention Opportunity Assessment
Cost Information

Revision No.:
Revision Date:
Page: 4

PPOA ID Number: WMC61202001TLSR PPOA Title: 83-GAL OVERPACK OF TRU WASTE DRUMS

Fixed Waste Handling Costs

Type	Description	Existing Amount	Existing Cost	Proposed Amount	Proposed Cost
HW (kg)			$0.00		$0.00
HL (m3)			$0.00		$0.00
IN (kg)			$0.00		$0.00
LL (m3)			$0.00		$0.00
LM (m3)			$0.00		$0.00
SA (kg)			$0.00		$0.00
TR (m3)	Void volume space in overpack	1.28E+02	$6,178,176.00	0.00E+00	$0.00
TM (m3)			$0.00		$0.00
TS (kg)			$0.00		$0.00
Cost Savings:	$6,178,176.00				

<u>Total Cost Savings Summary for the Process(s):</u>

Materials Cost Savings:	$252,332.50
Labor Cost Savings:	$133,800.00
Fixed Waste Handling Cost Savings:	$6,178,176.00
Utility Cost Savings:	($2,550.00)
Total Cost Savings:	$6,561,758.50
Pay Back Period for Cost Savings:	0.25

Worksheet 3

Pollution Prevention Opportunity Assessment
Cost Information

Revision No.:
Revision Date:
Page: 3

PPOA ID Number: WMC61202001TLSR PPOA Title: STANDARD WASTE BOX OVERPACK OF TRU WAS

Fixed Waste Handling Costs

Type	Description	Existing Amount	Existing Cost	Proposed Amount	Proposed Cost
HW (kg)		0.00E+00	$0.00		$0.00
HL (m3)		0.00E+00	$0.00		$0.00
IN (kg)		0.00E+00	$0.00		$0.00
LL (m3)		0.00E+00	$0.00		$0.00
LM (m3)		0.00E+00	$0.00		$0.00
SA (kg)		0.00E+00	$0.00		$0.00
TR (m3)		0.00E+00	$0.00		$0.00
TM (m3)	Void Space in SWB	2.25E+02	$10,211,850.00	0.00E+00	$0.00
TS (kg)		0.00E+00	$0.00		$0.00
Cost Savings:	$10,211,850.00				

Total Cost Savings Summary for the Process(s):

Materials Cost Savings:	$367,500.00
Labor Cost Savings:	$133,800.00
Fixed Waste Handling Cost Savings:	$10,211,850.00
Utility Cost Savings:	$0.00
Total Cost Savings:	$10,713,150.00
Pay Back Period for Cost Savings:	0.18

Worksheet 3

Pollution Prevention Opportunity Assessment
Cost Information

Revision No.:
Revision Date:
Page: 3

PPOA ID Number: PBF061301001PLMS PPOA Title: 83-GAL POLYETHYLENE OVERPACK

Fixed Waste Handling Costs

Type	Description	Existing Amount	Existing Cost	Proposed Amount	Proposed Cost
HW (kg)			$0.00		$0.00
HL (m3)			$0.00		$0.00
IN (kg)			$0.00		$0.00
LL (m3)			$0.00		$0.00
LM (m3)		2.10E-01	$6,044.22	0.00E+00	$0.00
SA (kg)			$0.00		$0.00
TR (m3)			$0.00		$0.00
TM (m3)			$0.00		$0.00
TS (kg)			$0.00		$0.00
Cost Savings:	$6,044.22				

Total Cost Savings Summary for the Process(s):

Materials Cost Savings:	($112.10)
Labor Cost Savings:	$1,242.00
Fixed Waste Handling Cost Savings:	$6,044.22
Utility Cost Savings:	$0.00
Total Cost Savings:	$7,174.12
Pay Back Period for Cost Savings:	0.00

Appendix B

Tables Listing Deleterious Waste Streams to 55-gal Steel Drums

Table B-1. Deleterious waste streams to 55-gal steel drums. Sheet ______ Of ______

Bar code	Waste stream identification number	Waste type	Waste state	Description of the waste	Process generating the waste	Time in storage (years)	Material type of original drum	Type of over-pack or repack	Time to failure (years)
53719	N/A	IN	Solid	Spent nitrate resins	Not identified	10	Carbon steel	Repack in carbon steel	7
N00468	N/A	IN	Liquid	10% triisooctylamine, dibutyl n-n-diethylcarbamyl phosphate, alcohol (undefined type) and hydrochloric acid residue with dibutyl n-n-diethylcarbamyl phosphate	Laboratory waste	8	Carbon steel	Repack in carbon steel	6
R00215	N/A	IN	Liquid	Oil/solvents	Not identified	7	Carbon steel	Repack in carbon steel	4
O00231	N/A	IN	Liquid	Oil and grease	Fuel oil spill	5	Carbon steel	Repack in carbon steel	4
N/A	N/A	Mixed waste	Sludge	Sodium nitrate with sodium fluroide sulfate (Na_3FESO_4) and oxonium iron sulfate hydroxide ($(H_3OFe_3(SO_4)_2(OH)_6$)	N-reactor fuel fabrication	10	Carbon steel	Carbon steel with poly liner	2
N/A	N/A	LL	Liquid	Tritiated heavy water	Reacotr operation	less than 30	Type 304 stainless steel	None	1 31
N/A	N/A	IN	Liquid	1,1,1-trichloroethane (TCA) sludge and other waste streams with trichloroethylene and tetrachloroethylene	Degreasing activities, other nonsolvent sources	1-10	Carbon steel	Carbon steel or repackage into carbon steel	5
N/A	HWSF LOG #1-331	HAZ.	Liquid	Halogenated and nonhalogenated contaminated water (solvents approximately 100 ppm)	Site remediation activities	5-10	Carbon steel	Carbon steel or repackage into carbon Steel	2
N/A	N/A	IN	Liquid	Abrasive blasting grit (with water in it)	Site construction activities	1-5	Carbon steel	Carbon steel	less than 1
N/A	M3-41	IN	Liquid	Spent freon-113	Degreasing activities	5	Carbon steel	Carbon steel	5
N/A	M3-119	IN	Liquid	Dilute nitric acid (pH 4) with mercury	Tank clean out	3	Carbon steel	Carbon steel	3
N/A	N/A	LL	Liquid	Bulked TCA still bottoms	Material leftover form recycle of used TCA	2	Steel	83-gal poly overpack	1
N/A	N/A	LL	Liquid	Bulked TCA still bottoms	Matrial leftover from recycled TCA	3	Steel	55-gal poly lined drum	1
N/A	N/A	LL	Liquid	Bulked TCA still bottoms	Material leftover from recycled TCA	3	Steel	55-gal poly drum	1
N/A	N/A	IN	Liquid	Citric acid based cleaning solution	Cleaning secondary side of a heat exchanger	3	55-gal poly	Repacked into blue poly drums	3
N/A	A75	TR	S	Cemented TRU sludge waste form	Residue and evaporation distilate are immobilized in cement	15	Steel	85-gal steel	2
				Paint stripper on rags	Paint stripping operation	13	Steel	85-gal steel	2

Table B-1. (continued).

Bar code	Waste stream identification number	Waste type	Waste state	Description of the waste	Process generating the waste	Time in storage (years)	Material type of original drum	Type of over-pack or repack	Time to failure (years)
				Mixed low-level waste; lead contaminated soils	Lead contaminated soil from decontamination and decommissioning	1	Steel	85-gal steel	1 2
N/A	N/A	N/A	Liquid	Rainwater entering TRU waste drums	Diurnal temperature cycling	9	Carbon steel	Repack in carbon steel drums after dewatering	4.5

Appendix C

Dummy Drum Analysis

Lockheed
Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: May 9, 1995

To: L. R. Zirker, MS 8101

From: J. G. Arendts, MS 3760

Subject: DUMMY DRUM AXIAL STRENGTH - JGA-01-95

Reference: L. R. Zirker Fax to J. G. Arendts, "Dummy Drum Sketch," May 1, 1995

The axial (with respect to drum axis) strength of the 55-gal drum internal structure, described in the referenced transmittal, has been analyzed and compared with the corresponding strength of a typical unmodified 55-gal drum.

Results of the attached analysis indicate that, if their yield strengths are similar, the proposed dummy drum reinforcement structure has greater axial strength, in both yielding and buckling behavior, than an unmodified drum.

pa

Attachment

cc: V. W. Gorman
R. C. Guenzler
J. G. Arendts File

Dummy Drum Reinforcement Analysis

References

1. Welding Fittings - Flanges, Catalog 411, Tube Turns, Louisville, Kentucky, 1979.

2. "Specification Drum 55 Gal. DOT-17C," EG&G Idaho, Inc. Specification ES - 50365D, February 5, 1987.

3. S. P. Timoshenko and J. M. Gere, Theory of Elastic Stability, Second Edition, McGraw-Hill Book Co., New York, 1961.

Dummy Drum Reinforcing Structure Description

From the cover communication reference, the dummy drum has a significant amount of material removed from the drum wall; a reinforcing structure is emplaced within the drum to resist axial loads imposed on the dummy drum. Basically, the structure consists of four carbon steel 2 in. schedule 80 pipes, equally spaced within the drum circumference and oriented axially with the drum, welded to two steel plates which contact the inner surfaces of the drum lid and bottom closures. In addition, a number of transverse pipe braces are welded to the primary structural pipes resulting in a maximum unbraced axially loaded pipe length of approximately 24 in.

Load capacities based on yield stress

If the yield stress, σ_y, of the reinforcing stricture and unmodified drum are assumed to be the same, then the yield stress based axial load capacities are proportional to the respective cross-sectional areas. From Reference 1, a 2 in. schedule 80 pipe has the following nominal dimensions:

outside diameter, D_o, = 2.38 in.
wall thickness, t, = 0.218 in.

which yields D_i = 1.94 in. (inside diameter). The cross-sectional area, A_p, of one pipe is

$$A_p = \frac{\pi}{4}\left(D_o^2 - D_i^2\right)$$

$$= 1.49\ in^2.$$

The total axial area, A_s, and yield load, P_{sy}, of the structure are, then:

$A_s = 4A_p = 5.96\ in^2$
$P_{sy} = A_s\sigma_y = 5.96\sigma_y$ lb.

For an unmodified drum, from Reference 2, drum radius, R, and wall thickness, h, are:

R = 11.25 in
h = 0.06 in.

The axial area, A_d, and yield load, P_{dy}, of the drum are, then:

$A_d = 2\pi Rh = 4.24\ in^2$
$P_{dy} = A_d\sigma_y = 4.24\sigma_y$ lb.

Therefore, it is seen that, if both unmodified drum and dummy drum structure have similar yield strengths, the dummy drum structure has greater material strength-based axial load capacity than an unmodified drum.

Buckling Load and Stress

From Reference 3, the elastic buckling load of one structural pipe segment, P_{sb}, is:

$$P_{sb} = \frac{k\pi^2 E I_p}{L_p^2}$$

$$I_p = \frac{\pi}{64}\left(D_o^4 - D_i^4\right)$$

where: k = a constant dependent on the pipe end conditions (1.0 for pinned and 4.0 for fixed ends)

$E = 3x10^7$ psi, Young's modulus of the pipe material
$I_p = 0.88\ in^4$, pipe cross-section area moment of inertia
$L_p = 24$ in., unsupported pipe length.

If k is conservatively assumed to be equal to 1.0, upon substitution,

$P_{sb} = 4.52x10^5$ lb.

The corresponding axial stress, σ_{sb}, is:

$\sigma_{sb} = P_{sb}/A_p = 3.03x10^5$ psi.

This stress is much greater than typical carbon steel yield stress ($3.0x10^4$ to $4.0x10^4$ psi). Thus, axial strength of the column is governed by P_{sy}.

From Reference 3, the buckling stress for an unmodified drum, σ_{db}, may be estimated as:

$$\sigma_{db} = \frac{Eh}{R\sqrt{3\left(1-\nu^2\right)}}, \qquad \left(\frac{\pi R}{L_d}\right)^2 \leq \frac{2R}{h}\sqrt{3\left(1-\nu^2\right)}$$

$$= \frac{\pi^2 E h^2}{12\left(1-\nu^2\right)L_d^2}, \qquad \left(\frac{\pi R}{L_d}\right)^2 > \frac{2R}{h}\sqrt{3\left(1-\nu^2\right)}$$

where: v = 0.3, Poisson's ratio for the drum material

L_d = 35 in., axial length of the drum.

For the drum dimensions, the characteristic radius-to-length ratio is much less than the characteristic radius-to-thickness ratio; the first of the above equations governs calculation of the buckling stress. Upon substitution of appropriate drum dimensions and properties into this equation,

$$\sigma_{db} = 9.68\times10^4 \text{ psi.}$$

As was the case for the pipe reinforcement structure, this stress is much larger than typical yield stresses for carbon steel materials; material yielding governs axial strength of the unmodified drum.

In summary, if the yield stresses of all materials is similar, axial strength of the reinforcing structure to the unmodified drum corresponding strength is:

$$P_{sy}/P_{dy} = A_s/A_d = 5.96/4.24 = 1.4.$$