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Report of Survey Conducted at

**DEPARTMENT OF ENERGY
OAK RIDGE FACILITIES**

Operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
OAK RIDGE, TENNESSEE

MARCH 1993

BEST MANUFACTURING PRACTICES



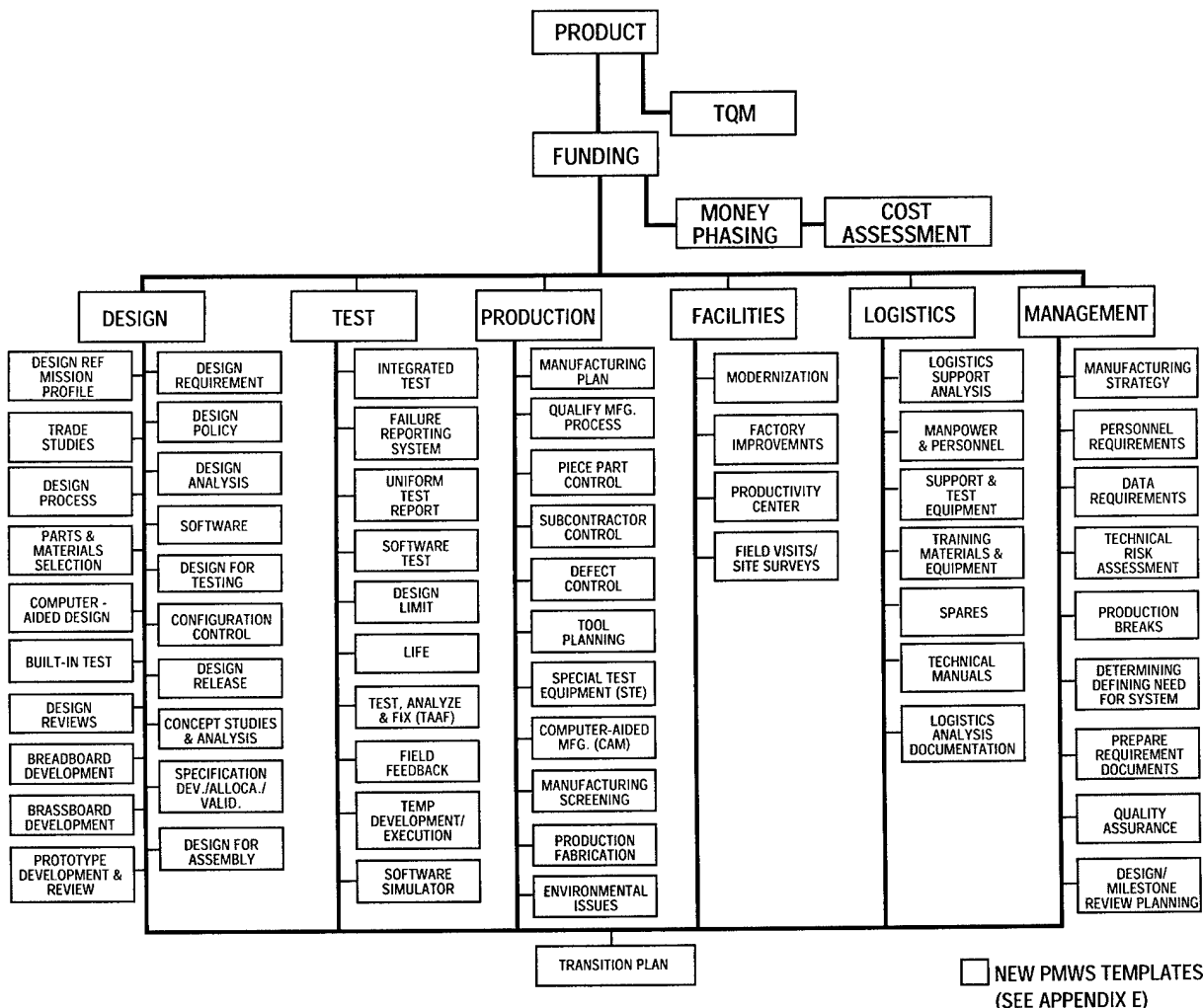
Center of Excellence for Best Manufacturing Practices

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AGT 02-03-7500



“CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION”



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SECTION 1

EXECUTIVE SUMMARY

1.1 BACKGROUND

The Navy's Best Manufacturing Practices (BMP) program team conducted a survey at the Department of Energy (DOE)-Oak Ridge Facilities including Oak Ridge National Laboratory (ORNL), the Y-12 Plant, and the K-25 Site, operated by Martin Marietta Energy Systems, Inc. (MMES) located in Oak Ridge, Tennessee the week of 29 March-2 April 1993. The purpose of the Oak Ridge survey was to review and document its best practices and investigate any potential industry-wide problems. The BMP program will use this documentation as an initial step in a voluntary technology sharing process among the industry and government.

1.2 BEST PRACTICES

The best practices documented at Oak Ridge are detailed in this report. These topics include:

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Organizational Improvement Programs at the Y-12 Plant	13
"Revolution Through Evolution" describes the Oak Ridge Y-12 Plant Total Quality Management effort that has evolved into currently implemented programs.	
Function Point Analysis for Estimation of Software Development Schedules	14
The Oak Ridge Y-12 Plant established a Software Metrics Team to address the problem of estimating software systems development. The team uses Function Point Analysis, a formalized method of estimating the size and cost of software applications development projects.	
Y-12 Packaging (Container) Program	14
The Oak Ridge Y-12 Plant Packaging Program provides safe, efficient, and economical packaging for transporting general cargoes, radioactive materials, and other hazardous materials.	

Item	Page
Concurrent Product and Process Engineering	15
The Oak Ridge Y-12 Plant maintains design, development, manufacturing and certification/testing technologies and capabilities that are imperative for complex/difficult-to-make machined parts and assemblies.	
Integrated Refractory Metals Manufacturing Supports Space Research	15
The ORNL Materials Processing Group has successfully invented, manufactured, and delivered hardware for six isotope-powered spacecraft.	
Composite Design and Manufacturing Methodologies	16
ORNL is a leader in the design and manufacture of components consisting of polymer matrix composite materials.	
Business Process Development Using IDEF	16
The Y-12 staff uses Integrated Computer-Aided Manufacturing Definition Language Software Engineering tools to model Y-12 manufacturing processes and Army Acquisition Community information management activities.	
Software for Nuclear Safety Analyses of Spent Fuel	16
The Standard Computer Analyses for Licensing Evaluation system of nuclear and heat transfer software was developed at ORNL to provide an easy-to-use system for criticality, shielding, and thermal analysis of nuclear facility and package designs.	
Quench Simulator	17
The Quench Simulator at the Oak Ridge Facilities is a computer model developed to simulate the quenching behavior of uranium/titanium alloys.	

Item	Page	Item	Page
Advanced Graphics Postprocessing	17	Super Laminate for Active Metals Vacuum Induction Melting	19
A virtual device interface program called PLOT was developed at Y-12 that accepts the output format of each type of CAD system in use and converts it into a common format used by the program to drive a variety of plotters.		The Y-12 Plant Materials Engineering Department was requested by DOE divisions to assist and evaluate disposal alternatives for over 235 tons of submarine reactor core hardware. Y-12 introduced a new world class technology by determining that melting reactive metals in a graphite system is now possible with the Super Laminate for Active Metals Vacuum Induction Melting process.	
CAD Data Transfer Using Computer-Aided Logistics Support Standards	17	Graphite and Carbon-Carbon Composite Research	20
The Y-12 Plant employs a staff to address resolution of difficulties in exchanging data among CAD systems of different manufacturers or software suppliers.		The Carbon Materials Technology Group at ORNL is actively involved in the development of carbon-based materials for high-tech applications in the nuclear (both fission and fusion) and aerospace industries.	
VIDEOSPEC: A New Approach to Glovebox Procurement	18	Test Method Development and Mechanical Property Testing of Metals, Ceramics, and Polymers	20
ORNL procured a custom fabricated isolation work chamber using a combination of three-dimensional computer simulation with written specification and hardware standards.		ORNL has designed and licensed a special fixture utilizing hydraulics to ensure accurate alignment of a conventional tensile test specimen.	
Communicating with Stereolithography	18	Calibrating Ultrasonic Delamination Testing	21
Y-12 is using a commercial stereolithography system to enhance communications between design and manufacturing personnel by building a plastic prototype directly from a surface or solid CAD model without the need for any traditional machining or other manufacturing equipment.		Because Y-12 needed to test for delamination flaws in high pressure work bottles for hydraulically operated rocket guidance systems, it created a simple calibration process for its ultrasonic measurement system.	
Engineering Visualization	19	Combat Modeling, Simulation, and Gaming	21
MMES uses computer visualization as a conceptual design tool for the engineer and to allow participation between technical and non-technical disciplines. The staff uses a high performance graphics workstation and robotics simulation software package to model man, machines, and other systems as they appear and function in the application environment.		The K-25 Site has been integrating its scientific and its proven computer conceptual, coded, and analytical models with the Y-12 Plant's Process and multiple outcome simulations and prototypes.	
Future Armor Rearm System	19	Weld Quality Control Services	21
This Armor Rearm System applies robotics technology to provide a safer, more efficient method of providing underway replenishment of tank ammunition.		The Weld Certification Program maintained by the Equipment Testing and Inspection group qualifies all welders employed by MMES, the Y-12 Plant, K-25 Site, and MMES prime and most sub-contractors.	

Item	Page	Item	Page
Ceramic Manufacturing	21	M-60 Coordinate Measuring Machine	25
The Y-12 Plant at Oak Ridge has over thirty years' experience making ceramic parts up to 21 inches in diameter from various materials including oxides, carbides, nitrides, cermets, salts, and beryllium and uranium materials.		Located within the Y-12 Plant Inspection Facility is one of the world's largest CMMs with a published measurement uncertainty of between 20 and 70 millionths of an inch, depending on part size, complexity, and material.	
Automated Data Acquisition System for Inventory and Tracking of Containers	22	Leica Laser Tracker	25
An Inventory Management Information System was developed and implemented to provide a fully integrated inventory system for tracking the movement, monitoring process steps, and recording the storage locations of the thousands of waste containers located throughout the K-25 Site.		A Leica Laser Tracker is a state-of-the-art portable inspection system now being used at Y-12 to offer replacement technology for precision theodolite measuring systems by providing comparable or slightly enhanced accuracy and consistent results not dependent on operator skills.	
Non-destructive Testing	22	Precision Metrology Expertise	25
MMES at the Oak Ridge Y-12 Plant maintains one of the most complete non-destructive testing facilities in industry.		The Y-12 Inspection Facility has made a concerted effort to position the facility in a complementary role to the National Institute of Standards and Technology (NIST) mission by serving the nation as a facilitative leader in the area of Precision Metrology.	
Precision Metal Forming	22	Inspection Facility and Equipment	25
The Oak Ridge Y-12 Plant has developed precision forming capabilities for a variety of materials and products.		The Oak Ridge Y-12 Plant Inspection Facility has converted its weapons manufacturing capability in precision metrology to a testbed for examining and solving common issues that face the American manufacturing industry.	
Automated On-line Inspection	23	Distributed Numerical Control	26
ORNL is applying its experience and facilities in automated on-line inspection to uses other than weapons production.		Y-12 has realized many benefits by changing from NC to DNC machines.	
Machine Tool Maintenance Program	24	Manufacturing Verification through NC Program Simulation	26
The Y-12 Plant machine tool maintenance program which services production machines capable of producing parts with tolerances as low as 50 millionths and down to 5 millionths requires a staff of highly trained maintenance personnel.		The Oak Ridge Facilities recognized the need to eliminate interference (collisions) among the tool holders, machine spindles, fixturing, and the part being machined. Software was developed for use on an engineering workstation to simulate the NC program.	
Non-film X-rays	24	Ion Milling	27
Y-12 has created the capability of producing non-film X-rays by adapting conventional radiography to a system that creates a digital image with improved precision.		The Optical Manufacturing Operational Development and Integration Laboratory (MODIL) has an ion milling cell which uses the impact of ionized argon on the surface of a material to dislodge surface atoms.	
Analytical Services	24		
The Y-12 Plant Analytical Services provide a comprehensive array of testing equipment.			

Item	Page	Item	Page
Kerf Collection System	27	Management of Excavated Soils	29
Because of related safety hazards and the value of reclaiming the lithium, Y-12 designed a kerf (or chips and dust generated during machining) collection system.		Construction activities at the Y-12 Plant have often required the excavation or other soil management within the facility. Because some of this soil may be contaminated, MMES adopted specific policies to ensure the proper management of contaminated or potentially contaminated soil at the plant.	
Isostatic Pressing Capabilities	28	Resource Conservation and Recovery Act Closures	31
The isostatic pressing capability at the Oak Ridge Y-12 plant is among the largest in the world. The working chamber of the oil isostatic press can reach pressures of up to 30,000 psi with oil temperatures up to 150 degrees C to compact elastomeric molds containing ceramic and/or metallic powders.		Due to the requirements of the Resource Conservation and Recovery Act (RCRA), certain landfill and hazardous waste areas at the DOE Oak Ridge Facilities had to be contained. Personnel applied their extensive expertise in RCRA permits, containment, closure plans, and dealing with all of the regulatory requirements.	
Non-spherical Cutters for Rapid Material Removal	28	Spill Control System	31
Y-12 was challenged to improve cutting times and final machined surface finishes for a series of jobs with complex surfaces and therefore incorporated the use of non-spherical (toroidal) cutters to greatly enhance the cutting speeds and depths of cut, achieving improved surface finishes and extending tool life.		The Y-12 Plant at Oak Ridge employs a unique system to control any hazardous waste spill that may occur into the nearby East Fork Poplar Creek.	
Expert Systems	28	Recycling Chemicals Used in Electroless Plating	32
Several expert systems have been developed at ORNL to capture the knowledge of experienced designers and machine tool operators.		Engineers at the K-25 Site have developed a technology known as ENVIRO-CP to eliminate hazardous and expensive problems associated with applying nickel plating.	
In Situ Soil Mixing Combined with Vapor Extraction for Treatment of VOC Contaminated Soils	28	Sensor Development for Environmentally Relevant Species	32
ORNL, in cooperation with university and private industry participants, has developed and successfully demonstrated an in-situ process to treat VOC contaminated soil utilizing soil mixing combined with thermal vapor extraction and peroxidation destruction.		ORNL and Michigan State University teamed to design, build, and develop a modified surface acoustic wave device whose frequency is selectively depressed by the absorption of poly chlorinated biphenols.	
In Situ Vitrification Method for Waste Disposal	29	Analytic Instrumentation	32
An extensive environmental restoration effort is underway at the DOE Oak Ridge to develop and apply technologies that can provide data or remediate a site in situ, thereby averting the need to excavate, creating problems and expense related to worker exposure, environmental releases, and waste disposal issues.		Y-12 has analytic instrumentation expertise in the design and test of field monitors for process characterization and monitoring of plant effluents.	
		Machine Coolant Management	33
		Y-12 has implemented a recycling program for its primary water based coolant for machining operations.	

Item	Page	Item	Page
Improved Handling of Recycled Materials	33	Predictive Maintenance Methods Using Vibration Analysis and Motor Current Analysis	36
Y-12 is tasked to provide nuclear weapon dismantlement and its efforts have expanded substantially, generating tremendous quantities of material for recycling. Existing recycle systems were initially inadequate and inefficient and to solve these handling problems, it developed tote pans for all depleted uranium storage and handling.		MMES uses mechanical vibration analysis and motor current analysis for predictive maintenance on large rotating AC equipment.	
Technology Logic Diagram	33	Glovebox Quick Glove Replacement System	37
The Technology Logic Diagram integrates and cross references information about a site's environmental and waste management problems with analyses of technologies which can potentially be applied to solve the problems.		MMES has worked with a contractor to develop a quick change mechanism with which a glove in the glovebox system can be replaced in a matter of minutes.	
Environmental Compliance Management Publications and Checklists	34	Damped Motion for Suspended Payloads in Overhead Cranes	37
The Oak Ridge Y-12 Plant has created a number of publications including Procedures, Directives, and Standards to guide Plant compliance with the wide variety of applicable environmental regulations.		The Oak Ridge National Laboratory and Sandia Laboratories teamed to develop and test algorithms for damped-oscillation, swing free transport of suspended payloads.	
Soldier Robot Interface Project Mobile Telerobotic Testbed	35	Single Point Diamond Turning of Optics	37
The Army's Soldier Robot Interface Project was developed at the Oak Ridge for the U.S. Army's Human Engineering Laboratory as an experimental testbed for a variety of human factors issues related to the military application of robotics.		Y-12 is using single point diamond turning which can achieve final design requirements exhibiting proper geometric forms with nanometer smoothness characteristics.	
Shop Floor Control	35	Advanced Servomanipulator for Remote Handling	38
Shop Floor Control represents one of the latest additions to the Manufacturing Management System.		An Advanced Servomanipulator was developed and built at ORNL to support nuclear fuel processing applications. This unique system is the first remotely operated servomanipulator that is designed to be completely maintainable by remote means.	
Machine Tool Retrofit Program	36	Y-12 Plant Capabilities Knowledge Based System	38
Y-12 identified three basic machine types to undergo retrofit in early 1980s based on Y-12's realization that to remain cost competitive and proficient at completing required tasks, the Plant needed to quickly initiate a machine restoration program.		The Oak Ridge Y-12 Plant Capabilities Knowledge-Based system is a unique, multi-purpose electronic brochure depicting the proven capabilities and expertise of the Y-12 Plant facilities, equipment, and personnel.	
Infrared Thermography for Roof Leaks	36	Vendor Documentation Database	39
Y-12 personnel developed an Infrared Thermography System for detecting roof leaks.		The Y-12 Plant developed a computerized inventory system with records on almost 28,000 of the approximately 100,000 documents for purchased equipment in the Plant.	

Item	Page	Item	Page
Optics MODIL	40	Union/Management Relations	41
The Optics MODIL maintains a mission to enhance the competitiveness of the national optics industry by developing and validating key – or high risk and high benefit – manufacturing processes, thereby reducing component cost and lead times while providing advanced scientific knowledge to an emerging discipline of this engineering science.		The DOE-Oak Ridge complex provides a good example of successful labor-management relations.	
Large Project Cost and Schedule Control/Reporting System	40	Central Training Facility	42
The DOE-Oak Ridge MMES Technology Services Division has developed a streamlined and user-friendly Cost and Schedule Control System.		The Central Training Facility at Oak Ridge is a unique operation that trains personnel responsible for maintaining security at the DOE Oak Ridge Operations Facilities.	
Technology Transfer	40	Dynamic Special Nuclear Materials Control and Accountability System	42
MMES emphasizes technology transfer at the DOE-Oak Ridge complex and demonstrates its support in several ways, including the appointment of a Vice-President and strong support staff.		The Dynamic Special Nuclear Materials Control and Accountability System at Y-12 is chartered to assist in preventing or detecting the loss of nuclear material through theft, diversion, or error.	
Work for Others	41	Industrial Security	42
MMES-Oak Ridge sponsors the Work for Others program that draws on an extensive talent base in computer science, mathematics, statistics, physical sciences, social sciences, life sciences, all engineering disciplines, and a highly skilled labor force.		The Y-12 Plant Oak Ridge Facilities Security Department conducts a comprehensive security program in support of MMES projects characterized by a flexible, multifaceted, and responsive approach to the security requirements of projects with classifications requirements from UNCLASSIFIED to SECRET-RD.	
Personnel Outplacement Services	41	Using I-CASE Technology	42
MMES is dedicated to helping personnel affected by the drawdown to find new employment opportunities. The company has established networks to help locate jobs based on benchmarking efforts of other placement programs.		Martin Marietta Energy Systems, Inc. has been building, developing and applying a set of Integrated Computer Aided Software Engineering (I-CASE) tools to help reduce long lead times for application development and the high cost of eliminating errors late in development or after the system is in operation.	
Statistical Education	41	Prioritization of Maintenance Job Requests	43
The importance of the application of statistical methods at Y-12 has long been recognized in the efficient production of quality items. For this reason, education of the workforce in statistical methods has been given particular attention since 1986.		The Maintenance Importance Generator program combines elements of federal and state policy, plant policy, physical plant particulars, maintenance personnel data, customer organization expertise, and maintenance expertise to develop a numeric value for each work order and establish priorities.	

Item	Page
Risk Ranking for Maintenance Planning	43

Y-12 Plant established a risk ranking methodology for maintenance planning and preventive maintenance. This is a formal method for balancing the level of detail of maintenance planning with the risks or hazards of equipment failure and for balancing the cost of preventive maintenance with the consequences and probabilities that could have been prevented.

Software Quality Assurance at Y-12	43
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The Oak Ridge Y-12 Plant, a major developer and user of computer software, initiated a formal program in 1983 to control software quality. Beginning in 1988 major initiatives were undertaken to further improve the software quality system.

1.3 INFORMATION

The following information items are detailed in this report:

Item	Page
Y-12 Ultrasonic Inspection Capabilities	45

The Oak Ridge Y-12 Plant ultrasonic capabilities provide for non-destructive measurement of the acoustic properties of production and development materials.

High Temperature Materials Laboratory	45
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The ORNL High Temperature Materials Laboratory is a center for research and development of advanced technologies to reduce the cost of manufacturing ceramics and other high temperature materials.

Casting and Machining of Complex Shaped Parts	45
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The Y-12 Plant addressed producibility issues in a fusion energy experiment because of complex geometry of a cast stainless steel twisted tee section in both near net shape casting and final machining. Y-12 therefore used a conventional CMM as a process development tool.

Item	Page
Development of Advanced Joining Technologies for Manufacturing	46

The Oak Ridge Y-12 Plant personnel represent considerable experience and capabilities in metal joining.

Materials Testing	46
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MMES at the Oak Ridge Y-12 Plant maintains a complete materials testing facility with the capability to evaluate quality in diverse products at all stages of manufacturing.

Optical Edge Inspection System	46
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The Oak Ridge Optical Edge Inspection System is a replacement for traditional processes employing casting edge impressions and analyses on optical comparators.

Process Quality Control for Inspection Machines	47
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The Y-12 Plant successfully initiated a Calibration Program as an SPC tool for quality control inspectors and machine operators to help ensure repeatability of production parts, demonstrate quantitative improvement in the machining process, and document evidence of dimensional inspection capability.

Automatic Inspection and Compensation Generation System	47
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Engineering personnel at the Y-12 Plant at Oak Ridge have developed an automatic testing and compensation generation system which conducts structured positioning and squareness tests to provide a graphic plot of the error data with warnings identifying potential machine tool non-conformances, while generating compensation data in the required format.

Precision Production Machining Program	47
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The Y-12 Plant at Oak Ridge has pioneered improvements in production machine tools that have resulted in machining capabilities of significant precision.

Item	Page	Item	Page
Soft Gaging for CMMs	47	Resource Conservation and Recovery Act Waste Minimization Initiative	50
The Fabrication Systems Department at the Y-12 Plant is working with CMM vendors and software specialists to develop a routine to generate a mathematical representation for soft gaging.		The Oak Ridge Y-12 Plant has undertaken an initiative to reduce or eliminate the generation of waste regulated as hazardous under RCRA.	
Enhanced Large Surface Inspection Capability	48	Hazardous Solvent Replacement Program	50
The Fabrication Systems Department at the Oak Ridge Y-12 Plant is developing an enhanced system to inspect large surfaces with complex curvature.		In response to stringent health and environmental issues, the Oak Ridge Y-12 Plant has instituted an active program to find substitutes for chlorinated solvents used for parts cleaning.	
Automated Inspection	48	Environmental Restoration Program	50
The Oak Ridge Y-12 Plant initiated a project in 1988 to automate inspection information.		An extensive environmental restoration effort is underway at Oak Ridge including development of a number of cutting edge remediation technologies to effect the clean-up of areas surrounding the Y-12 Plant, K-25 Site, and ORNL.	
Inorganic Membrane Technology	48	Use of Micro Techniques to Assist Macro Problems	51
The technical division of the K-25 Site at Oak Ridge has fifty years of experience in reverse osmosis inorganic membranes research, development and manufacture.		The ORNL has developed an in-house capability of highly trained personnel and state-of-the-art equipment to analyze a variety of sample types required by environmental regulatory agencies.	
Surface Coatings	48	Environment, Safety and Health Five-Year Plan for the Oak Ridge Y-12 Plant	51
The Oak Ridge Y-12 Plant has a large facility for providing surface coatings for various production applications.		The Oak Ridge Y-12 Plant created a Five Year Plan to identify activities and resources required during the 1995 to 1999 period to bring the Plant into and maintain compliance with environmental, safety, and health (ES&H) regulations and standards.	
Wastewater Treatment Facilities	49	Health, Safety and Environment	51
Oak Ridge Y-12 Plant personnel have extensive knowledge of wastewater management, and there are currently six facilities to treat the wastewater generated by the Plant.		The Oak Ridge Y-12 Plant has a Health, Safety and Environmental organization with extensive capabilities.	
Monitoring Wastewater Outfalls	49	Upgrading Repair History Programs	52
The Oak Ridge Y-12 Plant employs a well-designed system of monitoring the outflow of treated wastewater to the East Fork Poplar Creek which runs through the site.		Y-12 has developed a methodology to provide data through statistical analysis to reveal trends and recurring problems for improving maintenance effectiveness, cost, and reliability.	
Centralized Waste Tracking and Management	49		
The DOE-Oak Ridge Facilities are required to comply with the Tennessee Oversight Agreement which includes maintaining a comprehensive waste tracking system.			

Item	Page	Item	Page
Y-12 Plant Operational Readiness	52	Data Systems Research and Development Program	54
To ensure safe facility operation which is in compliance with overall governing requirements, an Operation Readiness Process is applied at Y-12.		The DSRD Program maintains a mission to provide direct support to U.S. government agencies to design, develop, and apply state-of-the-art information technologies to provide modern solutions to problems affecting mission performance of the Department of Energy and other federal agencies.	
Space and Defense Technology Program	52	Standard Generalized Markup Language	54
The mission of the Space and Defense Technology Program is to apply the collective capabilities of the DOE Oak Ridge Facilities to finding scientific and technological solutions to problems of national importance.		The Publications Division of MMES recognizes that national and corporate information is an asset and has therefore initiated efforts to develop the expertise to bring these assets under control for the benefit of the company.	
Information Resources Management	52	Y-12 Quality Information System	54
The Information Resources Managements Section of DSRD provides research and technical assistance to federal agencies in the planning, development, management and implementation of corporate information resources.		Y-12 invested in a Quality Information System known as SAS – a tailorable software package that allows the user to tailor the program to meet specific quality monitoring requirements.	
Y-12 Computer Integrated Enterprise Program	53	Mechanical Inspection Services	55
This program was initiated in 1974 to facilitate needed modernization efforts, improve basic business processes, and leverage technology resources.		Y-12 provides a variety of inspection and certification services for the Oak Ridge Y-12 Plant and other Martin Marietta Energy Systems Facilities in the Oak Ridge area.	
Information Center Concept	53	1.4 PROBLEM AREAS	
The Oak Ridge Y-12 Plant has created a corporate Information Center database to receive both classified and unclassified information.		The BMP Survey Team documented the following problem areas:	
Electronic Signature and Record Management System	53		
As a project in the Work for Others Program, MMES has developed a system to manage electronic records and an electronic signature capability.		Item	Page
Electronic Document Management System	54	Technology Transfer from National Laboratories	57
This system provides a client/server environment that can be applied to any electronic document or drawing file control situation in which there are access and configuration control requirements.		Experiences with technology transfer by the staff at ORNL have indicated this is an area that requires further study to protect the nation's considerable investment in the development of new technology at the national laboratories.	

SECTION 2

INTRODUCTION

2.1 SCOPE

The purpose of the Best Manufacturing Practices (BMP) survey conducted at the Department of Energy (DOE)-Oak Ridge Facilities operated by Martin Marietta Energy Systems, Inc. (MMES) in Oak Ridge, Tennessee was to identify best practices, review manufacturing problems, and document the results. The intent is to extend the use of progressive management techniques as well as high technology equipment and processes throughout industry and government facilities. The ultimate goal of the BMP program is to strengthen the U.S. industrial base and reduce the cost of defense systems by solving manufacturing problems and improving quality and reliability.

A team of engineers accepted an invitation from DOE-Oak Ridge to review the processes and techniques used in its facilities located in Oak Ridge, TN. Potential industry-wide problems were also reviewed and documented. The review was conducted at DOE-Oak Ridge on 29 March-2 April 1993 by the team identified in Appendix B of this report.

The results of BMP surveys are entered into a database for dissemination through a central computer network. The actual exchange of detailed data will be between companies at their discretion.

The results of this survey should not be used to rate DOE-Oak Ridge with other government activities, defense contractors, or commercial companies. The survey results have no bearing on one facility's performance over another's. The documentation in BMP reports is not intended to be all inclusive of the activity's best practices. Only selected non-proprietary practices are reviewed and documented by the BMP survey team.

2.2 SURVEY PROCESS

This survey was performed under the general survey guidelines established by the Department of the Navy. The survey concentrated on the functional areas of design, test, production, facilities, logistics, and management. The team evaluated DOE-Oak Ridge's policies, practices, and strategies in these areas.

Furthermore, individual practices reviewed were categorized as they relate to the critical path templates of DoD 4245.7-M, "Transition from Development to Production." DOE-Oak Ridge identified potential best practices and

industry-wide problems. These practices and other areas of interest were discussed, reviewed, and documented for distribution throughout the U.S. industrial base.

The format for this survey consisted of formal briefings and discussions on best practices and problems. Time was spent on the factory floor at DOE-Oak Ridge reviewing practices, processes, and equipment. In-depth discussions were conducted to better understand and document the identified practices and problems.

Demonstrated industry-wide problems identified during the Best Manufacturing Practices surveys may be referred to one of the Navy Manufacturing Technology Centers of Excellence. They are identified in Appendix C.

2.3 ACTIVITY OVERVIEW

The DOE-Oak Ridge Facilities are managed and operated by Martin Marietta Energy Systems, Inc. (MMES), a wholly owned subsidiary of the Martin Marietta Corporation. Three DOE facilities in Oak Ridge are part of five energy-related production and research facilities administered by MMES, with the remaining two sites located in Paducah, Kentucky and Portsmouth, Ohio. These facilities are operated under a long term cost-plus-award-fee Management and Operations Contract. This contract does not allow MMES to compete for work in the commercial sector but it does allow the performance of work for others outside of DOE. The Department of Defense has been and continues to be one of the largest customers. The extensive capabilities at Oak Ridge are housed on over 5,000 acres of land and employ over 7,500 personnel. The three sites include:

- Oak Ridge National Laboratory (ORNL). Originally ORNL was constructed as part of the World War II Manhattan Project when its mission was to produce and chemically separate the first gram quantities of plutonium as part of the effort to produce the atomic bomb. The ORNL currently maintains a primary mission to attain abundant, economic and environmentally acceptable sources of energy. It is one of the world's largest and most diverse centers for basic and applied scientific research and technology development.
- Oak Ridge Y-12 Plant. Also originally part of the Manhattan Project, Y-12 has produced components for various nuclear weapons vital to national defense. Its

present mission encompasses dismantling nuclear weapon components; providing special production support to DOE programs; and serving as a manufacturing technology demonstration center.

- Oak Ridge K-25 Site. As the third component of the Oak Ridge element of the Manhattan Project, K-25 (originally the Oak Ridge Gaseous Diffusion Plant) was constructed to separate the uranium-235 isotope for use in atomic weapons. Today, K-25 is a part of the Applied Technology Organization that is responsible for facilitating application of advanced science and technology developed at MMES-managed DOE sites to national problems. This mission is concurrent with the technology transfer efforts by the Applied Technology Organization to help industry gain benefits from research and technologies developed at DOE-Oak Ridge.

2.4 ACKNOWLEDGMENTS

Special thanks are due to all the people at DOE-Oak Ridge whose participation made this survey possible. In particular, the BMP program acknowledges the special efforts of Mr. Dave Beck for enabling this survey to occur. In addition, we also wish to recognize the contributions of

Mr. Allen Summey and the MMES BMP Steering Committee consisting of Paul Sooter and Janie Lunsford, Sam McSpadden, Dave Post, Dave Lindsey, Harvey Gray, Brigham Thomas, Dean Hartley, Kate Ingle, Bob Fellows, Susie Foust, Bill Reynolds and J.R. Foster.

2.5 ACTIVITY POINT OF CONTACT

The information included in this report is descriptive of the best practices and techniques observed at DOE-Oak Ridge; however, it is not all inclusive. The reader will require more detailed data for technology transfer. This data is available through the survey point of contact. The point of contact for this BMP survey is:

Mr. Allen Summey
Deputy Program Manager
Seawolf/Navy Program Office
Martin Marietta Energy Systems, Inc.
P.O. Box 2009
Building 9201-1, M/S 8211
Oak Ridge, TN 37831-8211
Phone: 1-800-356-4USA

(This phone number is connected to the Manufacturing Technology Information Service)

SECTION 3

BEST PRACTICES

The survey at the Department of Energy Oak Ridge Facilities presented the BMP team with a singular and challenging opportunity. Aside from the size of the survey which was the largest to date in the BMP program's history, the scope and nature of the work performed at these facilities had, for some time, been obscured in secrecy. Assimilating the survey information and documenting the significance of the diverse capabilities of the facilities provided this BMP team with its greatest task. This survey encompassed three of the five sites currently managed and operated for the DOE by Martin Marietta Energy Systems. Those three facilities – the Oak Ridge National Laboratory, the Y-12 Plant, and the K-25 Site – are supplemented by facilities in Kentucky and Ohio.

As one of the primary sites for the World War II Manhattan Project, the Oak Ridge complex was constructed to produce one of the first nuclear weapons; therefore, most of the work in development of advanced technology and manufacturing processes was restricted from general public distribution. Recent changes in the geopolitical environment, combined with the realization by Congress that the previous level of preeminence in the technological arena was no longer held by U.S. industry, prompted national initiatives to transfer technology from government laboratories to the private sector. As a result of the Congressional initiatives, many technologies developed at Oak Ridge, once restricted because of their weapons applications, are now offered for licensing under Cooperative Research and Development Agreements and other technology transfer arrangements. To foster this technology transfer, Oak Ridge literally "moved the fences," consolidating previously classified areas into unclassified manufacturing facilities for easier access by visiting companies. These industrial, accessible facilities are now called the Oak Ridge Centers for Manufacturing Technology and are designated DOE User Facilities. In addition to sharing advanced manufacturing technology, sophisticated scientific test equipment is available to technological researchers, through user facility arrangements, new connections are being pursued with academic institutions to extend manufacturing education.

Oak Ridge maintains a substantial aggregate capability in many diverse areas including manufacturing, manufacturing support, and research and development. In addition to these diverse physical capabilities evident during the BMP survey, the uncommonly high level of technical competency of the Oak Ridge personnel was considered a formi-

dable and highly applicable resource. Total Quality Management efforts have been in place in one form or another at Oak Ridge since the mid 1960s. This emphasis on excellence has fostered an environment that today can provide the U.S. industrial community with benefits derived from years of experience and expertise in many manufacturing and related processes.

Through the willingness of its previously separated entities to come together and share the applied sciences developed on site, Oak Ridge offers industry and government a key national technological asset. This dedication and capability was very evident in the presentations submitted to the BMP program survey team. The following best practices are therefore considered by the team to be among the best in industry.

3.1 PRODUCT

TOTAL QUALITY MANAGEMENT

Organizational Improvement Programs at the Y-12 Plant

"Revolution Through Evolution" describes the Oak Ridge Y-12 Plant TQM effort that has evolved into currently implemented programs. This effort was initiated as early as 1962, when Product Quality Control Teams were established, and followed in 1980 with the formation of PRIDE Circles.

In the early 1980s, Deming, Juran, and statistical training programs were started at Y-12. By the mid-1980s, the Plant had integrated the TQM effort into the production areas, expanded the effort to support and services, and augmented it with training. The Y-12 TQM strategy then emphasized continuous improvement, total customer satisfaction, and personnel involvement and empowerment in all products and services.

This evolutionary process continues today through a variety of programs, most significantly the increased emphasis is on communication through such projects as "Nightline," "Bosstalk," "Live at 7:45," Partyline, monthly TQM meetings, and Union/Management Workshops. Other principal thrusts include increased training on leadership, customer service, and people empowerment; and the Pathfinder Mandatory Assessment process, based upon the National Quality Award criteria.

The Organizational Improvement Program effort at the Y-12 Plant has been rewarded with an improved understanding of external as well as internal customers, increased workforce participation, reduced cycle times and costs, doing more with less, breaking down barriers with the unions, and the continuation of the TQM evolution.

3.2 FUNDING

COST ASSESSMENT

Function Point Analysis for Estimation of Software Development Schedules

The Oak Ridge Y-12 Plant Methods and Technology Support Department in the Computing and Telecommunications Services Division established a Software Metrics Team in late 1991 to address the problem of estimating software systems development. The team uses Function Point Analysis as a solution through the International Function Point User's Group (IFPUG). Function Point Analysis is a formalized method of estimating the size and cost of software applications development projects. This metrics function provides valuable input to the information management systems planning process which can be used for estimating schedules, and measuring productivity, quality, and improvement.

Function Point methodology is based on the amount of function delivered to the user instead of counting the lines of code. The Function Point counting practice facilitates measurement earlier in the process – considerably earlier than code. IFPUG counting practices are based on five years of benchmarking industry efforts that are published in the Function Point Guidelines. The Oak Ridge Software Metrics Team adopted this software methodology, received training in Function Point measurement, and applied it to new software development.

To further improve the quality of its estimating capability, the Software Metrics Team established a Checkpoint System purchased from Software Productivity Research, Inc. to track and capture internal Function Point metrics, analyze variances between actual project performance and estimates, and compare productivity rates with industry, thereby providing the best metrics for estimating software. Function Point analysis not only provides traceability, but can be taught to others and explained to the customer. Estimates within + 20% are achievable with the possibility of improvement to + 10%. Productivity can be monitored with a high degree of confidence. Since the beginning of this initiative in late 1991, approximately 35 Martin Marietta Energy Systems personnel have received training and applied their skills in Function Point analysis and Checkpoint software to over 60 software projects.

3.3 DESIGN

DESIGN REQUIREMENTS

Y-12 Packaging (Container) Program

The Oak Ridge Y-12 Plant Packaging Program provides safe, efficient, and economical packaging for transporting general cargoes, radioactive materials, and other hazardous materials. This packaging program is focused on five factors necessary for success—quality assurance, design safety, container packaging experience, a mature production program, and strict cost and schedule controls.

The Quality Assurance Plan and Procedures have provided the foundation for the Y-12 Plant container production program for over four years. During this time, the program has provided more than 2,000 certified drum-type packages that have been carefully managed using configuration controls including tracking of all containers and listing of their locations in a database.

In design safety, material containment, nuclear criticality safety, and radiation shielding are essential considerations of every nuclear package designed and certified at the Y-12 Plant. In addition to design safety, a test plan for qualification tests is often included to ensure compliance with regulatory requirements, assist in the development of operating procedures and specifications, and support the preparation of reports detailing the results of design analyses and container tests.

The Y-12 Plant has cultivated a very capable and experienced work force in container packaging through management commitment and employee education in container development and management. Relevant packaging experience of personnel in the program ranges from six to 38 years, with many employees having earned related graduate degrees.

A mature production program with a realistic manufacturing plan has proved successful over the years at the Y-12 Plant. The plan involves a flow process that includes DOE control points, customer surveillance, container design and development, production, and product qualification and acceptance. During FY'92, more than 1,000 hazardous material containers were produced to support current weapon and returns programs. Cost and schedule controls inherent in the program management system at the Y-12 Plant have been coupled with the production program.

Y-12 Packaging has met all published and approved schedule and budget constraints set by DOE, and plans to continue actively pursuing its mission of ensuring the availability of all types of required packaging, solicit additional work in hazardous material packaging, and pursue marketing opportunities in the national and international arena. Diversification of packaging efforts will be empha-

sized and capabilities will be expanded to match potential customer needs.

DESIGN PROCESS

Concurrent Product and Process Engineering

The Oak Ridge Y-12 Plant has the design, development, manufacturing and certification/testing technologies and capabilities that are imperative for complex/difficult-to-make machined parts and assemblies. The principal enabling technologies that allow for these processes to proceed in a timely, accurate, and cost effective way center on the use of concurrent engineering infrastructure elements that include a large (many nodes) computing network, comprehensive information system, and the implementation of shared computing tools. Because of the need for tight informational control from design through production, the actual Electronics File Manager has the ability to securely and verifiably handle many information/user nodes while still allowing for vital information sharing necessary for real-time concurrent engineering design. The concurrent engineering process makes use of an MIS that includes a CAD System (VAX cluster); capability for on-line comment/approve capabilities; generations of data for NC machines; process engineering data; and fabrication and inspection DNC.

The advantages of concurrent processes include identifying manufacturing/assembly problems earlier in the design cycle; refining and addressing design/manufacturing dependencies early; providing product and process modeling; and simultaneously providing simulation information to all segments of the design/manufacturing team to validate and verify processes and provide an early start on product documentation and training aids when necessary.

Oak Ridge estimates its CAD drafting and modeling has provided a 300% gain over two-dimensional manual drafting, and three-dimensional modeling – while costly – has paid for itself by allowing for corrections and changes that streamline many downstream manufacturing and testing processes.

The use of the CAM tool ANVIL has been instrumental in a productivity increase in the manufacture of complex articles such as parts that require more than just turning and basic milling, as well as in allowing for the feasibility of producing a part using multi-axis milling. As much as a five-time increase in material removal was seen using this capability on a part needing variable lead and tilt angle control and using toroidal cutters.

Two of the many tools that Y-12 applies to complex industrial manufacturing problems are stereolithography for rapid prototyping, and a specially designed Hydroforming Tool Design Advisor that makes use of a knowledge-

based system to capture the expertise of retiring metal forming process specialists.

Integrated Refractory Metals Manufacturing Supports Space Research

The U.S. space programs have been taking advantage of unique refractory metal design and processing capabilities at the Oak Ridge National Laboratory (ORNL) Metals and Ceramics division. The Materials Processing Group provides key materials support for space system power supplies. This group has successfully invented, manufactured, and delivered hardware for six isotope-powered spacecraft which include Voyager, Galileo, and Ulysses, and is now working on hardware for NASA's new Cassini mission.

An isotope-powered supply extracts heat from nuclear fuel and converts it to electricity. The design problem given ORNL was to develop a containment system for the plutonium-oxide fuel in a spacecraft power supply that would provide reliable containment under off normal credible accident conditions, such as failure on the launch pad, early launch abort, or spacecraft reentry. The containment system had to be constructed of an alloy that would be compatible with the radioactive fuel and other graphitic parts in the power supply throughout the many years that could be its long-term operational life. The alloy would have to be designed to be ductile at reentry and impact temperatures so as to provide containment on impact in any credible accident scenario.

To meet these unique requirements, ORNL invented and qualified an iridium alloy that could be formed into a thin clad to enclose the fuel (Figure 3-1). The alloy, composed

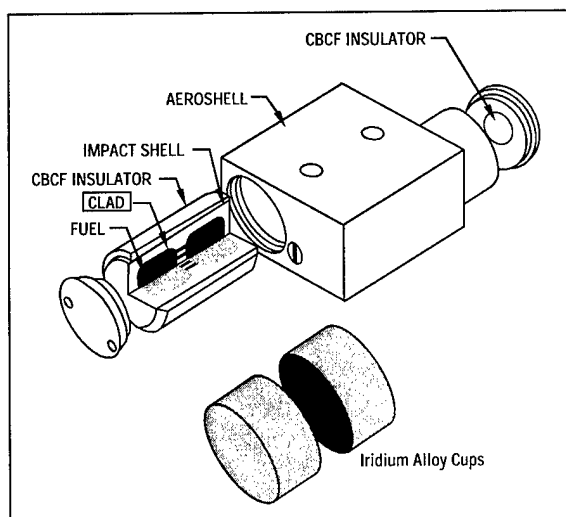


FIGURE 3-1. IRIIDIUM ALLOY FUEL CUP ASSEMBLY

of iridium, tungsten, thorium, and aluminum, is formed into small cups, half the size of the fuel pellets. Two cups are then welded together over the fuel. Rigorous planning and monitoring was implemented to maintain the quality of the alloy used in the space programs. Inspection and certification represents 40% of the labor cost to produce the iridium blanks before they are formed into the cups. The cup assembly is also subjected to high velocity, high temperature impact tests to demonstrate its containment properties.

ORNL has continued to develop the iridium alloy to reduce the manufacturing costs, improve its performance characteristics and margins, and make the alloy more environmentally acceptable. It is hoped that the radioactive thorium in the alloy can be replaced with cerium in a new process under development.

ORNL's unique capabilities and facilities allow this work to be conducted. Manufacture of this alloy is infrequent and requires high level security, as well as unique and expensive equipment. Oak Ridge estimates that 30% of its work is for private companies. This is the only facility in the country which can extrude up to five-inch diameter ingots at temperatures up to 2,000 degrees Celsius. The facility can consolidate starting materials received in almost any commercial form, purify the materials using state-of-the-art electron-beam melters, and melt the materials using a computer-controlled, consumable arc-melting facility. Facilities also include the pilot-scale facilities necessary to machine, extrude, forge roll, or draw advanced refractory alloys.

Composite Design and Manufacturing Methodologies

MMES is a leader in the design and manufacture of components consisting of polymer matrix composite materials. It has developed design methodologies and construction techniques for the production of polymer composite materials that take into consideration raw material characteristics, lamina design properties, laminate theory, and fabrication techniques. The result is the production of parts with high reliability and predictable quality and performance.

Because of the nature of the projects as well as the immaturity of the composites industry, MMES became involved in all aspects of the composite design, construction, and testing processes as well as safety and waste issues. This experience provides insight into the design and construction of laminate materials not found in a typical design shop. This unique perspective has been captured in computer programs written specifically to address the special needs of the design of composite materials. These design models of composite structures are dependent upon the composition of the fiber and the filler.

Curing time is one of the most significant factors with respect to time and cost of the manufacture of laminate materials. MMES is now evaluating methods to decrease the required time to cure laminate materials. Two methods under consideration are microwave processing and electron beam curing. MMES has developed techniques for the manufacture of resolved shapes requiring the use of equipment designed and built in-house. The equipment and manufacturing methodologies emphasize exact fiber placement to maximize component efficiency and performance.

SOFTWARE

Business Process Development Using Integrated Computer-Aided Manufacturing Definition Language

The Oak Ridge Y-12 Plant Data Systems Research and Development (DSRD) personnel have developed considerable expertise in the application of Integrated Computer-Aided Manufacturing Definition (IDEF) methodologies and other information modeling techniques to the problem of business process development. The staff use IDEF-based Computer-Aided Software Engineering (CASE) tools to model Y-12 manufacturing processes and Army Acquisition Community information management activities. IDEF experiences include the management of IDEF projects, facilitation of information management workshops, construction of information models using CASE tools, and the use of related information modeling techniques in conjunction with IDEF. The DSRD staff has also analyzed and evaluated different commercial IDEF and non-IDEF CASE tools.

The development of IDEF models is often a difficult process due to the varying skills and knowledge of the individuals who participate in the modeling process. The Y-12 DSRD staff has developed a workshop approach to IDEF modeling which has been very useful in overcoming some problems associated with the modeling process. Both management and technical attendees at modeling workshops are successful at using IDEF0 activity modeling techniques. Because IDEF1x data modeling is more complex, more focused workshops are used to address this area. DSRD workshops have been successful because of the use of numerous, small focused workshops, trained facilitators with subject matter experience, a clear definition of the workshop purpose for participants, advanced planning, and the development of strawman information models in advance of the workshop.

Software for Nuclear Safety Analyses of Spent Fuel

The Standard Computer Analyses for Licensing Evaluation (SCALE) system of nuclear and heat transfer software

provides standard analytical sequences for the safety analysis of equipment and facilities intended for the handling, storage and transport of spent reactor fuel and other radioactive materials. SCALE was developed at Oak Ridge National Laboratory for the Nuclear Regulatory Commission in order to provide an easy-to-use system for criticality, shielding, and thermal analysis of nuclear facility and package designs. This program has evolved since 1976 when it was developed to allow the use of the KENO Monte Carlo code in well defined analytical sequences in the calculation of the k-effectiveness of complex systems. The development of SCALE was instigated because of the poor quality of existing safety analyses as well as the need for easy-to-use systems for novice and/or occasional users.

Using SCALE, the software user can perform sophisticated criticality safety, radiation shielding and heat transfer analyses by selecting the appropriate standard analytical sequence and providing the system description in easily visualized engineering parameters. Important features of SCALE include its modular system of well-established programs and data, control modules that automate data processing and functional analysis into standard analysis sequences, easy parameter input into the control modules, and system maintenance and enhancements provided under active quality assurance and configuration plans.

SCALE has been continually updated and improved, with over \$4 million spent to develop and maintain the program. Seven new software and documentation releases of SCALE have been distributed to worldwide organizations. SCALE can be used for safety evaluations of production, research, and storage facilities and transportation packages with fissile and/or radioactive materials, design calculations, and spent fuel and high-level waste characterization.

The use of SCALE has improved the quality of safety analyses, and its versatility and ease-of-use has reduced training time for users. Because it is technically accepted, well documented, and continues to be maintained and improved under an approved quality assurance and configuration control plan, the SCALE system will promote standardization and ease the qualification of the safety analyses submitted in the licensing.

Quench Simulator

The Quench Simulator at the Oak Ridge Facilities is a computer model developed to simulate the quenching behavior of uranium/titanium alloys. The model is used to predict transient temperature distributions, residual stress profiles, microstructure, mechanical properties, and distortion of the alloy upon quenching and utilize this information to help solve heat treatment problems.

The model incorporates the use of two codes, the thermal analysis code TOPAZ and the stress analysis code NIKE. It requires extensive property characterization of an alloy as a function of temperature and microstructure. Verification studies have been performed and predictions supported through neutron diffraction analysis. In addition to predicting the amount of residual stress upon quenching, verification of components that have undergone stress leveling (1%-2% permanent set after heat treatment) has been performed.

The Quench Simulator has the proven capability to evaluate material substitution and optimize material performance. It can be used to eliminate costly errors in the production of close tolerance components and is significantly ahead of the current information and models available in industry. There is a three-year, \$10 million dollar research and development effort, in conjunction with the National Center for Manufacturing Sciences and the three other DOE Defense Program Labs, that will further the application of this technology and include the characterization of ferrous material.

COMPUTER-AIDED DESIGN

Advanced Graphics Postprocessing

The Oak Ridge Y-12 Plant has several CAD platforms ranging from AutoCAD PC to ANVIL VAX/VMS and also has a variety of graphics output devices or plotters. Each of these components was obtained for specific tasks, but as systems were increasingly being integrated, it was necessary to connect them in different combinations. A virtual device interface program called PLOT was developed at Y-12 that accepts the output format of each type of CAD system in use and converts it into a common format used by the program. Once in this format, the data can be re-converted into any format used by the Plant's plotters. PLOT currently supports 18 plotter input file formats and 29 CAD output devices for a total of 512 possible combinations.

PLOT was designed for portability and to accept new CAD systems and plotters. A technique of regression analysis and testing was developed that automated much of the task of ensuring that new equipment will work correctly without long plotting runs of each new possible combination. PLOT is presently being used almost 7,000 times per month.

CAD Data Transfer Using Computer-Aided Acquisition and Logistics Support Standards

The Oak Ridge Y-12 Plant has a staff to address resolution of difficulties in exchanging data among CAD systems of different manufacturers or software suppliers. The

Computer-Aided Acquisition and Logistics Support (CALS) system is a growing set of data, format, and procedure standards to facilitate this transfer of data among organizations involved in logistics. One standard – the Initial Graphics Exchange Specification (IGES) – is intended to enable the transfer of CAD data between different CAD systems. However, in some cases the IGES standard has not been implemented completely or correctly in the CAD systems. There are some ambiguities in IGES, and some data bases are more complex than the standard was developed to accommodate.

When possible, the Y-12 staff helps the senders and receivers of data reach mutual agreements for using CALS in ways that will work. If this is not possible, they will try to develop an edit program that can overcome the difficulties automatically. These software solutions (contained in a library called CADxFER) are written so they can be used again if the same problem occurs with transfers between other combinations of CAD systems. If neither mutual agreements nor software solutions will solve the problem, the staff uses analytical techniques to save as much data as possible and highlight portions of a transfer where human interpretation and correction is required.

Y-12 is currently involved in approximately 1,000 IGES file transfers a month, most of which are facilitated by mutual agreements or software edits. To attain this, the staff has become expert in how individual CAD systems work and how IGES has been implemented for them. This effort has resulted in the staff working with suppliers to help improve their products. In addition, the CADxFER may be of value to other organizations.

VIDEOSPEC: A New Approach to Glovebox Procurement

The Oak Ridge Facilities procured a custom fabricated isolation work chamber – or glovebox – using a combination of three-dimensional computer simulation with written specification and hardware standards. This combination, called a VIDEOSPEC, eliminated the need for numerous engineering drawings and resulted in the finished glovebox being obtained in less time with enhanced quality assurance and reduced installation costs.

The glovebox is a chamber that isolates a work item and its often hazardous environment from workers but still allows them to manipulate items and materials in the chamber by inserting their hands and arms into arm-length rubber gloves that extend into the chamber. The gloves are attached to an oval seal or gloveport on the transparent walls of the glovebox thereby permitting workers to look into the chamber as they manipulate objects while being isolated from the hazardous chamber environment.

Newer glovebox designs are safer, have enhanced human factors and contamination control, more government imposed requirements, and also are more expensive. To keep design costs and human factor problems and installation difficulties to a minimum, a three-dimensional computer model of a glovebox with the required characteristics was constructed. The manual operation of this model was then simulated by including the fabrication of a moving, three-dimensional human model, thus permitting visual identification of human factor problems otherwise not noticed using conventional design practices. Glovebox parameters were quickly evaluated through computer graphic simulation which produced a trouble-free glovebox design. Similarly, the glovebox model was then inserted into another computer visual model of the plant facility which facilitated the best use of space and minimized installation problems.

Communicating with Stereolithography

The Oak Ridge Y-12 Plant Fabrication Systems Department Development Division is using a commercial stereolithography system to enhance communications between design and manufacturing personnel. A stereolithography system is used to build a plastic prototype directly from a surface or solid CAD model without the need for any traditional machining or other manufacturing equipment. Thin slices (cross sections) of the CAD model are sent to the system layer by layer. While a platform is slowly lowered into a tank of ultraviolet curable photopolymer resin, an ultraviolet laser scans the CAD data onto the surface of the resin directly over the platform. The ultraviolet laser point touching the resin cures it, layer by layer, as the gradually solidifying part attaches to the platform and slowly forms, lowering into the tank with the platform.

The Y-12 stereolithography system is supported by extensive CAD expertise. Inputs are provided from Pro/Engineer, ANVIL-5000, and AutoCAD systems. While the CAD displays are graphic and useful, the displays can be difficult to interpret; therefore, creating inexpensive conceptual models that can be touched proved to be a useful visualization tool. The Y-12 Division uses the models to check form/fit/function as part of bid packages, CAD verification, manufacturing planning, CMM part program testing, tooling design, facility modeling, assembly models for display/training purposes, and mold creation. The stereolithography system has also been used to produce prototype hardware for experimental applications, such as lithium scoops, at reduced costs compared to conventionally produced hardware.

CAD data preparation and materials cost are two primary expenses of this process. The polymer resin used to create the prototypes and models has a cost of almost \$500 per

gallon. Since very few models consume a gallon of resin, this is an economical and useful tool.

CONCEPT STUDIES AND ANALYSIS

Engineering Visualization

MMES has successfully applied computer visualization technology to manufacturing system engineering. Engineering visualization provides both a conceptual design tool for the engineer and a communication vehicle to allow participation between technical and non-technical disciplines. The MMES staff uses a high performance graphics workstation and robotics simulation software package to model man, machines, and other systems as they appear and function in the application environment. Graphical simulations are realistic, three-dimensional color models of physical components, kinematic motion, and multi-device interaction. The real-time graphics capabilities allow users to walk through functional models, viewing them as they will appear in operation.

Although the graphical simulation software was originally developed for robotic system design, MMES has successfully adapted the package for a number of system design applications. The tool kit allows engineers to identify and evaluate potential collisions, reachability, user interaction, and overall design functionality. MMES has developed human models for ergonomic analyses. Simulations have also been used by management and technical staff alike to understand facility layout, structure, and mechanics of a complex system before construction or manufacturing begins. Some examples of the applications for which MMES has used the system include robotic plasma spraying, NC verification, glove box development, modeling of a male diver, and weapon system evaluation. The system has resulted in early identification of technical problems and errors that would have otherwise delayed the project or increased its cost.

PROTOTYPE DEVELOPMENT AND REVIEW

Future Armor Rearm System

The ORNL Future Armor Rearm System (FARS) makes extensive use of robotics technology to provide a safer, more efficient method of providing underway replenishment of tank ammunition. FARS (Figure 3-2) represents a totally integrated solution between the fighting vehicle and the supply vehicle. The system, consisting of a carousel containing a combination of 120mm and 140mm shells used for various missions, allows the tank commander to select the correct shell for the mission. The system also has the capability of unloading shells from the tank.

The FARS was an Advanced Technology Demonstrator program in which the Army provided a chassis modified by ORNL. The Army also modified an M1A1 tank to accept shells according to instructions provided by ORNL. The shells, lift table, and transfer mechanism are all contained on a carousel, which allows the transfer arm on the supply vehicle to align with the receiver on the tank under a wide situation of terrain conditions.

Super Laminate for Active Metals Vacuum Induction Melting

The Oak Ridge Y-12 Plant Materials Engineering Department was requested by DOE divisions to assist and evaluate disposal alternatives for over 235 tons of submarine reactor core hardware. The material consisted of Zircaloy 4 which had classified shapes and possible stray radioactive elements. The options included burial, determined an unacceptable option; electric arc melting which, although effective, was very costly; and the less expensive Vacuum Induction Melting (VIM) process which could yield recyclable material if proven successful.

Traditional crucibles used in the VIM process are constructed of graphite which can withstand 2000 degrees C.

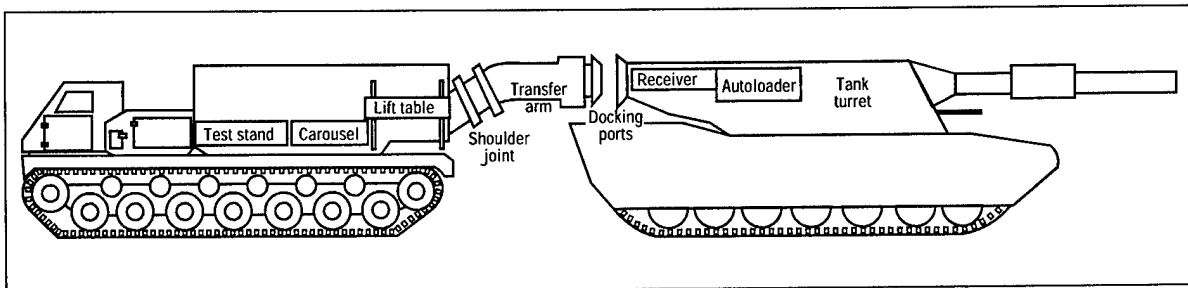


FIGURE 3-2. FUTURE ARMOR REARM SYSTEM AND XM-91 AUTOLOADER SYSTEMS

However, graphite causes detrimental material problems due to the carbon reaction with this reactive alloy while in the molten state. The objective then was to develop a crucible coating which would prevent the carbon reaction from occurring. Experimental development began with seven choices of refractory material, four metal coatings and six various crucible base materials. Within 18 months of the first meeting, Y-12 had successfully developed an effective crucible coating that would inhibit the carbon reaction and maintain functional rigidity throughout the process (Figure 3-3).

By meeting this challenge, Y-12 introduced a new world class technology. Melting reactive metals in a graphite system is now possible with the Super Laminate for Active Metals Vacuum Induction Melting process. To date, 500 pound ingots have been cast with a cost savings of three to 10 times the magnitude of traditional electric arc melting. Y-12 is refining the process to include enhanced plasma spray capabilities for small crucibles and molds.

Graphite and Carbon-Carbon Composite Research

The Carbon Materials Technology (CMT) Group of the ORNL Metals and Ceramics Division is actively involved in the development of carbon-based materials for high-tech applications in the nuclear (both fission and fusion) and aerospace industries. In the process, this group is creating a database for the carbon materials (graphites and carbon-carbon composites) developed. Examples of some of these materials are GraphNOL N3M, a high-strength graphite developed for missile nose tips for the Navy, and Carbon-Bonded Carbon-Fiber, a light-weight thermal insulator developed for NASA.

The CMT Group is supporting U.S. deep space programs and has developed a carbon-carbon composite impact shell for use in the radioisotope thermal electric generator in spacecraft. The material has optimized energy-absorption characteristics to withstand the impact and reentry temperatures should the spacecraft accidentally return to earth.

The Group is developing a design database for the carbon-carbon composite control rods developed for the Modular High Temperature Gas Cooled Reactor. The effects of the reactor environment on the properties of the graphite will be monitored to support future design. The effects of temperature, pressure, Helium coolant chemistry and oxidation, and neutron irradiation will be monitored. The Group will be searching for indicators of strength and strain failures such as elastic constants, fatigue behavior, fracture mechanics data, thermal physical properties, and oxidation behavior and mechanisms. Testing for the effects of neutron irradiation is a unique capability of this group. It expects to apply the capability and the design database to develop a

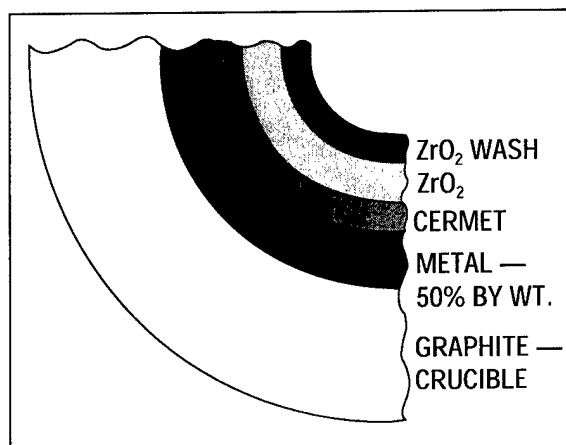


FIGURE 3-3. PLASMA-SPRAY LAMINATED COATING SYSTEM

neutron irradiation tolerant carbon-carbon composite material to be used as the first wall armor in the Joint European Torus fusion reactor.

The CMT Group's unique characterization facilities for carbon-based materials include high temperature thermal physical properties, thermal conductivity from -190 degrees to 2,000 degrees C, and thermal expansion and specific heat from room temperature to 1,400 degrees C. It has created its own high-temperature heat-treatment and graphitization furnace capable of graphitizations at temperatures in excess of 3,000 degrees C in a five-inch diameter by 30-inch long hot zone. A High Pressure Test Loop developed by the Group can test in an environment from room temperature to 1,000 degrees C at 1,000 PSI pressures and flow rates up to 37 SCF per minute.

3.4 TEST

DESIGN LIMIT

Test Method Development and Mechanical Property Testing of Metals, Ceramics, and Polymers

Tensile testing of composite specimens has unique requirements due in part to the critical nature of the loading. Conventional tensile specimens have threaded ends and are capable of withstanding small misalignments in the test apparatus; however, composite materials require more precise axial loading. ORNL has designed and licensed a special fixture utilizing hydraulics to ensure accurate alignment of the test specimen. The laboratory has the capability of applying combined tensile and torsional loads for creep-fatigue testing. In addition, testing can be performed in air or other controlled environmental conditions. A database

has been developed which consists of test results and material characteristics for silicon carbides, silicon nitrides, and aluminas. Data types include creep, cyclic fatigue, density, hardness, tensile strength, and wear.

Calibrating Ultrasonic Delamination Testing

The Development Division at the Oak Ridge Y-12 Plant has had to create much of its design and analysis equipment to support the 25 years of high performance composites experience. One group of equipment is the Ultrasonic Test Equipment and software.

The Division needed to test for delamination flaws in high pressure work bottles for hydraulically operated rocket guidance systems. It had established through very elaborate studies that ultrasonic B and C-scans could accurately locate the flaws, but each of the different shapes of the prototype bottles being developed had different measurement characteristics. Since composites are not as mechanically well characterized as metallic structures, a method had to be developed to inspect the different shapes.

To address this problem, the Development Division created a simple calibration process for its ultrasonic measurement system. A prototype of each new shape is deliberately manufactured with precisely located delamination flaws. The flaws are simulated by inserting two 0.01-mm thick, circular Teflon shims between the layers of filament in the composite structure. The shims are positioned side by side to create a non-adhering air gap between the Teflon layers. The prototype is then tested on the ultrasonic test equipment. The test software enables the new shape to be characterized.

SOFTWARE SIMULATOR

Combat Modeling, Simulation, and Gaming

The Oak Ridge K-25 Site has been integrating its scientific and its proven computer conceptual, coded, and analytical models with the Y-12 Plant's process and multiple outcome simulations and prototypes. The latest examples of the K-25/Y-12 efforts resulted in simulation prototypes for the Army Corps Command Group Venice in 1991 and the future Command and Control Vehicle in 1992. In addition, K-25 personnel provide independent verification and validation of the models, simulations, and prototypes. K-25 has also recently developed, implemented, and demonstrated simulations for the processes and technical systems for all levels of command post training exercises for joint U.S.-Korean theater-level forces. The Advanced Research Projects Agency has worked with K-25 on similar simulations.

3.5 PRODUCTION

QUALIFY MANUFACTURING PROCESSES

Weld Quality Control Services

The Weld Certification Program maintained by the Equipment Testing and Inspection (ET&I) group qualifies all welders employed by MMES, the Oak Ridge Y-12 Plant, K-25 Site, and MMES prime and most sub-contractors. The testing facility contains 14 weld booths with the capability of certifying gas tungsten metal arc, gas metal arc, and shielded metal arc. Special processes such as laser welding or electron beam welding can also be qualified but are conducted in the production welding areas. The certification codes normally used are ASME-Section IX, AWS-D1.1, or Military Standard 248D. The inspectors are qualified to AWS-QCI (standard for qualification of welding inspectors), and the recordkeeping system maintained in the weld shop office is complete.

For new process development, the welding engineer provides a preliminary weld specification indicating welding parameters from which the inspector arranges for a welder to prepare a test coupon. All operators prepare their test coupons from material that is prepared, stored, and identified by weld test shop personnel. Test specimens are then prepared and tested in accordance with the specified codes. Capabilities include visual examination, radiography, tensile testing, bend testing, and impact testing. The actual parameters used during the welding are then recorded to produce the Procedure Qualification Record.

This system of certification is exceptional because of the number and variety of welders and processes that require tracking. The ET&I group is currently in the process of re-qualifying all weld procedures according to new standards and has ordered a software system to aid in documenting and tracking needed certifications.

Ceramic Manufacturing

The Y-12 Plant at Oak Ridge has over thirty years' experience making ceramic parts up to 21 inches in diameter from various materials including oxides, carbides, nitrides, cermets, salts, and beryllium and uranium materials. The objective is to make near-net shape parts with the needed properties of full density, high purity, and high strength, and as cost effective as possible.

The primary method to densify the ceramics used at Y-12 is quasi-isostatic hot pressing, accomplished by employing a furnace capable of reaching 2,500 degrees C and determining the part shape by a high strength graphite die. Y-12 has also experimented with hot isostatic pressing using a

gas autoclave that can reach temperatures of 1,000 degrees C and 30,000 psi argon pressure. However, these processes are expensive because of low production rate and process length time.

An alternative method of densifying ceramics being developed at Y-12 is microwave sintering. This method reduces processing time up to a factor of 10, reduces processing temperatures by several hundred degrees, provides superior material properties, and can be accomplished in near-net shape. A very large microwave furnace has been developed that can reach temperatures of 2,400 degrees C and has microwave frequencies of 2.45 and 28 GHz. Y-12 is also experimenting with variable frequency ranges to more effectively heat the part.

The ceramics manufacturing capability at Y-12 is world class as demonstrated by the numerous patents awarded to the personnel. A patent has been applied for in the microwave sintering process, and this Plant continues to advance the technology of ceramics manufacturing and become an important industrial resource for this process.

PIECE PART CONTROL

Automated Data Acquisition System for Inventory and Tracking of Containers

An Inventory Management Information System (IMIS) was developed and implemented by the Data Systems Research and Development Department at the Oak Ridge K-25 Site. IMIS provides a fully integrated inventory system for tracking the movement, monitoring the process steps, and recording the storage locations of the thousands of waste containers located throughout the Oak Ridge K-25 Site. A common network connects widely separated process areas. Bar code readers are combined with computer terminals and printers to provide automated data acquisition and reporting in real time to the various user groups.

The hardware consists of off-the-shelf computer terminals, printers, interactive and portable bar code readers, and a UNIX host mainframe. The IMIS software was developed by the Data Systems Research and Development Department since no software existed in the exact configuration that could provide the data acquisition and management inventory capabilities required for the Oak Ridge site. The system is mostly modular, and the UNIX operating system facilitates the user interface and also renders it transparent. The tracking can be timely conducted with the telecommunications network.

IMIS provides for accurate and easy data collection in the field, automatically looks for errors in the reported data, improves the reliability of the data, reduces the handling of the data, provides a current tracking status, provides access to inventory history, greatly improves data processing and

reporting, and is widely available to the user community. When fully implemented, the container inventory and tracking is estimated to be four times faster using half the personnel, and will have an accuracy of greater than 99%. Potential savings of over \$100,000 per inventory performed are possible.

DEFECT CONTROL

Non-destructive Testing

MMES at the Oak Ridge Y-12 Plant maintains one of the most complete non-destructive testing facilities in industry. These capabilities are built on a technical base of state-of-the-art facilities and personnel qualified to ASNT Level I, II, and III.

Site capabilities include areas from hand held probes to fourteen axis gaging and radiography, radiation gaging, ultrasonics, dye penetrant/magnetic particle/visual, eddy current/magnetic, bulk density, nuclear, and pressure/leak (10^{-9} CC/Sec). In-house capabilities include a gage laboratory that certifies all standards with traceability to the National Institute of Standards and Technology (NIST). A research and development laboratory evaluates state-of-the-art non-destructive evaluation methods and performs feasibility studies. Design engineering provides concepts and detail drawings for unique fixtures and gages. Unique equipment such as a 20KEV X-Ray Penetrometer as well as other normal equipment located at one central facility make the MMES Y-12 Plant one of the most complete non-destructive evaluation sites in existence.

Precision Metal Forming

The Oak Ridge Y-12 Plant has developed precision forming capabilities for a variety of materials and products. These methods include conventional (Deep Draw) Forming, used for thick materials up to 1.5 inches in thickness; Hydroforming used for forming thinner materials; Superplastic (Blow) Forming (Figure 3-4) used to form through-wall materials requiring uniform wall thickness; and Water Die Forming also used for thin material requiring unique shapes and uniform wall thickness.

In addition to the precision forming of blanks for machining, Y-12 has employed a CMM inspection process of the formed blanks. The purpose of the process is to prove new forming processes and tooling, establish limits for future forming operations, and verify the formed blank geometry to ensure it can be machined to specifications.

Using a CMM to perform the inspection process and provide the results, Y-12 personnel can deliver the inspection data through the classified broad band network to the VAX computer system running the SPC and CAD systems.

If a decision is made to use a blank that does not meet the established limits, the results can be passed to the process engineer in the machine shop, allowing for modification of the setup or machining procedures to salvage a part that might otherwise have been scrapped.

The Y-12 Plant has continually improved the forming processes, and as a result is now able to form parts to near net shape forms. This capability has resulted in reduced costs for both materials and machining times. In addition, precision forming has resulted in a significant reduction in the generation of hazardous waste materials.

Automated On-line Inspection

The Advanced Computation and Machine Vision Group at the ORNL is applying its experience and facilities in automated on-line inspection to uses other than weapons production. Its goal is to develop machine vision enabling technologies for high-speed applications with large data throughput. As a specialty laboratory, this Group is developing novel computational approaches and solutions, custom designing software and algorithms, and integrating it with off-the-shelf hardware. The result is a workable, field deployable prototype that has been specifically integrated to address solutions to difficult problems of national importance.

The developmental process flow used by ORNL involves the generation of specification requirements; reviewing available optical design and optical processing techniques; application of image processing, image analysis and human perception models; and integration of hardware and software to develop a system that effectively assesses the product, provides for production control, and enables the operator to respond immediately.

There are several projects currently pursued at ORNL:

- One system under development, sponsored through a Cooperative Research and Development Agreement (CRADA), is an on-line inspection system to assess workmanship defects such as chips, pits, inclusion, and dimensional measurement for ceramic substrates used in state-of-the-art electronic assemblies. The present process is accomplished manually. The semiconductor industry is also interested in the system for rapid automatic analysis and classification of defects on wafers.
- Another developmental system will help the FBI modernize its fingerprinting process. The current process is a slow, manual operation that requires a significant amount of filing space. The system being developed at ORNL will digitize the fingerprint cards and allow

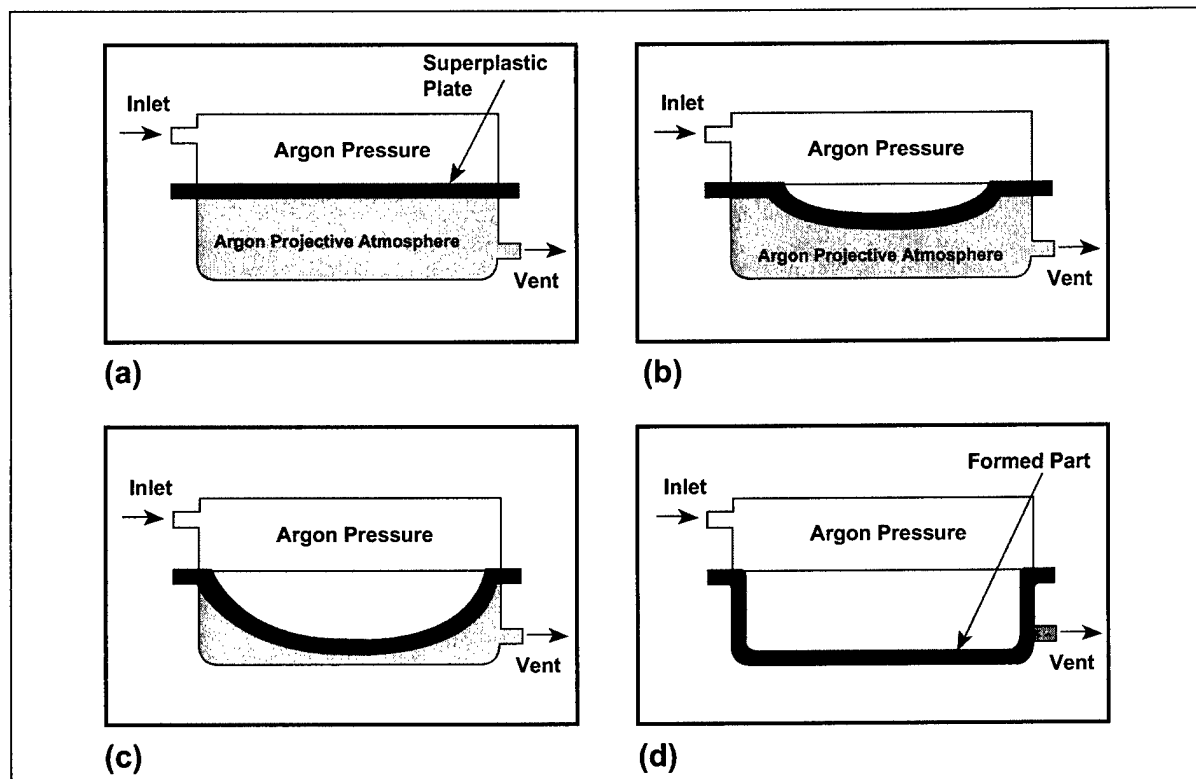


FIGURE 3-4. SUPERPLASTIC BLOW-FORMING METHOD

users to identify suspects within seconds. The system scans in the present hard copy cards at a rate of 1,000 per hour (front and back).

- Another system being developed for the Treasury Department and Postal Services will be used to inspect currency and postage stamps. These two products are presently also being inspected manually. The new process will utilize image signal processing, texture and color modeling, geometric processing, reasoning, and object modeling.

The machine vision program at ORNL is making significant technical advances in the area of industrial inspection for quality assessment and manufacturing control. It is developing enabling machine vision technologies for a broad range of applications of national importance. Through ORNL's innovative solutions to difficult inspection problems, it is providing production tools to the customer which enables them to be more competitive and productive.

TOOL PLANNING

Machine Tool Maintenance Program

The Oak Ridge Y-12 Plant machine tool maintenance program is a comprehensive program that services production machines capable of producing parts with tolerances as low as 50 millionths and down to 5 millionths using diamond turning. Consequently, the personnel needed to maintain this accurate machinery must be highly competent. The maintenance personnel at Y-12 have over 500 hours of training in the installation, electrical, and mechanical aspects of the production machines as well as vendor supplied training.

To achieve the accuracies required for these highly complex machine tools, initial training time invested in the maintenance personnel has provided the long term benefits. Not only does Y-12 Plant personnel maintain the capability of the machines, but they also investigate ways to enhance the machine's capability including the use of air bearing spindles, installation of a jackshaft spindle assembly, use of automatic ball toolsetters to aid in the setup of machines, and a hydraulic chip breaking process. These enhancements were developed by Y-12 engineers to increase accuracies and to prolong the life of the machine. The Y-12 Plant at Oak Ridge has developed a comprehensive maintenance program that prolongs machine life, a critical consideration during periods of budget constraints where modernization and capital expenditures are limited.

SPECIAL TEST EQUIPMENT

Non-film X-rays

The Oak Ridge Y-12 Plant has created the capability of producing non-film X-rays by adapting conventional radiography to a system that creates a digital image with improved precision. A part can be placed on a four-axis positioner where a 420 kV X-ray source hits the part and is captured by a scintillating fiber-optic converter screen and transmitted to an image analyzer and water-cooled camera. The non-film X-ray system has automatic recording and data acquisition capabilities and measures a four square centimeter block of data. The system currently can accommodate components up to 50 inches in height and 18 inches in width but is adaptable to other sizes by modifying the fixtures and incorporating the portability of the X-ray heads. In addition to the advantages offered by the flexibility of this system, there is also the benefit of elimination of associated processing chemicals needed to produce traditional film.

Analytical Services

Oak Ridge's Y-12 Plant Analytical Services provide a comprehensive array of testing equipment. For example, the Analytical Digital Scanning Microscope is equipped with a large analytical chamber capable of handling specimens eight inches in all three dimensions. Another unique capability, the Surface Multiprobe analyzer, combines X-ray Photoelectron Spectroscopy, Auger Electron Spectroscopy, Secondary Ion/Neutral Mass Spectroscopy, Ion Scattering Spectroscopy, and Thermal Desorption Spectroscopy in one vacuum chamber. This capability allows complete microanalysis with the preparation of one sample.

The Fourier Transform Infrared Spectroscopy (FTIR) is another analytical tool that Y-12 has applied in capacities other than the equipment's normal use. The FTIR equipment has had attachments configured to allow simultaneous FTIR Gas Chromatography testing while performing infrared and mass spectral searches through the on-line Sadtler and Sprouse IR libraries and the NIST Mass Spectral Library. Y-12 has over 62,000 Sadtler standard spectra with a search time of less than four minutes. The Y-12 Plant also has an extensive environmental radiometry laboratory consisting of six high resolution gamma-ray detectors, 70 multi-plexed solid-state alpha spectrometers, two autoloading thin-window proportional counters, two NAI (TI) well crystal and one Low Energy Photo Spectroscopy.

The unique aspect to this test equipment capability is the equipment hook-up to an Ethernet network, thereby allowing backup and multiple analysis to occur simultaneously.

Therefore, the unique characteristic of the Y-12 facility is not only the number of analytical tools but also the ability to simultaneously evaluate a sample with complementary analytical tools providing more data. This effort reduces misinterpretation of analysis.

The Y-12 facility is currently involved with a regional assistance program through the University of Tennessee to allow public use of this Y-12 testing equipment by providing four free days of service for Tennessee companies that request assistance. There are plans for a larger technology transfer program which will broaden the consortium and involve the Tennessee Valley Authority and cover a seven state region.

M-60 Coordinate Measuring Machine (CMM)

Located within the Oak Ridge Y-12 Plant Inspection Facility is one of the world's largest CMMs with a published measurement uncertainty of between 20 and 70 millionths of an inch depending on part size, complexity, and material. The machine has a volumetric working envelope of 55 inches by 48 inches by 51 inches (X, Y, and Z axis respectively), and a table capacity of over 1.75 tons. Room temperature control is maintained to within + 0.1 degree F through a Hewlett Packard Environmental control system that takes stratified readings from thermistors located throughout the self contained room. NIST has stated that, "[This machine represents] a unique asset in the field of precision dimensional measurement, potentially the most accurate CMM of its class in the world." Due to the extreme precision characteristics of this machine, NIST and Y-12 have been working on a plan for Y-12 to become one of the first national laboratories with three-dimensional accreditation. Once accreditation is received, the CMM can be used to measure and certify the accuracy of dimensional standards and other artifacts.

Leica Laser Tracker

The need to accurately inspect and measure parts and assemblies that are too large for conventional CMMs has been identified and resolved by the Quality Service personnel at the Oak Ridge Y-12 Plant. The Leica Laser Tracker is a state-of-the-art portable inspection system now being used in various applications throughout the Plant. The laser tracker offers a replacement technology for precision theodolite measuring systems by providing comparable or slightly enhanced accuracy and consistent results not dependent on operator skills.

The Leica system consists of a tracker head assembly and retro reflector; two compatible, networked IBM PCs (one used as the application processor and the other as the tracker

processor); and a controller consisting of power supplies, two motor amplifiers, two encoders and interferometer electronics. The laser tracker can measure a surface from a distance of up to twenty meters allowing a substantial flexibility with large irregular shapes. It has been verified to be accurate within +0.0022-inch within an eight foot cube. Used routinely to measure components or assemblies that are too large for conventional CMMs, it has also been used to verify machine setups and to certify dimensional features and tooling ball location in large assemblies. Since its initial procurement, the laser tracker has been in demand for production work as well as special jobs. Because of this demand and its wide acceptance, a second unit has been purchased to provide needed additional capacity, and a third unit is now on order.

Precision Metrology Expertise

The Oak Ridge Y-12 Inspection Facility has made a concerted effort to position the facility in a complementary role to the NIST mission by serving the nation as a facilitative leader in the area of Precision Metrology. This group has demonstrated active participation in emerging areas of national significance such as the Dimensional Measurement Interface Specification (DMIS); the Cooperative Research & Development Agreements (CRADAs) with NIST for accreditation of key Y-12 plant assets; the Y-12 facilitated workshops such as the Advanced Gear Metrology Workshop to strategically address areas of concern to industry; and through the National Laboratories "Work For Others" Program for which the Y-12 Inspection Facility has provided valuable inspection data for component parts of national interests.

Inspection Facility and Equipment

The Oak Ridge Y-12 Plant Inspection Facility has converted its weapons manufacturing capability in precision metrology to a testbed for examining and solving common issues that face the American manufacturing industry. Consequently, the Y-12 Plant Inspection Facility is a leader in precision metrology through the use of high precision CMMs. Nine existing machines have been selected to handle small, medium, and large parts with accuracies from less than 50 micro inches to less than 200 micro inches. Within this laboratory setting, the thermal environment is controlled from + 1 degree F to less than + 0.1 degree F.

Because of the variety of CMMs within this facility, Y-12 experienced common industry-wide problems. Multiple machine specific calibration routines, multiple part programming languages and machine controls require extensive operator cross-training. To address these issues, Y-12

is developing an Intelligent Inspection System with objectives to provide one standardized operator interface, one analysis software package, and one part programming language – DMIS compliant. The Generic Analysis tool Y-12 has selected is Brown & Sharpe's Quindos software. The operator's interface is a Silicon Graphics workstation running under the Motif Windows environment. Custom developed machine controller interfaces have been developed jointly with Brown & Sharpe. The Common Part Program Language is DMIS compliant and passes through another interface for this control.

Y-12 anticipates scheduling the first Intelligent Inspection System coming on line by April 1994 and has set a goal for having all nine CMMs within the facility on line by 1995.

COMPUTER-AIDED MANUFACTURING

Distributed Numerical Control

In the 1980s, the Oak Ridge Y-12 Plant determined that many benefits in parts production could be realized by switching from paper tape programs generated for the NC/CNC machines to DNC. DNC provides for the computerized generation of programs and direct downloading from the main frame computer to the computer at the NC/CNC controlled machines. Numerous benefits were identified including unlimited tape length, easy tape editing, better configuration control, faster tape turnaround time, reduced tape reader maintenance, and fewer data errors.

Y-12 has over 240 controllers but during the transition, one controller was selected – the GE/2000. Presently, 114 controllers have been converted. The software selected was GE/Numerical Control and Monitoring. Numerical Control and Monitoring/Intelligent Factory Workstations were also installed. These workstations provide for linked color graphics with an Integrated Behind the Tape Reader PC board with high resolution. Ethernet links the three 11/750 VAXs to the NC/CNC machines. The programs can be downloaded directly to the machine controllers. With the DNC software, Y-12 personnel can monitor the machine operation time and the "percentage of cycle on" which is a comparison of the actual feed rate to the program feed rate.

With the change to DNC, Y-12 has realized many benefits including:

- Normal turnaround time on program changes reduced from six days to two days (2 to 3 hours on rush jobs);
- Operation time on an Excella straddle mill, previously requiring 16 NC tapes, decreased by 50%;
- No NC tapes such as paper or mylar maintained for DNC machines, resulting in a reduction in handling, storage, and inventory requirements;

- Tape readers eliminated as the number one source of CNC/NC machine malfunctions (previously accounted for 32% of all failures).

Manufacturing Verification through NC Program Simulation

The Oak Ridge Facilities recognized the need to eliminate interference (collisions) among the tool holders, machine spindles, fixturing, and the part being machined. Working with Deneb Robotics, Inc., a software tool kit (IGRIP VIRTUAL NC) was developed for use on an engineering workstation to simulate the NC program.

The CNC machine is kinematically modeled and placed in memory storage for use with the software. (The engineering modeling cost is approximately \$12,000 for each unique CNC machine.) Also modeled in software systems are the tool holders, tooling, and fixturing. The software system provides a simulated color automation showing NC path driven machine movements and material removal. When collision occurs, the colors on the screen highlight the collision (Figure 3-5), and machine positions and lines of NC code can be viewed and printed out on a collision detection report. The lines of code indicate where in the NC program the collision occurred. The machinist during actual prove-out would normally be focused on the cutter path leaving the rest of the machine environment in a vital, collision-prone state. This manufacturing verification simulation system allows the programmers to view the complete picture. Windows in the software allow other pieces of information such as lines of code to be displayed. The software allows personnel to verify probing routines and post processors accuracies, potentially even prior to installation of a machine.

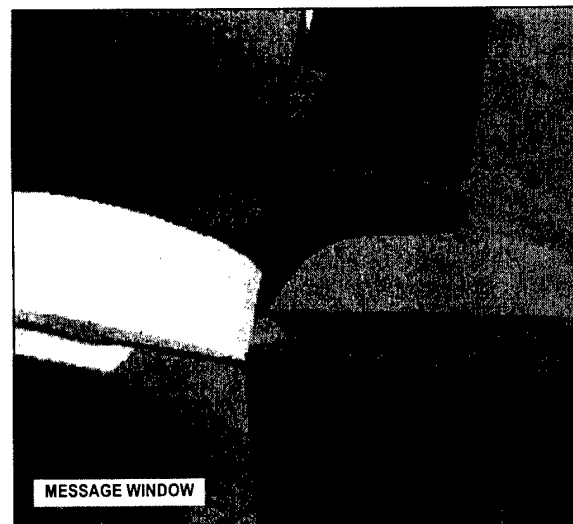


FIGURE 3-5. COLLISION MESSAGE WINDOW

The Oak Ridge Facilities have been able to realize \$120,000 savings through 500 NC programs. These savings have been identified in the areas of weld repair, NC program checking, post processor debugging, reprogramming, probing setups, process evaluation, and process planning. Hidden cost savings are estimated at \$200,000-\$400,000 because there have been no machine catastrophic crashes. Another hidden cost is an estimated \$150,000 savings in dry run and machine down time.

Ion Milling

The Optical Manufacturing Operational Development and Integration Laboratory (MODIL) within the Y-12 plant site at Oak Ridge has four cells for machining material to high quality optical surfaces. One machine is an ion milling cell which uses the impact of ionized argon on the surface of a material to dislodge surface atoms. With characterized process parameters, surface material is selectively removed by controlling the position and dwell time of the ionized argon beam, thus improving the figure of optical components. In the Y-12 cell, two systems utilize a beam of ionized atoms fired in a vacuum on a work surface, dislodging work surface atoms.

A part with a target four inches in diameter is mounted vertically in a vacuum chamber in the larger system. Peaks of 3,000 to 5,000 angstroms are identified for error mapping. The map is convoluted with a beam profile to create a map of dwell time for peak reduction. The inert gas (argon) ion beam is rastered across the workface and the

depth of cut is controlled by the dwell time. Location of the beam is X-Y coordinate controlled. A neutralizer is utilized to eliminate charged particles on the workface to eliminate any beam rejection. The peaks are reduced by two thirds. The smaller tungsten filament-actuated system is used for research on smaller parts. Materials such as aluminum, beryllium, or electroless nickel roughen rather than improve smoother surfaces. This problem is overcome by coating the surfaces of these materials with gold or copper.

This process accomplishes in a few hours that which conventional polishing and inspection techniques require 20 to 30 days to complete. This process is also independent of thermal and mechanical isolation. Future plans call for integrating the coating with milling to improve the turn-around time. These plans also include use of a holographic interferometer to reduce the size of the ion gun and vacuum chamber.

PRODUCTION FABRICATION

Kerf Collection System

The Oak Ridge Y-12 Plant performs machining of products containing lithium, a highly volatile material that also absorbs moisture, emitting hydrogen gas. Therefore, Y-12 personnel carry out machining in a glove box. Because of related safety hazards and the value of reclaiming the lithium, Y-12 designed a kerf (or chips and dust generated during machining) collection system (Figure 3-6). The system accumulates the dust at the part with a vacuum line,

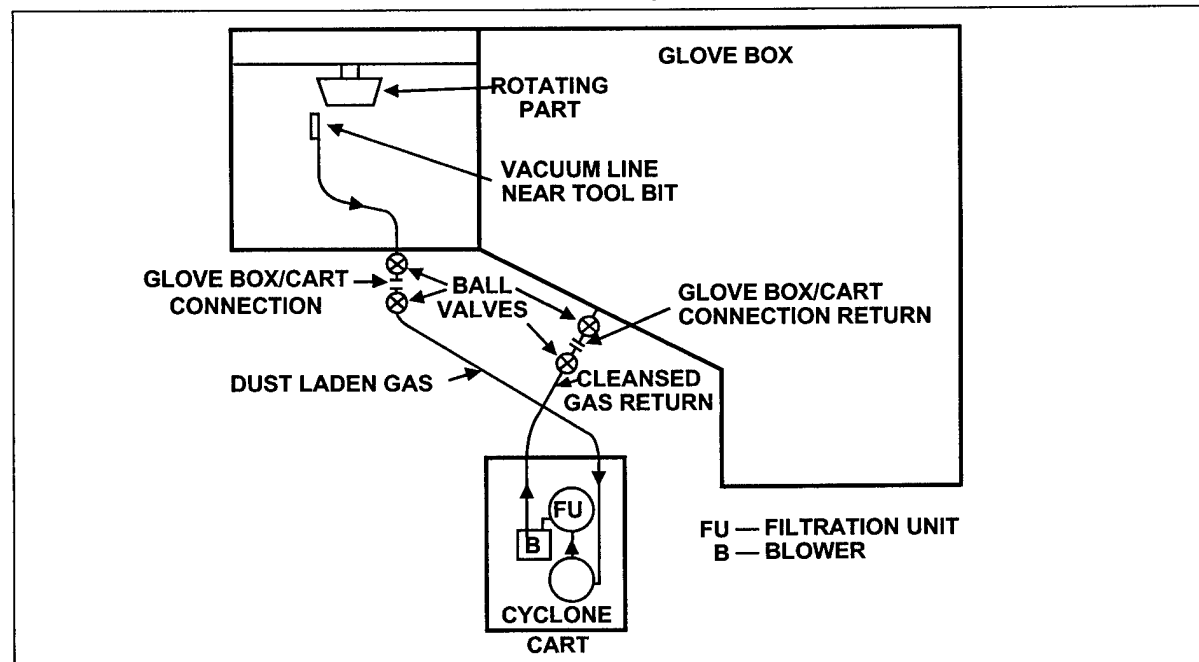


FIGURE 3-6. KERF COLLECTION SYSTEM, GLOVEBOX, AND CART

and the line is connected to the collection system through ball valves. The dust air mixture is then filtered, separated, and collected in kerf cans for disposition. The system controller allows automated cleaning of the filter after a set period of time or if a pressure drop occurs within the filter. This kerf collection system can be cleaned and used for materials other than lithium and could be used with any dry machined, high cost, high value, pyrophoric or environmentally hazardous material.

A smaller portable system was designed for use with other machines that have glove boxes. The smaller system had specially-designed, smaller components and has an approximate cost per unit of \$100,000.

Isostatic Pressing Capabilities

The isostatic pressing capability at the Oak Ridge Y-12 plant is among the largest in the world. The working chamber (60 inches in diameter and 60 inches deep) of the oil isostatic press can reach pressures of up to 30,000 psi with oil temperatures up to 150 degrees C to compact elastomeric molds containing ceramic and/or metallic powders. These isostatic pressing facilities are also supported by a rubber shop that produces elastomer molds of various sizes and shapes. Because powdered materials are highly sensitive to atmosphere and moisture, the facilities are located in a humidity-controlled shop, and the outgassing furnaces are capable of being loaded from an inert atmosphere. These furnaces and the glove box are new and still in the installation process but will be capable of reaching 600 degrees C at controlled rates to produce various properties. The forming facilities are currently going through a renovation in which the hydraulic press systems are being upgraded with computerized controls. The capabilities of the Y-12 ceramic processing facilities are currently being utilized by the Coors Corporation for ceramic materials testing.

Non-Spherical Cutters for Rapid Material Removal

Traditional machining methods to machine complex blend surfaces and free-form surfaces has typically employed the use of a ball end mill to achieve the final geometric surface configuration. However, ball end mills have limited performance characteristics such as allowable depth of cut, feed rates, and step-over distances. The Oak Ridge Y-12 Plant was challenged to improve cutting times and final machined surface finishes for a series of jobs with complex surfaces.

Y-12 incorporated the use of non-spherical (toroidal) cutters to greatly enhance the cutting speeds and depths of cut, achieving improved surface finishes and extending tool life.

Due to the geometric composition of the torus cutter, the tool cannot be presented perpendicular (normal) to the surface of the part but must be presented with a positive lead angle referred to as the non-spherical lead angle. Through the use of CAM software, Y-12 NC programmers have been able to develop variable lead angles by creating and adjusting vector meshes to the desired lead angle to optimize the metal removal rates. Y-12's experience with this innovative machining technique has indicated a starting lead angle of 45 degrees and reduced down to 5-10 degrees for optimum performance. Through the innovative use of these cutters and NC program modification and optimization for complex surfaces, Y-12 estimated savings of over \$450,000 for one job.

Expert Systems

Several expert systems have been developed at ORNL to capture the knowledge of experienced designers and machine tool operators. These expert systems have been developed using FORTRAN instead of commercially available expert systems development tools. Three examples of expert systems are the Oralloy Casting Advisory System, Hydroforming Tool-die Design Advisor, and the Rolling Information Generation System.

The Oralloy Casting Advisory System consists of two parts – a database of casting data and an advisor for new castings. The database contains mold data, composition data, and casting operation data. The user of the expert system provides part size and tracer percentages. The system will determine the mold design, casting method, and input tracer amounts. The Rolling Information Generation System is used to assist in the manufacture of rolled plates. The user of the expert system provides the size of reheat cages, the minimum size the plate can be re-rolled, the maximum diagonal size of the mill, and the power of the shear. The expert system then creates a rolling schedule, which tells the roller operator how much to reduce the size of the plate on each pass, and when to rotate the billet to obtain the desired size.

ENVIRONMENTAL ISSUES

In Situ Soil Mixing Combined with Vapor Extraction for Treatment of VOC Contaminated Soils

The ORNL, in cooperation with university and private industry participants, has developed and successfully demonstrated an in-situ process to treat VOC contaminated soil utilizing soil mixing combined with thermal vapor extraction and peroxidation destruction. These processes were demonstrated at the DOE Portsmouth Gaseous Diffusion Plant near Piketon, Ohio.

Land plots were designed twenty years ago at many facilities to facilitate digestion of organic wastes by bacteria occurring naturally in the soil, at that time an acceptable practice. Process waste oils containing degreasing solvents were biodegraded in these plots. Because these oils contained some compounds including VOCs that could not be digested, contaminants remained in the soils and migrated to groundwater beneath the plots. In situ – or in place – soil treatments today are given a high priority by DOE to provide an effective alternative to cleaning up sites without the requisite extensive excavation of soils and associated worker exposure, storage, treatment, and disposal issues.

After more than a year of studies and laboratory tests managed by ORNL, a field demonstration was conducted at a large oil biodegradation plot at the Portsmouth facility. Four separate in-situ processes were demonstrated side by side. The most successful processes were peroxidation destruction and thermally enhanced vapor extraction combined with soil mixing. Peroxidation destroys VOCs by a chemical reaction when a diluted hydrogen peroxide mist is applied through an ambient air stream. Thermal vapor extraction involves mixing the contaminated soil with hot air or steam injection to vaporize the VOCs. The vapors are collected in a shroud covering the treatment area and are run through a mobile treatment unit containing both a carbon filter and a high efficiency particulate air filter to remove contaminants.

The peroxidation destruction method performed well with more than 70% VOC removal after one hour of experimental treatment. Enhancing thermal vapor extraction with peroxidation will optimize the process. The in-situ nature of this process reduces the problems and costs associated with worker exposure and storing, treating, and disposing of excavated wastes.

In Situ Vitrification Method for Waste Disposal

An extensive environmental restoration effort is underway at the DOE Oak Ridge Facilities. The objective of this effort is to develop and apply technologies that can provide data or remediate a site in situ, thereby averting the need to excavate, creating problems and expense related to worker exposure, environmental releases, and waste disposal issues.

In Situ Vitrification (ISV) involves melting a disposal trench in place to produce a solid, relatively impermeable mass of glass and crystalline material encapsulating the wastes (Figure 3-7). This ISV process is achieved by placing a metal dome with four graphite electrodes into the trench and heating the trench to 1,500 degrees C, creating a man-made magna chamber melting the trench and the waste within the trench. The metal dome is placed over the melt to collect gases and particulates released from the melt. The

collected off-gas is cooled, scrubbed, and filtered to remove any released materials before discharge. Once cooled, the matter vitrifies into a glass like substance which can not be penetrated by ground water. This method is a cost effective means of removing small isolated areas of contamination/waste. There is low worker exposure to the waste and considerable monitoring of events in the chamber.

This method has been conducted on a pilot scale at ORNL and will be conducted on a real trench at ORNL in 1994. There are several characteristics of the ISV technology that offer attractive benefits to government and private applications including:

- Offering an advantage for radioactive sites since the airborne release pathway associated with excavation can be eliminated/minimized;
- Offering significant cost advantages for some sites compared to alternatives involving complex treatment trains made up of several technologies because of the ability of ISV to simultaneously process mixtures of radioactive and hazardous chemical-contaminated soil;
- Providing superior physical and chemical leaching properties of the glassy residual ISV product that is important for the safe, permanent immobilization of radioactive materials.

Management of Excavated Soils

Construction activities at the Oak Ridge Y-12 Plant have often required the excavation or other management of soil within the facility. Because some of this soil may be contaminated, MMES adopted specific policies to ensure the proper management of contaminated or potentially

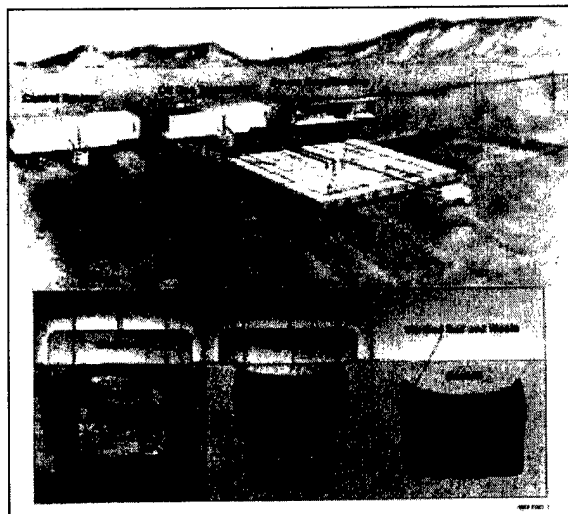


FIGURE 3-7. IN SITU VITRIFICATION

contaminated soil at the Plant. A system was established using applicable regulatory requirements and cost effective decisions for determining soil management options.

This plan is based on the concept that each soil generating project must be viewed independently. Generalized practices result in oversimplification of the regulatory conditions and can be determined for the facility as well. Routine containerizing and storage of soil is expensive, can result in misclassification of the soil, and can lead to non-compliance

as both the Resource Conservation and Recovery Act (RCRA) and Toxic Substances Control Act have limitations on certain types of storage unless covered by an extension and/or the Federal Facility Compliance Agreement.

A decision tree (Figure 3-8) and analysis have been developed for five types of contamination as well as for soil where no contamination is suspected. For each type of soil contamination the decision tree and analysis identifies and

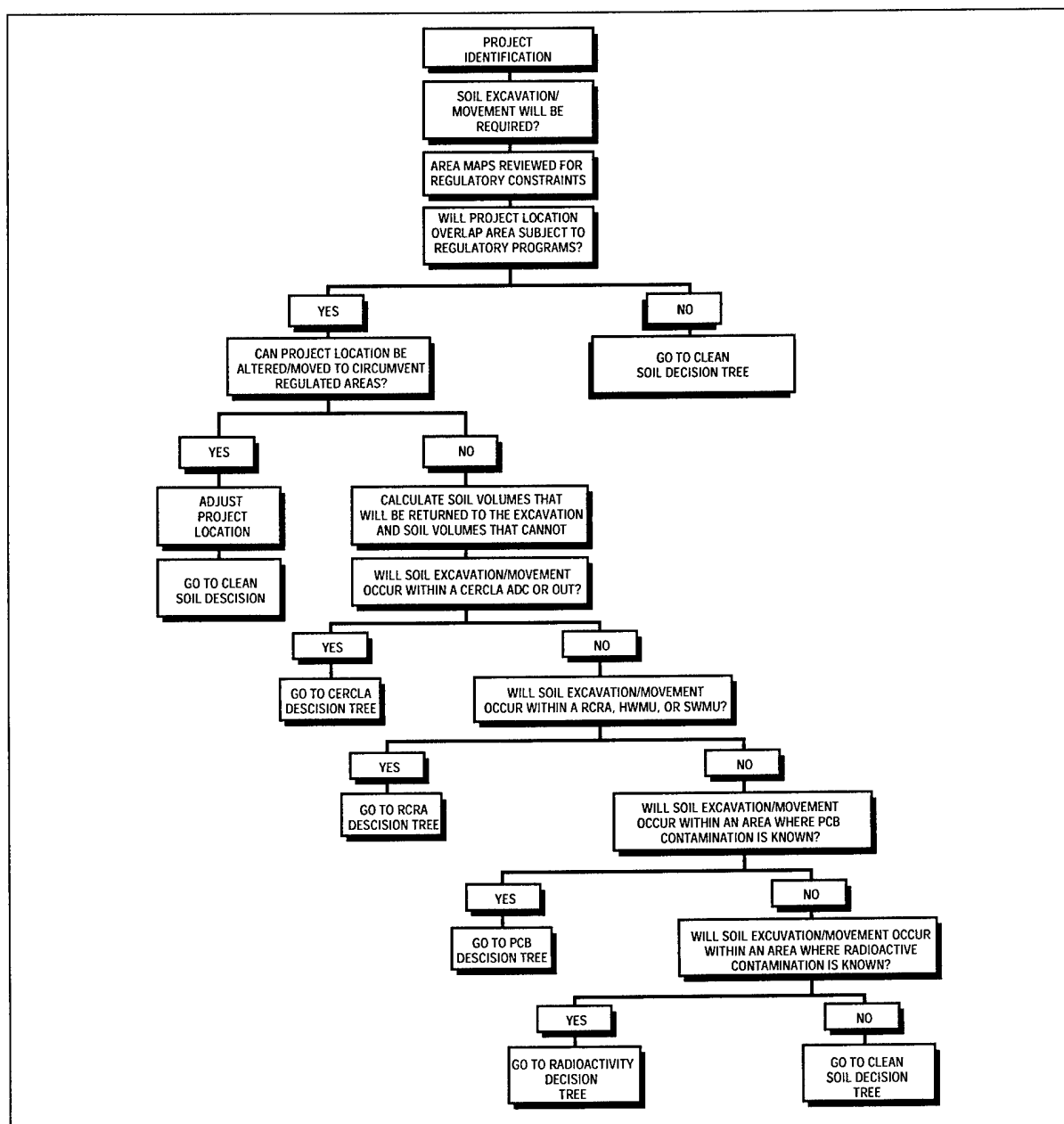


FIGURE 3-8. MASTER DECISION TREE

discusses applicable, current regulatory requirements; sampling and analysis requirements; and management and/or disposal options available.

The regulatory requirements associated with contaminated soil are complex and will vary according to site conditions. This Soil Management Plan provides a standardized method for managers to determine the options available for selecting soil management scenarios associated with construction activities.

Resource Conservation and Recovery Act Closures

Due to the requirements of the RCRA, certain landfill and hazardous waste areas at the DOE-Oak Ridge Facilities had to be contained. Leaching was occurring from the buried wastes into the groundwater system through the numerous faulted rock layers, and therefore the means of preventing the surface water from penetrating the filled areas needed to be developed. The Oak Ridge Facilities personnel applied their extensive expertise in RCRA permits, containment, closure plans, and dealing with all of the regulatory requirements.

Areas as large as 90 acres had to be capped, and the solution that was developed was to contour the top surface into a berm shape. Two feet of clay was highly compacted to a permeability of 1×10^{-7} cm/sec. The clay was then covered with 30 mil poly vinyl chloride (PVC) welded into one piece. A drain net with a filter on top was then placed on top of the PVC to allow the water to drain as much as possible before reaching the PVC in lieu of the normal one foot of sand. Two feet of earth was placed on top to provide for green cover growth (Figure 3-9). This method has proven effective at stopping the leaching and could have wide application to many industrial and municipal landfill operations. Over 600 wells are in use at Oak Ridge for monitoring the leaching.

Spill Control System

The Y-12 Plant at Oak Ridge employs a unique system to control any hazardous waste spill that may occur into the nearby East Fork Poplar Creek. Actually a tertiary level of spill protection, this system operates only after the first and second levels of containment have failed. If necessary, the tertiary system uses a combination of creek surface skimming,

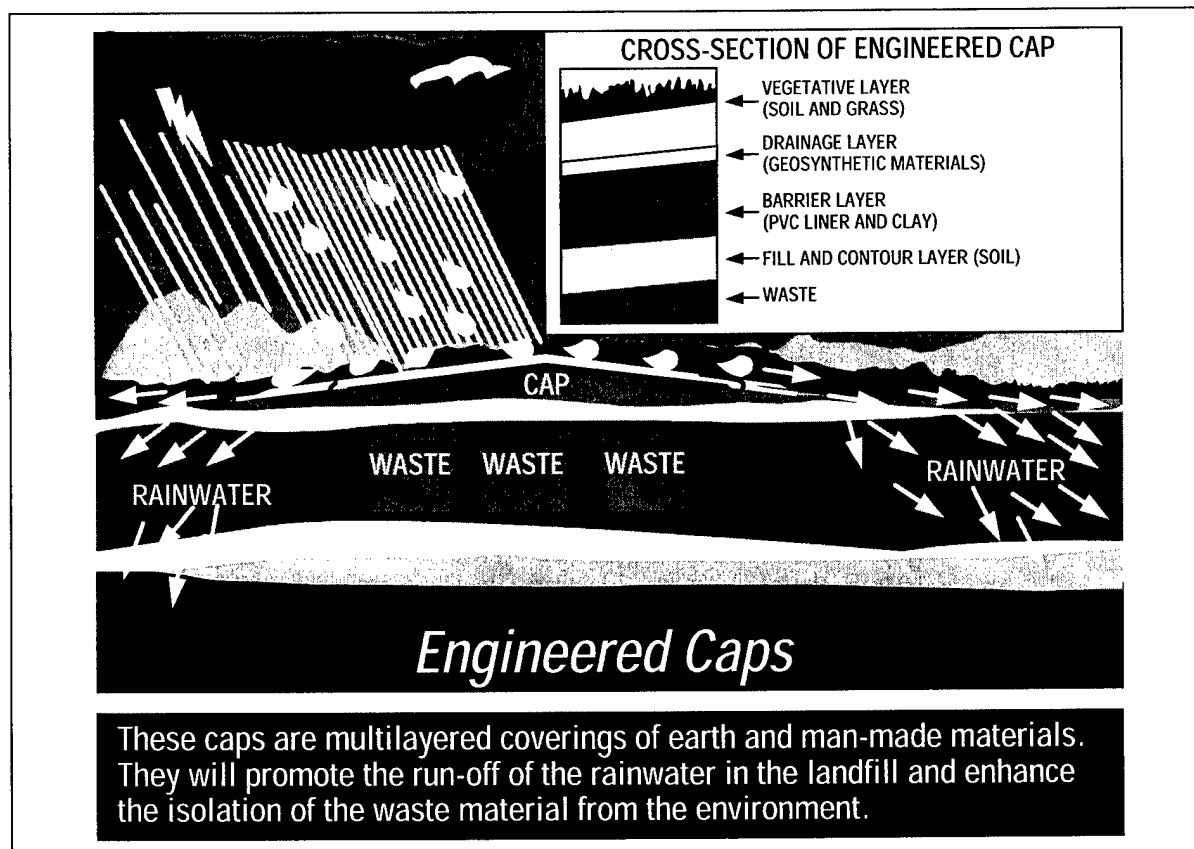


FIGURE 3-9. ENGINEERED CAPS

spill containment, and creek diversion to prevent spilled materials from contaminating surface water systems.

The East Fork Poplar Creek runs through the Y-12 Plant, the Y-12 constructed "New Reality" pond, and eventually flows into the Clinch River. As the first element of the tertiary control system, an oil skimmer has been installed immediately downstream from Y-12. The skimmer will remove spilled material floating on the creek surface. Unremoved surface contaminants and submerged contaminants not picked up by the skimmer flow into the New Reality Pond. In the event of a spill, the pond outflow can be shut off so that contaminated creek water can be contained. When the contaminated portion of the creek has been captured in the pond, creek entry to the pond is terminated, and the creek is diverted around the pond. The contained water can then be treated in the pond.

The unique capability to divert the natural flow of East Fork Poplar Creek allows Y-12 to protect against surface water contamination which has previously been traced as far as Chattanooga. The diversion concept may be applicable to other large government and private industry sites, and the expertise of the system creators could benefit a variety of facilities with similar spill control challenges.

Recycling Chemicals Used in Electroless Plating

Because nickel coating improves corrosion resistance, surface luster, reflectivity, hardness, and wear resistance, many consumer and industrial products are protected by a layer of nickel. Unfortunately, the process of nickel plating generates large amounts of waste which is both hazardous and expensive to handle. Engineers at the Oak Ridge K-25 Site have developed a technology known as ENVIRO-CP which eliminates these problems. By simple and cost efficient technology, plating solutions from electroless nickel baths are not only treated to result in environmentally benign chemicals, but the nickel waste itself is rejuvenated and recycled. Because of the obvious advantages of this system, several large private companies have expressed an interest in becoming licensed for this technology. An additional benefit of this process is that it may be extended to other plating solutions with equal effectiveness. Use of this ENVIRO-CP has the potential of saving the plating industry billions of dollars in energy and disposal costs.

Sensor Development for Environmentally Relevant Species

The ORNL needed a low cost, effective, and portable sensor apparatus to detect poly chlorinated phenols (PCBs)

in support of gasket and duct removal projects. ORNL and Michigan State University teamed and directed their collective resources to design, develop and build, a modified surface acoustic wave (SAW) device whose frequency is selectively depressed by the absorption of PCBs. This technology provides an extremely sensitive technique to quantitatively measure PCB levels. The SAW device is manufactured in house and has been applied in analysis of PCBs found in oil, sludge, water, and cement. Sample preparation and analysis is accomplished in seven minutes at a cost of \$5 to \$10 per test. Current price tests are \$40 per test and produce potentially hazardous waste.

As a result of this effort, additional benefits in the areas of non-selective polymers, functional polymers, polymer oxide glasses, and siliconization reagents were realized. This sensing device can also detect several other organic chemicals of interest in environment monitoring. A reduction of up to 75% of the extensive laboratory analysis can be eliminated by using the portable sensor apparatus. Techniques are continually being developed for concrete and rubber samples and to further increase the detection limit for PCBs.

Analytic Instrumentation

The Oak Ridge Y-12 Plant has analytic instrumentation expertise in the design and test of field monitors for process characterization and monitoring of plant effluents. A state-of-the-art laboratory is used to match the best analytical solutions to the problem, and instrumentation expertise in the development of field monitoring equipment is used to provide the equipment that is portable and will meet customer requirements.

The field monitors provide immediate feedback on a process or effluent stream so immediate action can be taken to correct any discrepancies. Examples of the type of equipment that have been developed include a Continuous Low Level Uranium Monitor, Portable Low Level Uranium Monitor, Remote Sensing FTIR Spectroscopy, Hardened Weather Stations, Robot Obstacle Avoidance, Killer Bee Tracker, Site Identification of Organic Pollutants, Detection of Chlorinated Solvents, Gaseous Hydrogen Sensor, Fuel in Water Detector, and Gaseous Emissions Measurement. The equipment is developed and tested to ensure that it will meet the customer's requirements, and training is also provided to the customer.

Application Specific Integrated Circuits are designed when necessary to meet the requirements of the end use and the function to be performed. This capability to design and test the equipment provides a unique opportunity for customers to find solutions to monitoring problems that could not be easily solved in the past.

Machine Coolant Management

The Oak Ridge Y-12 Plant has implemented a recycling program for its primary water-based coolant for machining operations. The Y-12 Plant identified the problem of disposal of its coolants for machining operations in the mid-1980s. A search was conducted for a general purpose coolant without the problems of nitrosamines that were declared to be carcinogenic, and the replacement had to be recyclable. The coolant selected (not applicable to carbide grinding operations) was Trim Sol made by Master Chemical. Since this coolant could be used in 95% of the operations, the previously used five coolants could be consolidated into one.

Each machine has its own sump and undergoes periodic cleaning with the coolant recycled through a centrifugal system. The recycling produces sludge and tramp oil that must be disposed of as hazardous waste. The system also incorporates skimmers to remove oil from the coolant to reduce the bacterial growth.

The coolant undergoes quality assurance testing to ensure that it still meets the concentration, concentration ratios, pH, and corrosion criteria. Microbial contamination density and identification is performed. The measurements are simple but more sophisticated than most machining industries perform. The coolant vendor is required to notify MMES of any changes in the formulation of the coolant. Technical Support teams consisting of Process Engineering, Chemical Engineering, a Corrosion Engineering Specialist, Microbiologist, and Industrial Hygienist, also have the support of the vendor for any problem resolution.

The coolant eventually breaks down biologically or is contaminated and must then be disposed of. The recycling efforts reduce the amount of coolant that would have been disposed of from almost 5,000 gallons to 500 gallons per month resulting in substantial savings in replacement and disposal costs.

Improved Handling of Recycled Materials

The Oak Ridge Y-12 Plant is tasked to provide nuclear weapon dismantlement. This program has expanded substantially over the last two years, generating tremendous quantities of material for recycling. Existing recycle systems were initially inadequate and inefficient when the flow of returned materials increased by orders of magnitude.

In the recycled depleted uranium stream, this large flow of metal created new problems and exacerbated existing problems concerning employee health and safety, adequate storage of material, and disposal of waste products. Handling this material consisted of disassembly, placing the material into 55 gallon drums sent to the scrap processing area, then sending it to the warehouse for storage, and on to

the foundry to cast into billets. Finally, the material was sent back to the warehouse for storage. Most of the drums proved inadequate and were crushed, scratched, or dropped during the awkward handling of the drums. The drums were then contaminated and had to be treated before disposal, adding another problem. In addition, a fire hazard associated with dumping uranium out of drums needed to be eliminated.

The solution to these handling problems came by expanding the use of tote pans for all depleted uranium storage and handling. The tote pan (Figure 3-10) is a low, rectangular, heavy duty container with built-in forklift and stacking features – and through further design enhancements – also includes locking rings for the pan. Some pans were also made deeper. By using these tote pans, there has been minimized personal injury and fire hazards; the pans are easier to transport with a fork lift; are more efficient to stack and store; a greater visibility of contents which facilitates efficient packing and inventory ease; and the pans are more durable and totally reusable, thereby eliminating additional drum disposal.

An improved structured process flow was also implemented, routing all recycled depleted uranium to the scrap processing area where the proper storing and staging functions are performed. The fillet totes are sent directly to the foundry, then on to the warehouse. This process flow eliminated an additional trip to the warehouse, thus decreasing the number of handling steps with resulting employee safety.

Expanding the use of tote pans and the changes in the recycle process flow have corrected many problems in personal health and safety, reduced storage requirements for materials returned to the Y-12 Plant from weapon dismantlements, minimized a waste stream for contaminated 55 gallon drums, and resulted in more efficient recycling operations of depleted uranium.

Technology Logic Diagram

The Technology Logic Diagram (TLD) integrates and cross references information about a site's environmental

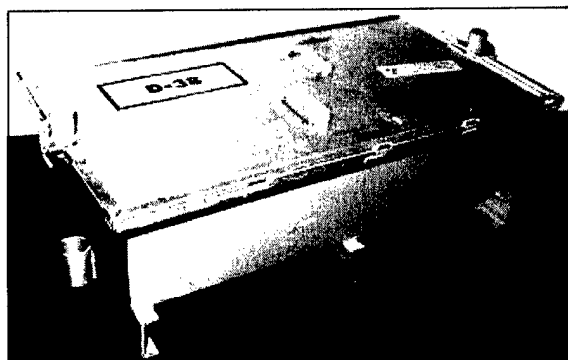


FIGURE 3-10. TOTE PAN

and waste management problems with analyses of technologies which can potentially be applied to solve the problems. The Oak Ridge K-25 Site TLD (available in hard copy and as a database) was developed by a team from Martin Marietta Energy Systems and is expected to be a prototype for the development of TLDs for other DOE facilities. The TLD addresses all environmental management activities at the K-25 Site including Decontamination and Dismantlement, Remedial Action, and Waste Management. The Decontamination and Dismantlement of the K-25 Site alone is expected to be a massive and expensive effort, and the TLD will provide a planning tool to assist in the selection of cost effective technology options.

For each environmental management activity, the logic path (Figure 3-11) flows through DOE goals, specific site problems and legal requirements to potentially applicable technologies. The status of each technology is described along with the scientific development needed to mature the technology, implementation needs, and cost. Each technology option is described in separate supporting volumes to the TLD. The diagram references points of contact who can provide detailed information on each technology. The TLD technique identifies the research necessary to develop each technology to a state that allows for technology transfer and application to each EM activity.

Use of this TLD provides several benefits to the DOE community, universities, and private industry. It identifies

a host of technologies that can be used to solve environmental management problems. It acts as a vehicle to identify the deficiencies in technologies which otherwise would hold promise to speed remediation, allow safer project activities, and result in better, lower cost remediation efforts. Utilizing the TLD, improvements to existing technologies, demonstration of promising technologies, development of immature technologies, and support for fundamental technology investigations become options which can be explored to deploy the suite of technologies necessary for successful environmental management.

The TLD will aid in strategic planning, improved prioritization, and enhanced focus and leveraging of RDT&E efforts. Finally, the filtering aspects of the diagram that include regulatory drivers, technology costs and implementation needs allow the selection of technologies that will meet committed schedules and milestones.

Environmental Compliance Management Publications and Checklists

The Oak Ridge Y-12 Plant has created a number of publications including procedures, directives, and standards to guide plant compliance with the wide variety of applicable environmental regulations. These thoroughly researched documents include comprehensive checklists designed to ensure that internal inspectors evaluate all possible compliance issues in regulated areas.

As part of the well-developed overall Y-12 Compliance Program, guidance documents have been prepared for air permitting procedures, clean air program compliance documentation, PCB 30-day storage areas, PCB storage over 30 days, RCRA satellite accumulation areas, RCRA interim status units, and RCRA 90-day accumulation areas. Each publication clearly details procedures for the compliance management of each area described. The guidelines provide definitions of terms, identify each staff position with a compliance or management role in the covered area, specify the procedures to be followed by each involved position, and thoroughly explain regulatory requirements.

Compliance inspections are performed weekly by Y-12 staff. Inspectors use well-designed checklists to guide them through each possible evaluation area. For example, the RCRA and PCB storage checklists cover areas such as container compatibility, labeling, container placement, and leaks. The Y-12 Compliance Management Guidelines help ensure full compliance with environmental regulations. The checklists add thoroughness to a highly effective internal inspection program. The regulatory analysis and environmental management expertise which led to the creation of the guideline documents could assist a broad range of government and private facilities in the United States. The checklists can be modified to account for all state and local rules at any regulated facility.

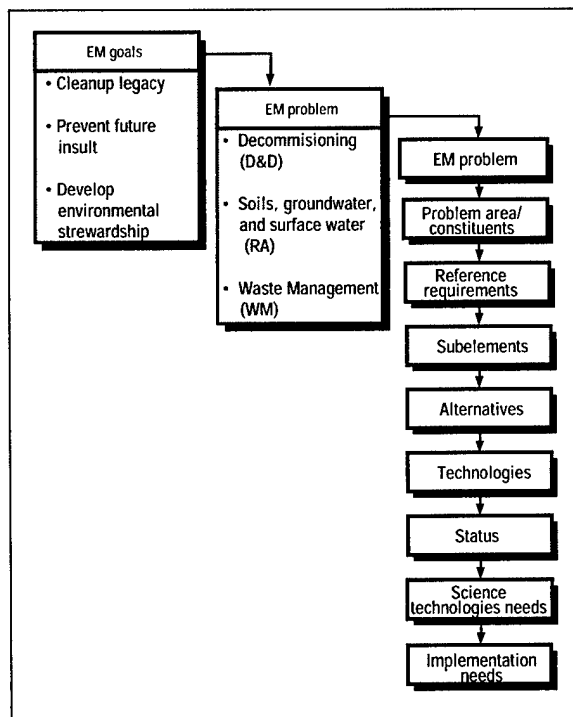


FIGURE 3-11. TECHNOLOGY LOGIC DIAGRAM

Soldier Robot Interface Project Mobile Telerobotic Testbed

The Soldier Robot Interface Project was developed at the DOE Oak Ridge Facilities for the U.S. Army's Human Engineering Laboratory as an experimental testbed for a variety of human factor issues related to the military application of robotics. A remotely-operated, all-terrain vehicle was borrowed from the Army and modified extensively to carry out a remote hazardous landfill survey. The robot, which is operated from a nearby base station vehicle, was equipped with environmental sensors to survey contaminated solid waste storage areas. A demonstration of the robot's survey abilities was conducted at a solid waste storage area at Oak Ridge containing contaminated materials buried in trenches decades ago. This test successfully demonstrated the feasibility and the potential safety, cost, quality, and efficiency benefits of using unmanned sensor platforms to perform semi-autonomous waste site characterization measurements.

3.6 FACILITIES

MODERNIZATION

Shop Floor Control

The Manufacturing Management System for the Y-12 Plant at Oak Ridge was established to improve production management methods to more quickly support customer needs. This system replaced 40 stand-alone systems with seven integrated ones that share common data and are completely integrated (Figure 3-12).

Shop Floor Control (SFC) represents one of the latest additions to the Manufacturing Management System. The SFC system runs on a DEC VAX cluster using Wordstream software. SFC lists jobs to the shop floor in priority order and collects data on parts and material to provide status parameters and history of use. SFC also monitors resource qualifications on both personnel and equipment to ensure certification and calibration requirements are met. It provides real-time SPC

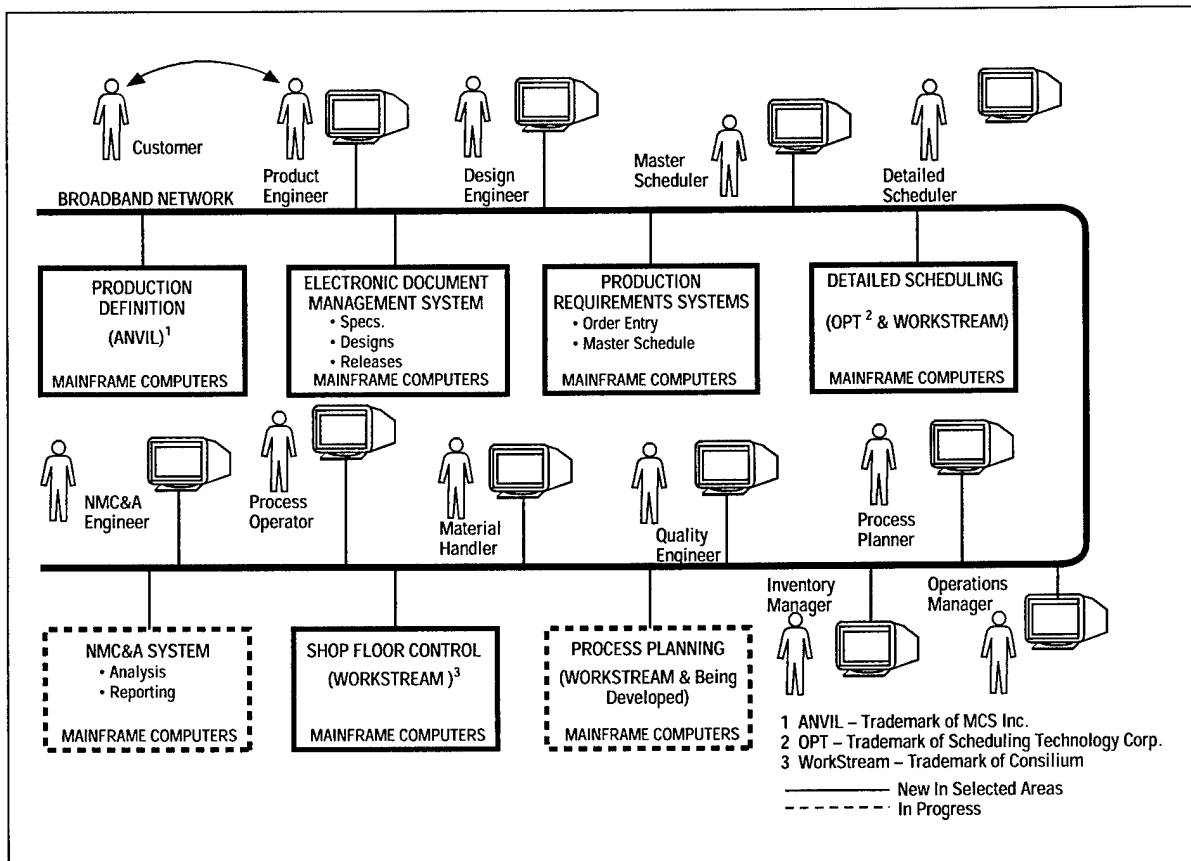


FIGURE 3-12. Y-12 MANUFACTURING MANAGEMENT SYSTEMS

and validates data at time of entry. By maintaining a complete genealogy of parts and material, SFC provides management with a certification trail from raw stock to finished product. On the shop floor, SFC supplies a complete electronic work-package that displays the necessary text and graphics required to accomplish the work assigned. It generates individual lot (part) schedules based on information taken from the Production Requirement System and the Detailed Scheduling System.

SFC's use of a unique security shell based on the user's role and privileges to control, update, and view data in the Manufacturing Management System ensures system integrity. Data entry on the shop floor has been kept to a minimum through bar code scanning and menu driven screens. Using off-the-shelf products and minimizing custom design has given Y-12 a Manufacturing Management System capable of satisfying customer needs while reducing the overall cost of maintaining independent systems.

Machine Tool Retrofit Program

The Oak Ridge Y-12 Plant identified three basic machine types to undergo retrofit in the early 1980s. This effort was based on Y-12's realization that to remain cost competitive and proficient at completing required tasks, the Plant needed to quickly initiate a machine restoration program. Retrofit was determined to be more cost effective than purchasing of new equipment. As a result MMES established the Production Capabilities Restoration program.

Controllers for the three basic machines were replaced with General Electric 2000 controllers that could communicate with a host computer. The DNC interface allows the host to download part programs without a paper tape media. The DNC link also allows the host computer to monitor various conditions such as cycle time and idle time, enhancing the Plant's scheduling operations. The completion of the restoration program resulted in Y-12 having more than 100 machines with identical controls, thereby making operation and maintenance more efficient, training easier, and minimizing spare part inventories.

Additional retrofitting consisted of replacing drive motors with DC motors, replacing resolver feedbacks with encoder feedbacks, changing spindle feedbacks to encoders, removing hydraulic components, and redesigning chip removal systems. Through excellent planning and coordination of the various trades personnel, this retrofit program was accomplished by taking four machines at a time out of service, completing the complete retrofit, and returning the machines to service in an average time of 32 days.

Total cost of material and labor for this effort was approximately \$16.8 million. Replacement costs for the 105 machines would have been approximately \$70 million. Yearly savings in energy, hydraulic oil procurement costs, recycling and disposal total \$979,000. In addition to the yearly savings of equipment operation, MMES now has

state-of-the-art equipment that has common controllers and is capable of holding better machining tolerances than new factory equipment.

FACTORY IMPROVEMENTS

Infrared Thermography for Roof Leaks

The Oak Ridge Y-12 Plant facility has been susceptible to roof leaks because of the large size and age of the buildings. The facility spent more than \$2 million dollars each year to maintain over four million square feet of roofs, many of which were over 25 years old. Because of water migration, conventional methods could not accurately determine the source of water intrusion. The Y-12 Plant Site Management Services Department developed an Infrared Thermography System for detecting roof leaks.

The Infrared Thermographic System is a non-destructive technique that uses an electronic scanner to convert infrared radiation to light. Video images are produced by scanning latent heat radiation from moisture trapped in roofing material that shows the precise location of the greatest amount of moisture. This system enables the user to conduct surveys to continually assess the condition of existing structures and effect early, cost-effective repair. Additionally, the infrared system can be used to detect leaks in steam lines, tanks, heat loss in equipment and buildings, as well as problems with high voltage lines.

Predictive Maintenance Methods Using Vibration Analysis and Motor Current Analysis

MMES uses mechanical vibration analysis and motor current signature analysis (MCSA) for predictive maintenance on large rotating AC equipment. By using these analysis methods, downtime of critical rotating equipment is decreased, catastrophic failures are prevented, and effective use of maintenance resources can be facilitated.

There are 1385 pieces of equipment and over 7,000 measurement points in the vibration analysis program which has been used since 1984. The analysis hardware and software was procured from Computational Systems Inc. The program consists of four phases. Equipment is monitored by data collection and inspection, analysis interprets the vibration spectra, performance indicators are reported and maintenance job requests are initiated when required. Repairs are accomplished based on the maintenance job requests. Vibration analysis monitors equipment while it is operating and can detect many different problems thereby eliminating unnecessary periodic maintenance. Servicing is performed only when needed. Use of this analysis method prevents catastrophic failures and allows more effective planning and scheduling of maintenance work. Over the past four years, use of vibration analysis has resulted in nearly one million dollars in cost savings.

Motor current signature analysis (MCSA) is another analysis method which is increasingly being applied. It offers some advantages over vibration analysis since it is performed on-line. It is less labor intensive, increases the monitoring rate, and allows for earlier fault detection. Only one monitoring point is required. Data is collected non-intrusively and reduces the exposure of maintenance personnel to injury. An MCSA pilot system developed completely in house is in operation at the Y-12 Chiller Facility and has been used to demonstrate application of MCSA and for system development. A full scale system is presently being procured and built.

Glovebox Quick Glove Replacement System

Gloveboxes are frequently used at the Oak Ridge Facilities to shield plant workers from exposure to hazardous materials. Workers manipulate hazardous materials and perform other tasks in gloveboxes through rubber gloves that allow the worker to reach into the enclosed work area. The hazardous environment also causes wear on the gloves which may develop a hole or crack after several months of use. Work must be stopped in the glovebox area for several hours while the glove is replaced. MMES has worked with a contractor to develop a quick change mechanism with which a glove can be replaced in a matter of minutes.

The Oak Ridge facilities use a non-conventional oval pass-through in their glovebox areas for greater freedom of movement. The quick change system is comprised of a special fixture for installing the new glove, the new glove, and a mechanism for removing trapped room gases from the space between the old glove and the new glove. Gloves are attached to the glovebox by the pressure fit of a plastic flange. The replacement process for a new glove includes:

1. Hand fitting a new glove on top of the damaged glove flange;
2. Attaching the quick change fixture to tooling holes on the glove box over the new glove;
3. Removing trapped gas – if necessary – from the space between the two gloves;
4. Turning down a wheel on the fixture, forcing the new glove flange into the attachment position;
5. Popping the damaged glove into the glovebox;
6. Removing the fixture;
7. Moving the damaged glove to the glovebox waste material removal area.

A cover is also provided for quickly sealing the damaged glove area if glove replacement cannot be performed immediately. This low tech approach to glove replacement has reduced the glove replacement time from several hours to a matter of minutes and simplified the process.

Damped Motion for Suspended Payloads in Overhead Cranes

The Oak Ridge National Laboratory and Sandia Laboratories teamed to develop and test algorithms for damped-oscillation, swing-free transport of suspended payloads. Transportation of objects using overhead cranes can induce pendulum motion of an object. This motion is an undesirable function for remotely controlled cranes in nuclear waste handling areas. The motion usually must be damped or allowed to decay before the next operation can take place. Several minute delays may result from this pendulum action. Damped oscillation transport and swing free stops are possible by properly programming the acceleration of the transporting crane.

Sandia Laboratories developed the damping algorithms that require closed loop positioning, robotic motion, trajectory planning, and programmable acceleration profiles. A full scale test of this capability was conducted at the ORNL. The test setup was based on a 27-foot cable and a 55-gallon drum containing an approximately 900-pound weight, and tests were conducted over a U-shaped path. Without damping, the pendulum produced up to three feet of oscillation. With the application of the damping algorithms, less than .5-inch of residual swing resulted. This system can be applied to many commercial overhead crane and robotic applications.

PRODUCTIVITY CENTER

Single Point Diamond Turning of Optics

One main objective for the Oak Ridge Y-12 Plant Optics MODIL is the development and proofing of advanced manufacturing technologies for optics manufacturing. Single point diamond turning is a common optics manufacturing process which can achieve final design requirements exhibiting proper geometric forms with nanometer smoothness characteristics. To develop improvements in this manufacturing technology, the Optics MODIL Laboratory has selected a Rank Pneumo Nanoform 600 single-point diamond turning machine that produces surface finishes in the 500 nanometer range. Because of the delicate vibration and thermal sensitivity nature of this precision process, vibration isolation is incorporated into the machine design and the machine mounting foundation pad. A positive air pressure curtain, constructed of thin polyvinyl strips hung from the ceiling, is maintained around the immediate perimeter of the machine to provide a thermal barrier to guard against large atmospheric temperature gradients that may affect the final surface finish.

To machine secondary eccentric non-linear features within a parabolic optic part, the laboratory is piloting a prototype Fast Tool Servomechanism developed by the University of North Carolina. This technology provides rapid CNC-controlled Z-axis tool movement necessary to machine

eccentric features without secondary setups and fixturing. With these added features, the single-point diamond turning lathe can machine finished part quality for complex optical forms.

Y-12 planned enhancements to the single point diamond turning process include outfitting the machine with spectrographic metrology equipment (OmniscatR model) provided by Brealt Research Organization. Edge quality and profile description of the single-crystal natural diamond cutting tool is also an area for continuous improvement to these manufacturing processes. Through the integrated use of LVDT non-contact sensors and a PC with National Instruments LAB VIEW development software, a complete graphical representation of the diamond tip surface can be mapped and analyzed. Irregularities within the edge quality will dictate to the machine tool operator the proper orientation of the diamond tip to achieve optimal quality features.

3.7 LOGISTICS

SUPPORT AND TEST EQUIPMENT

Advanced Servomanipulator for Remote Handling

An Advanced Servomanipulator was developed and built at ORNL to support nuclear fuel processing applications. The system has no direct mechanical links between the operator control room and the remote manipulator. This unique system is the first remotely operated servomanipulator that is designed to be completely maintainable by remote means. Remote maintainability indicates that worker exposure to radiation is reduced. The entire system can be repaired without human beings entering a high radiation reprocessing cell environment. The ORNL system provides capabilities similar to standard through-the-wall master/slave servomanipulator systems, yet has the necessary mobility to serve larger areas.

The remote manipulator is a dual arm system that provides force feedback to the operator performing the task. The manipulator system is attached to an overhead crane also modified to allow remote maintenance. Each arm of the manipulator has six degrees of freedom and a peak load capacity of 50 pounds. A bank of television monitors are provided in the control room area to provide visual feedback to the operator. Remote television cameras may be repositioned by the operator using the same set of controls provided for the servomanipulator. The operator sits in a chair which has arm controls located on either side (Figure 3-13). ORNL staff have applied remote maintainability concepts to experimental systems which might have to be

maintained in the hazardous environment. Some examples of maintainability concepts include self-centering components and bolt mechanisms with limited ranges of movement to avoid being accidentally removed from the part. Possible applications of this technology could encompass remote tasks in space environments and environmental cleanup.

TRAINING MATERIALS AND EQUIPMENT

Y-12 Plant Capabilities Knowledge Based System

The Oak Ridge Y-12 Plant Capabilities Knowledge Based System is a unique, multi-purpose electronic brochure depicting the proven capabilities and expertise of the Y-12 Plant facilities, equipment, and personnel. The system functions as an electronic brochure with pictures, graphics, and detailed text for marketing, training media, and trade show applications. The Knowledge-Based System covers six topic areas – research and development, design engineering, manufacturing, quality determination, support systems and maintenance, and computing and telecommunications. Each of these general topics is then broken into

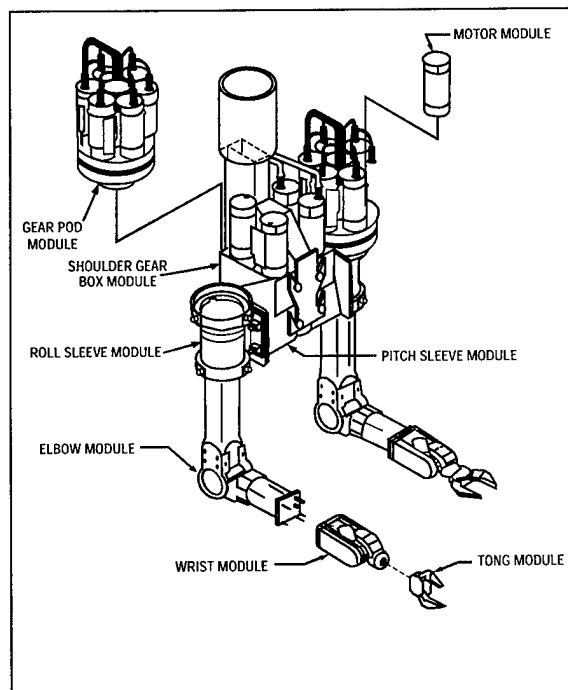


FIGURE 3-13. ARMCHAIR CONTROLS FOR ADVANCED SERVOMANIPULATOR

detailed sub-topics (Figure 3-14) that become more detailed and technical at each sub-menu level.

By viewing the complete system, users unfamiliar with Y-12 visualize not only the entire complex, but can also observe how the over 1,300 machine tools and test equipment are used. The system includes project examples such as the machine tool upgrade being conducted in the factory application oriented laboratories. This system is easily updated to include breakthroughs and other new information such as the addition of new machine tools to the teaching factory.

Y-12 distributes copies of this electronic brochure to anyone with compatible software and hardware. These

requirements include DOS 5.0, Windows 3.1, 120-210 MB hard disk, 25 MHz, 386 Processor (486 preferable), 4M of RAM, and 256 simultaneous colors (640 X 480 resolution). Also required is the LEVEL 5 Object Expert System (run-time only) produced by Info Builders Inc.

TRAINING MANUALS

Vendor Documentation Database

The Oak Ridge Y-12 Plant developed a computerized inventory system with records on almost 28,000 of the approximately 100,000 documents for purchased equipment

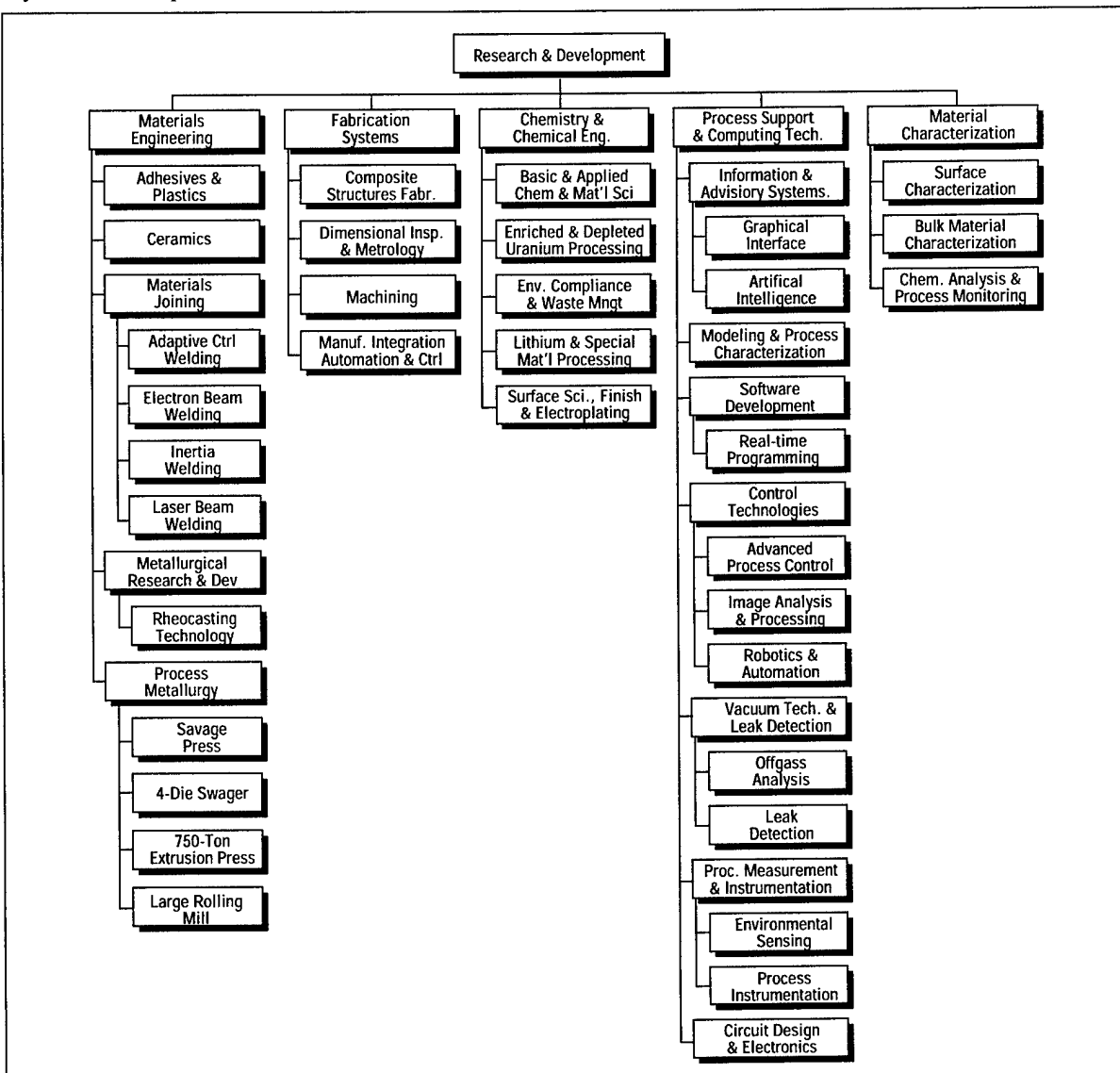


FIGURE 3-14. Y-12 CAPABILITIES KNOWLEDGE BASED SYSTEM EXAMPLE

in the Plant. This system was developed after the Plant determined that the inability to find the necessary documentation was costing \$500,000 a year in lost maintenance craft time. The system is easy to use and runs on an unclassified system with access through terminals. There is a help feature to locate a document if the make, model, and location of a machine is known. One key feature of the system is a record of the precise location of a document's normal storage location and a record of loans. This simple system would be particularly useful to organizations where institutional memory is being disrupted by reorganization and downsizing.

3.8 MANAGEMENT

MANUFACTURING STRATEGY

Optics Manufacturing Operations Development and Integration Laboratory

The U.S. Space Defense Initiative Program has selected ORNL as the first Optics MODIL. Its mission is to enhance the competitiveness of the national optics industry by developing and validating key – or high cost and high risk – manufacturing processes, thereby reducing component cost and lead times while providing advanced scientific knowledge to an emerging discipline of this physical science.

To foster these initiatives, the Optics MODIL has developed a working Process Validation Testbed to validate and develop new manufacturing concepts. Included in this manufacturing laboratory is an ultra-precision single point diamond turning lathe, diamond grinding capability for complex shapes, ion milling, and precision metrology.

Technology transfer and identification of industry issues and priorities is orchestrated through quarterly workshops with industry, hands-on demonstrations at the Process Validation Testbed site, active participation with industry specific sites, industrial briefings, an on-line Optics Database, professional publications, and traveling exhibits.

The six active CRADAs with industry also demonstrate the MODIL's ability to bridge the technology development and the commercialization gap.

Large Project Cost and Schedule Control/Reporting System

The DOE-Oak Ridge MMES Technology Services Department has developed a streamlined and user-friendly Cost and Schedule Control System. Because of the ease and effectiveness demonstrated by this system and the difficulty to use many of the pre-prepared control systems, the Navy approved experimental use of this system on the Seawolf Project with favorable results. The system has now been expanded for use on several other Navy projects at the request of both the MMES operating groups and the Navy.

The system consist of three modules:

Graphic Scheduling. This module consists of two schedule trackers – the Shop Floor Specific Scheduler allows the craftperson to interface with the project level Critical Path Schedule and is updated by the craftperson. The project Critical Path Schedule provides the overall picture over many years for the craftpersons and projects management, shows plus/minus schedule problems, and accommodates a what-if analysis.

Cost and Schedule Planning Document. This module allows personnel, from the shop floor to vice-president to easily see budget outlays for a given project. This module is user friendly, consists of spreadsheets combined with graphics, and allows the user to see when costs will occur and what activities are driving the costs.

Cost and Schedule Reporting Document. This document is a modified Cost/Schedule Control Systems Criteria used to report Budget Cost to Work Schedule, Budget Cost to Work Performed, Actual Cost to Work Performed, variances, and budget at project completion. This report ties directly to the Cost and Schedule Planning Document.

The MMES Cost and Schedule Control System has been successful in practice on the Seawolf Project for over 18 months. Little training is required to use the system which uses off-the-shelf EXCEL and MacDraw software.

Technology Transfer

MMES has emphasized technology transfer at the DOE-Oak Ridge complex from the time it submitted its proposal for the basic management and operating contract in 1984. This dedication is manifested in several ways, including the appointment of a Vice-President and strong support staff to the effort. The Licensing Program is another example and has established 75 licenses that have generated over \$2 million in royalties from over \$66 million in sales. A program of royalty sharing uses the receipts for payments to inventors, awards to other personnel, payment of patent and technology transfer costs, and federal income taxes. The Partnership Development Program bridges the gap between government-funded research and development and technology commercialization. It promotes a wide range of relationships including Cooperative Research and Development Agreements (CRADAs). Today, 66 CRADAs in effect are valued at over \$97 million. The company has made arrangements for other companies and entities to use some of its most advanced facilities in Oak Ridge. The Oak Ridge Centers for Manufacturing Technology have been established and modern equipment has been moved to more accessible Y-12 facilities. MMES has also established relationships with the State of Tennessee and the Southeast region to provide assistance to manufacturers.

Work for Others

MMES-Oak Ridge sponsors the Work for Others (WFO) program that draws on an extensive talent base in computer science, mathematics, statistics, physical sciences, social sciences, life sciences, and all engineering disciplines. The WFO program's objectives are to make Oak Ridge's unique research and development capabilities available to both federal agencies and the private sector to solve complex problems of national importance; improve present capabilities for future DOE programs; and transfer technology to industry in order to strengthen the U.S. industrial base.

A federal mandate states that the WFO program, which is non-profit, must not place DOE in competition with the domestic/private sector. MMES acts as an agent for DOE in performing the WFO program. In FY'92, the WFO program totaled \$259 million and included advanced work in the environmental, information, management, materials, precision machining, hardware prototyping, and robotics technologies. In keeping with high ethical and technological standards, the Oak Ridge WFO personnel are committed to provide superior product quality and deliver the product on time. This unique program affords the entire U.S. industrial base an opportunity to solve the most complex problems and to strengthen the U.S. position in the global market.

PERSONNEL REQUIREMENTS

Personnel Outplacement Services

Like many other defense-related organizations, Martin Marietta Energy Systems is absorbing major reductions in budgets and staff levels. The company is dedicated to helping the personnel affected by the drawdown to find new employment opportunities. The company has established networks to help locate jobs based on benchmarking efforts of other placement programs. At the personal level, there is a wide range of services available that includes composition and distribution of resumes, education programs, stress counseling, job search and interview counseling, and referral within the company. On the date that a reduction is announced, a placement center is opened and made accessible to employees on all shifts to provide these services.

Statistical Education

The importance of the application of statistical methods at the Oak Ridge Y-12 Plant has long been recognized in the efficient production of quality items. For this reason, education of the workforce in statistical methods has been given particular attention since 1986. Production statisticians have designed teaching philosophies and methods of instruction especially effective in helping employees learn and apply useful statistical methods that have greatly benefited the Y-12 Plant.

The key to the success of this educational program was recognizing that the effectiveness of an instructional program would be measured in terms of the subject matter quality and the likelihood that the learned material would be applied. This realization prompted inquiries such as "who is the customer and what are the statistical tools needed by the customer to improve their work processes?"

Based on the cumulative experience of production statisticians at the Y-12 Plant, since the late 1940s, statisticians have created several core courses geared to the actual needs of plant employees. A course called "Grassroots" is taught to general audiences in which a workbook with relevant examples and live in-class demonstrations teach principles like measurement control and the effective use of control charts. Adaptations of the material with specific examples have been prepared for working areas such as Plant Laboratory, Industrial Hygiene, and the Industrial Safety Department. To more effectively integrate statistics into TQM, a workshop called Facilitated Process Improvement has been developed. The workshop helps groups identify processes to be improved, forms teams to improve the processes and record progress, and decides how to reward successes.

Based on the implementation of this statistical education program, Y-12 offers lessons to others:

- Discussions and projects are preferred over lectures;
- Emphasize getting useful answers as opposed to the "right" answer;
- Put just enough structure in projects so the task is defined and people can work it, but not so much that activities are mechanical;
- Team teaching is very effective;
- Test and get feedback;
- People learn best when they are excited about applying what they learn.

Union/Management Relations

The DOE-Oak Ridge complex provides a good example of successful labor-management relations. In 1988, Total Quality (TQ) efforts were initiated with Joint Training Retreats where labor and management assembled to determine differences and similarities and how to apply new solutions to continuing problems. These small groups from both sides began to work as teams. Other actions – particularly those related to production floor TQ measurement such as statistical process control and concurrent engineering – had been in place for years, but had not been applied to the personnel and values areas. The unions then began participating on benchmarking teams, to illustrate one of the TQ continuous improvement tools.

The current TQ focus remains a driving force behind union-management relations and has been accepted by union leaders and most members. The 18 different unions – spearheaded by the Atomic Trades and Labor Council – are using TQ to not only work “smarter” to keep jobs, but also to consistently improve health and safety and community outreach at Oak Ridge.

The Oak Ridge Health and Safety Tripartite Program of DOE/Union/Management has become the National Labor Relations Board model for all other DOE facilities, as well as other companies having numerous on-site unions.

Central Training Facility

The Central Training Facility at Oak Ridge is a unique operation that trains personnel responsible for maintaining security at the DOE Oak Ridge Facilities. The facility consists of 712 acres, an indoor and outdoor firing range, training rooms, towers, a simulated house of tires, and paved trails through the woods that provide scenarios for training. A wide range of firearms and tactics training has been developed and is conducted on site and also through Mobile Training Teams. Training is performance based and may be site specific. The training staff consists of highly qualified and dedicated personnel. Many of the staff are nationally ranked marksmen, certified by the National Rifle Association, and have prior military background. The training, philosophy, techniques and programs are available to qualified activities.

Dynamic Special Nuclear Materials Control and Accountability System

The Dynamic Special Nuclear Materials Control and Accountability System (DYMCAS) at the Oak Ridge Y-12 Plant is chartered to assist in preventing or detecting the loss of nuclear material through theft, diversion, or error. DYMCAS is an accounting, inventory, and accountability system that tracks the inventory inclusive of nuclear metal and scrap through the Plant and can be compared with physical inventories of nuclear assets as needed. The system reconciles the assets by weight and reconciles shipments and receipts when assets are transferred within the plant, or received and/or shipped from the plant to other facilities.

DYMCAS resides on a VAX cluster and provides emergency inventories and exception reports when accounts do not reconcile. The system also provides information such as data edits and tolerance checks. It is redundant, cross-connected and provides for full data backup. A 15-minute uninterruptable power supply allows for systematic power-down of the system in case of local power failure. A critical system attribute is its ability to provide audit trails and

personal accountability through PIN and bar-coded credentials of those who are responsible for the assets. Access is partitioned by both function and security access level.

Industrial Security

The Y-12 Plant Oak Ridge Facilities Security Department conducts a comprehensive security program in support of MMES projects. This program is characterized by a flexible, multi-faceted, and responsive approach to the security requirements of projects with classifications requirements from UNCLASSIFIED to SECRET-RD. The Security Department handles program elements that include physical security, information security, computer security, operational security, and Technical Surveillance Countermeasures.

Within the Y-12 Plant facilities, separate secure areas can be established as required. A comprehensive access control system involving central enrollment, partitioned access, guard forces, inspection, and detection equipment protect the layered restricted and limited access zones. Some design work is conducted in the transit/transportation security arena with the development of security containers and closed container inspection systems.

Complementing the physical access control, barrier systems, and intrusion sensors is a highly trained guard force. The security forces range from unarmed guards to heavily armed tactical response – or SWAT – forces. The site security manager has direct access to the facility's upper management and cooperates with life safety management on areas of possible conflict. The site security manager also communicates with the technical divisions to ensure their security requirements are pro-actively addressed. The facility security services provide an added value through the range of services they support and the exceptional reaction force training facility available within MMES.

DATA REQUIREMENTS

Using Integrated Computer Aided Software Engineering Technology

The Oak Ridge Y-12 plant has been building, developing and applying a set of Integrated Computer Aided Software Engineering (I-CASE) tools since 1988. These tools were acquired to help reduce long lead times for application development and the high cost of eliminating errors late in development or after the system is in operation. I-CASE is a set of integrated software engineering tools that, depending on the application, can be multi-functional from a single vendor or from multiple vendors with standardized translation mechanisms. The tools reside in a host repository or

encyclopedia and are applied through the developers' workstations using procedures and methods developed by Y-12 personnel. This technology is being applied to internal applications within Y-12 and in the Work for Others (WFO) Program.

Numerous applications in the WFO Program have produced substantial results. Many of these involve reverse engineering of existing code for re-use in other applications, accelerating the development process by adapting proven designs. Without the use of I-CASE tools, reverse engineering would be a difficult and tedious manual process. A principal tool has been the Texas Instruments Information Engineering Facility tool which supports the information engineering methodology used at Y-12. Benefits for customers in the WFO Program include: increased productivity, greater user satisfaction, lower maintenance costs and software re-use, better management of resources, and enhanced documentation.

Internally, Y-12 has recently begun eight Information Engineering Facility projects. Several are currently in production with most in the business system implementation phases. The seven stages of the information engineering methodology used at Y-12 are presented in Figure 3-15. Extensive training in information engineering methods and tools has been conducted.

TECHNICAL RISK ASSESSMENT

Prioritization of Maintenance Job Requests

Maintaining the facilities and equipment at the Oak Ridge Y-12 Plant is a major task with yearly costs of almost \$80 million to maintain over 200 major buildings, 200 minor structures, and all contained equipment. There are approximately 25,000 work order requests in the backlog and 500 received every day. Maintenance is an aspect that is not easily related to normal production goals or accomplishments. The Plant needed a simple, effective means to set priorities.

The Maintenance Importance Generator Program combines elements of federal and state policy, plant policy, physical plant particulars, maintenance personnel data, customer organization expertise, and maintenance expertise to develop a numeric value for each work order and establish priorities. The program also uses risk ranking data in an expert system to accomplish the ranking. Listings of work order requests, organized by priority and location, are provided to maintenance planners and supervisors to guide their work. This logical approach has successfully addressed the maintenance requirements of this organization in the face of stringent safety, environmental, and security requirements.

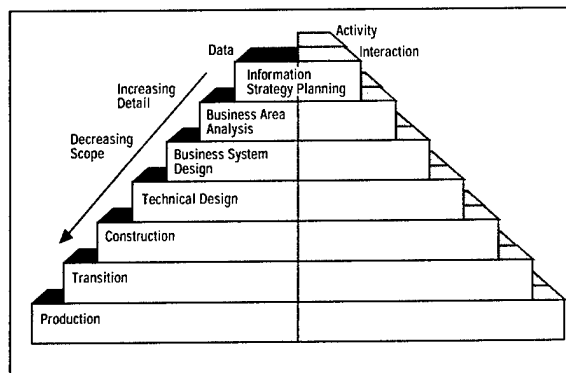


FIGURE 3-15. SEVEN STAGES OF INFORMATION ENGINEERING

Risk Ranking for Maintenance Planning and the PM Program

The Y-12 Plant Site Management Services Department established a risk ranking methodology for its maintenance planners. This is a formal method for balancing the costs of preventive maintenance with the risks and consequence of a structure, system, or component failure that could have been prevented with proper maintenance. Y-12 first developed categories for the consequences of the types of events that might occur to determine their relative importance. It then developed classes of probabilities that an event might happen. The plant then inventoried its buildings and equipment, assigning each a value based on the consequences and probability of failure. This information was displayed on a matrix that maintenance managers could use to schedule preventive maintenance. Failures that could threaten life, environmental damage, or security are given the highest priority. Below these levels, the costs of maintenance are balanced with the costs and probabilities of failure.

Parts of this overall approach have been in operation for years and others are still under development. The data in the matrix is being used in the Maintenance Importance Generator for prioritizing work order requests. A critical aspect of the risk ranking system is the type of analysis that it imposes. It is a practical way to plan preventive maintenance and it would help prevent complacency among all levels of management.

QUALITY ASSURANCE

Software Quality Assurance at Y-12

The Oak Ridge Y-12 Plant, a major developer and user of computer software, initiated a formal program in 1983 to

control software quality. All formal procedures and requirements relating to software were collected and analyzed by a team of eight to ten personnel from organizations that develop, use, or are affected by software. The team developed a system for classifying software by risk, size, and use as a basis for arraying quality procedures and requirements on a rational basis. After this array was developed, it was reviewed by almost 150 people in the affected organizations to produce a consensus document that was acceptable to all Y-12 areas.

Once the Reference Source, a comprehensive notebook, was completed, the developer recognized that a culture change would be needed to put the complex material into use quickly. An extensive program was therefore developed, beginning with training for sixteen people who would become the trainers. This effort was followed by general awareness programs and more specific training for managers and users.

Although a comprehensive notebook was needed to document the requirements and procedures, it was recognized that

comprehension and consistent application would be difficult. A contract was awarded to a local firm to develop two self-contained Hypertext disk versions for personal computers (IBM and Macintosh). These single disk systems, which were provided during the training sessions, have largely replaced the notebooks for most users. They enable personnel to identify the roles of specific organizations, the requirements and the reasons for the requirements for each class of software in each stage of the software life cycle.

In combination, the rationally developed requirements and procedures, the mandatory training programs for all associated with software development and maintenance, and the convenient Hypertext reference for quick referral, comprise a well-designed software quality system. Software validation and testing provisions have been included in the procedures. While this system may not be directly transferable to other organizations as a package because of unique requirements, it could be an excellent guide for others who must develop software quality systems of their own.

SECTION 4

INFORMATION

4.1 DESIGN

DESIGN ANALYSIS

Y-12 Ultrasonic Inspection Capabilities

The Oak Ridge Y-12 Plant ultrasonic capabilities provide for non-destructive measurement of the acoustic properties of production and development materials. These measurements aid in the selection of materials for design and inspection of material integrity. A customer may be interested in any of a number of material properties such as ratio of longitudinal to shear velocity. Or a customer may be interested in the integrity of welds, adhesive bonds, composites, or ceramics.

Various pieces of commercial equipment and specially adapted equipment are grouped together to form workstations or systems to measure the material properties. These systems include:

- **Materials Properties Workstation** – This station measures velocities with accuracies to 0.001%, and a reference standard is used to correct set-up errors. Dual waveforms are used in a cross correlation technique to provide precision velocity measurements from which attenuation is measured, and moduli and Poisson's Ratio are determined.
- **MIDUS Ultrasonic Inspection Station** – This computer-controlled six-axis plate and rotary scanning system can follow simple contours and has automated data acquisition and analysis.
- **Multiscan Ultrasonic Inspection System** – This computer-controlled, five-axis, high resolution plate and rotary scanning system can follow complex contours.

Material properties and inspection can be determined on metals, composites, ceramics, plastics, elastomers, and liquids. The velocity and attenuation of a material is sensitive to many properties such as material modulus, density, texture, anisotropy, stress rate, composition, grain size, impurities, viscosity, and fatigue. These measurements can be made at temperatures ranging from -40 degrees C to over 200 degrees C.

PARTS AND MATERIAL SELECTION

High Temperature Materials Laboratory

The ORNL High Temperature Materials Laboratory is a center for research and development of advanced technologies to reduce the cost of manufacturing ceramics and other high temperature materials. The laboratory contains most apparatus required for testing advanced materials including electron microscopes, X-ray diffractometers, and various mechanical properties test equipment. The center is open to new ideas for research and is available to users for cooperative research. Two types of user agreements have been developed including a proprietary agreement for organizations that need to keep the results of the research confidential, and a non-proprietary agreement that allows organizations to use the facility at no cost although the research must remain in the public domain.

4.2 PRODUCTION

MANUFACTURING PLAN

Casting and Machining of Complex Shaped Parts

The Oak Ridge Y-12 Plant was compelled to address producibility issues in the early stages of one of its fusion energy experiments. The complex geometry of a cast stainless steel twisted tee section (Figure 4-1) posed problems in both near net shape casting and final machining. In total, 24 machined tee sections were required to complete the final doughnut-like double helix assembly.

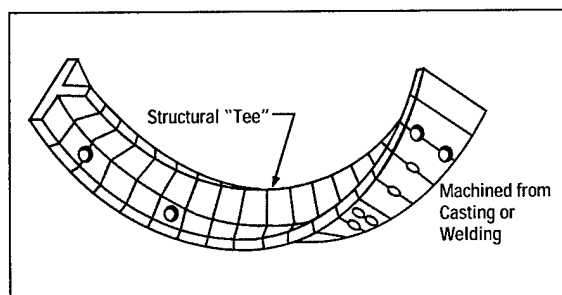


FIGURE 4-1. HF COIL ASSEMBLY

Initially, because of the unknown process variances in the casting process (thermal growth/shrinkage from uneven heating and cooling) for this type of geometry, an additional .75-inch of extra stock was added to the final machined features, adding 1,500 pounds of unwanted material to the first prototype casting. Three months later, under constant machining operations, the first prototype twisted tee section was still months from completion, and performance cost-to-contract was exceeding the original budget constraints.

The Y-12 Plant therefore utilized a conventional CMM to model a second prototype casting. Through the mathematical use of an optimization theory for this non-linear shape, a least-squares computer analysis provided the best-fit placement of the complex final machined part within the given casting envelope. This modified data was then relayed back to the casting vendor and used to provide a near net shaped part with only .125-inch extra stock.

When the new castings arrived, a temporary hard mounted conventional tooling ball was mounted to each twisted tee section to provide a durable and accurate data referencing point. The CMM and the optimization program were again used on each of the 24 cast segments to accurately describe each of the as-cast geometries. This data was then applied to develop customized NC programs that provided the best-fit for the final machined configuration. This innovative use of the CMM as a process development tool for casting and machining of complex geometries saved DOE millions of dollars on this project.

QUALIFY MANUFACTURING PROCESS

Development of Advanced Joining Technologies for Manufacturing

The Oak Ridge Y-12 Plant personnel represent considerable experience and capabilities in metal joining. Key areas of process experience include gas tungsten arc welding (GTAW), gas metal arc welding, electron beam welding, laser beam welding, friction welding, and resistance welding. Material experience covers a broad range of high-density metals and alloys, light-weight metals and alloys, refractory metals, high-strength steels, and stainless steel.

To improve these metal joining processes, Y-12's Materials Engineering Department has been experimenting with adaptive controls for the GTAW process. This automated system, developed by Ohio State University, consists of an integrated closed-circuit television camera mounted (coaxial with the welding) torch which monitors the weld puddle width and tracks the weld joint. Computer analysis of the vision system's output provides feedback to the weld

machine's cell controller to modify torch position, wire feed rates and electrical current. To date, there has been limited success with this approach; however, lessons learned on this process provide indications on how the next generation adaptive controller should be developed.

DEFECT CONTROL

Materials Testing

MMES at the Oak Ridge Y-12 Plant maintains a complete materials testing facility with the capability to evaluate quality in diverse products at all stages of manufacturing. Evaluation capabilities are built on a technical base of state-of-the-art materials testing facilities and personnel. Materials testing includes metallography, mechanical and physical properties determination and proof testing of metals, ceramics, composites over a wide range of loads, temperatures, humidity, and atmosphere. Y-12 maintains capabilities for strength and fracture toughness testing of brittle materials as well as for the testing of super plastic materials.

Equipment capabilities include a 10,000 pound torsional machine; a 550,000 pound proof-test programmable strain machine developed specifically for MMES; and micro-hardness testing equipment capable of checking hardness to less than 1/10 of a given hardness point.

The personnel at MMES have extensive experience in evaluating iron and steel metallurgy, aluminum metallurgy, stainless steels, specialty steels, different non-ferrous alloys and pure metals, powder metallurgy, welding metallurgy, weldments, ceramics, cermets, plastics, plating materials, corrosion and corrosion products, and various material combinations.

Optical Edge Inspection System

The Oak Ridge Optical Edge Inspection System is a replacement for traditional processes employing casting edge impressions and analyses on optical comparators. The computer-based system utilizes a laser light source to illuminate edge radii and chamfers, and a closed-circuit camera captures the diffusely reflected image. The project is in early development and should shortly be implemented on the shop floor. Presently the tool has been configured only for components with cylindrical symmetry. Oak Ridge anticipates benefits to include faster, more accurate analyses and elimination of process wastes generated from the traditional (casting) process. The accuracy of the present prototype device allows measurement of radius of curvature from 3-30 mils, with an accuracy that depends on the reflectivity of the object being imaged. Larger features could be measured if necessary. The cost to implement should be under \$25,000, including hardware and software.

Process Quality Control for Inspection Machines

The Oak Ridge Y-12 Plant successfully initiated a Calibration Program as an SPC tool for quality control inspectors and machine operators to help ensure repeatability of production parts, demonstrate quantitative improvement in the machining process, and document evidence of dimensional inspection capability. Through this effort, quality control inspectors have the "tools" – specifically dimensional inspection – that afford them the ability to establish process repeatability and accuracy of production parts. Through appropriate training, SPC has been made a day-to-day tool for the quality control professional and the skilled machinist.

TOOL PLANNING

Automatic Inspection and Compensation Generation System

Engineering personnel at the Y-12 Plant at Oak Ridge have developed an automatic testing and compensation generation system which conducts structured positioning and squareness tests to provide a graphic plot of the error data with warnings identifying potential machine tool non-conformances, while generating compensation data in the required format. Machine tool mechanical accuracy has typically been enhanced by axis and reversal error calibration for improving positioning error. More recently, other electronic machine accuracy compensation such as axis alignment (squareness) and beam sag compensation has been added to machine controller software. However, the problems associated with machine tool testing and application of the compensation techniques has limited the usefulness of these features.

All equipment used in the system developed at Y-12 is standard and typically available in large manufacturing facilities. The equipment includes a laser interferometer, computer, plotter, multimeter, electronic indicator, and an NC tape punch integrated into one system. With this system utilizing readily available equipment and software, a new dimension can be added to the machine tool compensation capability to improve manufacturing performance. Cost savings can be achieved through reduced manpower and machine downtime when machine testing is necessary, along with end results of a more accurate and repeatable machine.

Precision Production Machining Program

The Y-12 Plant at Oak Ridge has pioneered improvements in production machine tools that have resulted in

machining capabilities of significant precision. These innovations include air bearing components, laser interferometry, geometric and thermal error compensation, and computer controlled touch sensors. Flexible machining systems, precision T-base lathes, ceramic contour grinders, and precision jig grinders are maintained. This Y-12 world class job shop pushes the limits of machining tolerances while maintaining the capabilities, equipment, and technology to perform the required work.

Precision machining at the Y-12 Plant encompasses holding contour tolerances of less than 0.00005-inch, milling and drilling tolerances of less than 0.0002-inch, grinding tolerances in the millionths, and diamond point turning tolerances of 0.000005-inch. In the precision machining section of the plant, most of the equipment has been equipped with air bearings and patented jackshaft spindle assemblies. Automatic ball toolsetters were developed at Y-12 that allow the tooling to be set at the machine within 0.00004-inch. The Y-12 Plant has one of the most accurate large jig grinders worldwide. This machine was developed by Moore Special Tool Company and is one of only three existing in the world. The machine has been fitted with an advanced CNC controller and has three-dimensional jig grinding capability.

This facility also has capabilities for performing non-traditional machining such as EDM, ECM, and laser machining. Capabilities include machining of ferrous, non-ferrous, and exotic materials such as ceramics, graphite, pyrophoric, and hazardous and toxic materials.

SPECIAL TEST EQUIPMENT

Soft Gaging for CMMs

The Fabrication Systems Department at the Oak Ridge Y-12 Plant is working with CMM vendors and software specialists to develop a routine to generate a mathematical representation of soft gaging. This mathematical representation is of the worst case mating part of the part to be inspected. This effort replaces hard gaging that has several disadvantages including long lead time to produce; inflexibility to design changes; and costly design, build, certify, and maintain characteristics. Soft gaging provides an alternative approach that allows for the flexibility to adapt to multiple design changes. Instead of cutting hard gages, the CMM is programmed with the worst case geometric tolerancing representation. When fully developed, this concept will provide Y-12 an accurate, cost effective alternative to hard gages. Possible applications include inspection of threads, involute splines, locating (balancing) parts within castings and defining the mating part in match fittings.

Enhanced Large Surface Inspection Capability

The Fabrication Systems Department at the Oak Ridge Y-12 Plant is developing an enhanced system to inspect large surfaces with complex curvature. The goal is to provide a state-of-the-art inspection cell for complete dimensional measurement. The system uses non-contact probing technology to enable the user to map large surface regions faster and more effectively, and standard CMM probing technology for areas where increased accuracy is of greater concern. An array of available hardware and software tools is being integrated with a smaller Fanamatic CMM to develop the inspection cell. Once the approach is proven, the technology will be retrofitted onto a larger production CMM.

COMPUTER-AIDED MANUFACTURING

Automated Inspection

The Oak Ridge Y-12 Plant initiated a project in 1988 to automate inspection information. Participation was provided by a team comprised of personnel from the Development, Engineering, and Quality Services departments. The objective was to significantly improve CMM programming performance by providing new computer tools that would use Y-12's production CAD system.

Two systems were delivered in 1990 – the CimStation Inspection Module and the Automatically Programmed Metrology (APM) prototype. The CimStation module was developed by Silma, Inc. (Cupertino, CA) from specifications developed by Y-12 personnel. It is a graphics-based, off-line CMM programming system. Manually driven, it is not limited to a particular feature set and has no inspection intelligence. It graphically displays the CMM, the part, the probe, and any fixturing. A menu driven program creation and editing feature allows accurate program simulation prior to actual use on the shop floor.

The APM prototype is a semi-automated system for creating DMIS part programs for the CMMs. Running a VAX computer with graphics terminals, the software is written as a module of ANVIL-5000 v1.2. It required 50K lines of code and was developed in-house by Y-12 personnel using PASCAL, FORTRAN, Assembler language and ANVIL's interface kit. The "productionized" version of the prototype has been developed for a Unix-based workstation, adheres to Motif user interface guidelines, and is intended to be external to any CAD system. It has been rewritten using C++, a fourth generation of object-oriented program language and consists of three separate modules:

- Model Enhancement – used during CAD model creation

- Inspection Plan – used by Quality Service personnel
- Program Plan Generation – using inspection plan data and NC information to automatically create part programs.

APM is currently in its final year of a three-year effort to complete the production system. The Model Enhancement and Inspection Plan modules are complete and are being tested. The Program Plan is scheduled to be completed by September 1993.

PRODUCTION FABRICATION

Inorganic Membrane Technology

The technical division of the K-25 Site at Oak Ridge has fifty years of experience in reverse osmosis (RO) inorganic membranes research, development and manufacture. RO inorganic membranes can be manufactured from metal or ceramic materials that make them ideal for use in applications where high temperature or harsh corrosive environment are prevalent, and the high degree of reproducibility make them effective in providing precise separations. The economy with which they are now produced makes wide application available.

Oak Ridge has the capability to produce large quantities of these inexpensive, high quality, inorganic membranes in a modern, high technology facility. K-25 can develop, tailor, optimize and fabricate these membranes to produce pure water while concentrating oil and other hydrocarbons for easy disposal. They can be used to produce potable water from sea water at an affordable price. Pure water from the waste water process will dilute the concentrated salt from the potable water process for return to the sea, thereby creating no new waste products. Other applications of inorganic membrane uses include the remediation of other liquid wastes such as the removal of PCBs and other hazardous components from water.

While the process to produce these RO inorganic membranes is currently classified, Oak Ridge has a continued interest to go forward with deployment on a classified basis while also striving to have it declassified.

Surface Coatings

The Oak Ridge Y-12 Plant has a large facility for providing surface coatings for various production applications. These capabilities include electroplating and surface finishing, physical vapor deposition, and plasma spray. The electroplating and surface finishing processes cover anodize, black oxide, cadmium, chrome, copper, gold, and lead. The surface finishing facility has a staff of 18 people

(electroplaters, supervisors, technical support and engineers) and is also supported by Y-12 waste management and a physical laboratory for testing. One of the larger current projects includes the copper flash and gold plating of a 750 pound aluminum mirror.

The Y-12 surface finishing facility has achieved the capability to electroplate various substrates and shapes with no contact points; electroplate with varying thicknesses (1-20 mils +10%) on different shapes and substrates with no machining; perform thick, high speed lead plating (1/8-inch thick at .003-.004/hour); produce electroless nickel plating (with no contact points) on multiple parts and part types; join stainless steel and aluminum with nickel electroplating (1/8-inch thick); and plate aluminum ion using magnetrons on uranium.

Wastewater Treatment Facilities

Oak Ridge Y-12 Plant personnel have extensive knowledge of wastewater management, with six facilities on site to treat the wastewater generated by the Plant. For example, the West End Treatment Facility was built to treat 2,700,000 gallons per year of nitrate-bearing aqueous waste streams generated at Y-12 and to discharge the effluent into East Fork Poplar Creek, as required by the Tennessee Department of Health and Environment and the Environmental Protection Agency. The Central Pollution Control Facility and the Plating Rinsewater Treatment Facility were designed to treat a cumulative flow of 10.7 million gallons per year of non-nitrate aqueous waste streams and plating rinsewaters generated at Y-12. The effluent from these facilities also discharges into Poplar Creek. The operations of these facilities include neutralization, equalization, electrochemical reduction flocculation, clarification, filtration, and pH adjustment. Solids generated during processing are currently collected in 500,000 gallon storage tanks until a long-term solution for the mixed wastes can be developed.

Because of the massive size of the Y-12 operation and the unique hazardous materials and wastes managed, state-of-the-art wastewater treatment technology is essential. The innovative systems in use enable Y-12 to comply with the parameters of its National Pollutant Discharge Elimination System permit and to exceed compliance in many cases. The expertise involved in designing and managing Y-12's wastewater treatment systems could have nationwide applications to a variety of government and private facilities.

Monitoring Wastewater Outfalls

The Oak Ridge Y-12 Plant employs a well-designed system of monitoring the outflow of treated wastewater to

the East Fork Poplar Creek which runs through the site. This state-of-the-art system allows Y-12 to fully comply with the monitoring requirements of its National Pollutant Discharge Elimination System (NPDES) permits. In addition, an alarm system provides instant notification of potential permit violations.

After treatment in one of six on-site facilities, Y-12's industrial wastewater is discharged through 223 NPDES permitted outflows to the East Fork Poplar Creek. Immediately downstream from the plant, Y-12 has placed two in-creek, on-line monitoring stations which continuously analyze creek water for a variety of conditions including dissolved oxygen, conductivity, temperature, chlorine, and pH. When the monitors detect that permit parameters have been exceeded, an alarm is telemetered to a manned station. Technicians can be rapidly dispatched to the in-creek monitoring areas to take samples, assess the situation, and recommend corrective action.

Because Y-12 manages a large number of permitted outflows, a durable, efficient and cutting edge monitoring system is essential. The Plant must constantly guard against expensive violations of permit parameters. The monitoring system employed at Y-12 helps the Plant to fully comply with its permits. The system goes beyond compliance with its alarm function that allows rapid detection and correction of problems. This expertise involved in designing the Y-12 monitoring system has applications at any facility with an NPDES permitted wastewater outflow.

Centralized Waste Tracking and Management

The DOE-Oak Ridge Facilities are required to comply with the Tennessee Oversight Agreement which includes maintaining a comprehensive waste tracking system. Individual sites at Oak Ridge Facilities had their own methods of tracking with no reliable electronic central reporting point. The problem required cost effective and efficient standardization of data. The Oak Ridge Facilities have developed a centralized reporting system to receive waste management data from site systems through the use of batch uploads. Several LANs have been consolidated and standardized on a wide area network which uploads information daily. This effort complies with the agreement with the state of Tennessee and also has improved efficiency and decreased waste tracking costs.

There is currently an information exchange among DOE sites, and users are interacting and cooperating with each other, further enhancing productivity. The fully operational system will be on line in October 1993. Improvements are already being evaluated that will expand the system to other DOE sites and increase availability.

Resource Conservation and Recovery Act Waste Minimization Initiative

The Oak Ridge Y-12 Plant has undertaken an initiative to reduce or eliminate the generation of waste regulated as hazardous under RCRA. This effort involved the definition and evaluation of all RCRA waste streams to determine if reduction or elimination was possible, and the preparation of Action Plans showing how to achieve the desired results. A database containing all evaluation data is used to track progress and document successful efforts.

As RCRA hazardous waste management requirements grew increasingly stringent, Y-12 saw the need to reduce or eliminate hazardous waste streams wherever possible. All of the Y-12 Plant's RCRA waste streams in the uranium operations were evaluated to determine if they could be reduced or eliminated through improved inventory control, procedural changes, waste segregation, product substitution, process design modification, improved housekeeping, or employee awareness and education. Forty-two short term and 36 long term Action Plans were prepared to guide the implementation of each reduction or elimination effort that could be accomplished by utilizing these methods.

Prior to the waste minimization initiative, most wastes were disposed of as hazardous, including all waste oils. This initiative helped Y-12 to define and understand its waste streams, and to take actions to remove a significant amount of waste from the stringent and expensive RCRA regulatory scheme.

The RCRA Waste Minimization Initiative identified 75 RCRA waste streams within the uranium operations at Y-12. Using Action Plans developed from the evaluation of reduction and elimination methods, 37 waste streams have been eliminated. If all Action Plans are implemented and completed, Y-12 can reduce the amount of RCRA waste generated by 330,000 gallons from the FY'91 total of 465,000 gallons. Unquantifiable benefits include a better understanding of plant waste streams and an awareness of the importance of waste segregation and characterization.

Hazardous Solvent Replacement Program

In response to stringent health and environmental issues, the Oak Ridge Y-12 Plant has instituted an active program to find substitutes for chlorinated solvents used for parts cleaning. This effort involves replacing ozone depleting chemicals including CFC 113 and 1,1,1 trichloroethane; suspected carcinogens such as perchloroethylene and methylene chloride; and any solvent which produces an RCRA waste.

As an initial step, all chlorinated solvent usage at Y-12 was identified through surveys of purchase records, shop survey forms, and shop visits. A priority list for substitution

was created to focus on replacement of the most environmentally offensive solvents first. By tracking purchase records, program staff assured that no solvents were purchased for new uses during the evaluation of replacements. Replacement solvents were evaluated for toxicity concerns, waste disposal concerns, compatibility concerns, criticality concerns, cleaning ability, and effects on production.

These evaluations enabled Y-12 to replace vapor degreasing operations with ultrasonic cleaning which utilizes aqueous detergent. In addition, two non-chlorinated organic solvents have been implemented to replace chlorinated solvents used for cleaning of typical machine shop components with paper wipes. Solvent 140 and a Y-12 developed blend of solvent 140 and dipropylene glycol methyl ether are used in these "squirt bottle" applications. A patent is pending on the solvent blend.

The Chlorinated Solvent Replacement Program has resulted in a 92% reduction in chlorinated solvent use from 1987 levels. Replacement solvents have not affected product quality or production rates and have generally resulted in better cleaning. The program has enabled Y-12 staff to participate in solvent replacement activities within DOE and nationally, including several consulting contracts.

Environmental Restoration Program

An extensive environmental restoration effort is underway at the DOE's Oak Ridge Facilities. A number of cutting edge remediation technologies are being developed and used by ORNL scientists to effect the clean-up of areas surrounding the Y-12 Plant, K-25 Site, and ORNL. Oak Ridge is DOE's most complex site, both geographically and hydrologically. Over a period of 40 years, a diverse range of contaminants were disposed of by several methods including land burial, seepage pits and deep well injection. This has resulted in extensive contamination of soils, ground water, and surface water systems.

A variety of technologies are used by ORNL staff to characterize and remediate disposal sites. Many of these technologies are unique, state-of-the-art processes developed by ORNL. Some of the technologies in development and use include the study of sub-surface flow conditions by spiking and tracing ground water flow; in-situ grouting to reduce surface-based geophysical characterization; in-situ vitrification of trenches; bioremediation; ground water age dating; a colloidal baroscope; an Ultrasonic Ranging and Data System; aerial geophysical surveys; and an in-situ process for treating VOCs in soil through soil mixing and vapor extraction.

The overriding consideration in ORNL's restoration technology development program is to devise and apply technologies that can provide data or remediate a site in situ—or in place. This averts the need to excavate contaminated

sites. Excavation can create problems and expenses related to worker exposure, environmental release, and waste disposal issues. The ORNL site restoration technology program will result in reduced remediation costs, reduced worker exposure and expedited clean up. In addition, the program is working on a wide variety of technology that is transferable to remediation applications across the U.S. and internationally.

Use of Micro Techniques to Assist Macro Problems

The ORNL has developed an in-house capability of highly trained personnel and state-of-the-art equipment to analyze a variety of sample types required by environmental regulatory agencies. These environmental regulations require information on content and quantity of specific materials present in the soil, water, and air.

The equipment includes scanning electron microscopes, transmission electron microscopy, energy dispersive X-ray spectroscopy, and wavelength dispersive X-ray spectroscopy. ORNL is capable of soil and materials characterization, materials response and failure analysis, sensor development, and asbestos analysis.

Several ORNL analysis laboratories are certified by the federal government. By teaming with other ORNL groups as well as other DOE laboratories, this group (materials characterization) is ensuring that ORNL and the DOE are in compliance with environmental regulations while protecting and restoring local environments. The range of analytical equipment available in a central location at ORNL results in a large cost savings over the expense of using outside laboratories to support the immense environmental management efforts at Oak Ridge. This world class collection of expertise provides other federal facilities and private industry the opportunity to have a complete range of analytical services performed in a single location. ORNL experts can also support the development of advanced analytical capabilities at other locations.

Environment, Safety and Health Five Year Plan for the Oak Ridge Y-12 Plant

The Oak Ridge Y-12 Plant created a Five Year Plan to identify activities and resources required during the 1995 to 1999 period to bring the Plant into and maintain compliance with environmental, safety, and health (ES&H) regulations and standards. The plan was prepared in response to the Secretary of Energy's request for the DOE Safety and Health Five Year Plan to fully identify the scope of the problem, priorities, and pace of funding required to bring the agency into full compliance with all safety and health laws and regulations.

The Comprehensive Y-12 Plan covers each of the activities critical to plant compliance. The issues addressed include Federal Facilities Compliance Act compliance, self assessment, training, nuclear safety and construction activities. The document provides Y-12 plant managers and their staffs with a plan that identifies important ES&H management issues along with the strategies and programs formulated to solve problems and achieve and maintain compliance.

Long range environmental planning is an increasingly important activity, especially at large industrial facilities engaged in remediation efforts. The expertise of the Y-12 staff that developed the Five Year Plan could assist any facility in need of a similar program. In addition, the format and organizational structure of the Y-12 Plan can serve as a model for others.

Health, Safety and Environment

The Oak Ridge Y-12 Plant has a Health, Safety and Environmental organization with extensive capabilities. The organization includes Industrial Safety, Industrial Hygiene, Occupational Medicine, Fire Protection, Nuclear Criticality Safety, Environmental Activities, Health and Safety Upgrades, Health Physics, and Safety Analysis. These entities utilize the services of the Development, Quality, and Laboratory Services organizations to provide technical support. A wide range of environmental support expertise is available relative to all environmental laws. Permitting, environmental reporting, auditing and inspection, issue resolution, compliance strategy development, environmental sampling and analysis, and automated data management are examples of the capabilities in the Environmental Activities areas. The Health Physics department provides radiological health support in the areas of external and internal dosimetry, instrumentation, and workplace monitoring. Radiological facility support is included for engineering design, facility safety documentation, operational readiness reviews, and weapons radiological hazards.

Advanced detectors have been developed for dosimetry and instrumentation monitoring. One project being performed is monitoring Desert Storm personnel who have internal depleted uranium shrapnel. Other notable activities include:

- The Industrial Hygiene Department has developed a computerized respirator fit test that is currently being used as a portable test facility.
- A patent is pending on a gasket that is part of an HEPA - filtered vacuum unit designed to remove paint containing lead or asbestos.

- The Bioassay Laboratory of the Analytical Services Organization is a Center of Excellence.

This wide range of capabilities within the Health, Safety, and Environment Organization is a valuable resource locally as well as statewide and nationally.

4.3 FACILITIES

FACTORY IMPROVEMENTS

Upgrading Repair History Programs

The Oak Ridge Y-12 Plant Site Management Service Department has developed a methodology to provide data through statistical analysis to reveal trends and recurring problems for improving maintenance effectiveness, cost, and reliability.

The Oak Ridge Y-12 plant has a unique and complex maintenance and repair challenge with over 100,000 significant structures, systems, and components (SSCs) distributed over six million square feet of floor space located in more than 500 buildings. None of the existing repair history data is keyed to all the full feature complexities of the SSCs. Data is collected that reflects the complexity of the SSCs, provides a logical and efficient method to collect the data, allows the craftpersons to collect the data, and enables statistical analysis of the data to perform fault analysis.

A simple-to-use Repair History Form has been created and distributed to capture the data. The history form collects Logical Methods and Key Word Types. Data includes identifying a failed component, condition of the component, action taken, cause of failure, failure impact, and the "as-left" condition. Each data set provides multiple choices that are selected by the technical data entry personnel for each SSC. The upgrade is integrated with the already existing Maintenance Management System.

The program has been piloted for two years and data is continuing to be entered and analyzed.

4.4 MANAGEMENT

MANUFACTURING STRATEGY

Y-12 Plant Operational Readiness

To ensure safe facility operation which is in compliance with overall governing requirements, a structured methodology called the Operation Readiness Process (ORP) is applied at the Oak Ridge Y-12 Plant. This process is required by Department of Energy policy and provides management and the customer with the assurance that the

current increment of work has been performed consistent with management expectations. It also ensures the subject activity is ready to proceed to the next increment of work safety and in compliance with applicable requirements. Situations requiring application of ORP include start-up of new or significantly modified operations, reactivation of an activity after extended shutdown, implementation of a significant change in operating mode, decommissioning or dismantling, and specific management or customer direction. Applicable projects or activities are evaluated for risk of safety, health, environmental protection, public sensitivity, regulatory compliance, cost, and milestones to establish a graded approach to readiness review. A team and board approach is used to conduct the process and provide independence in the verification function.

Space and Defense Technology Program

The mission of the Space and Defense Technology Program (SDT) is to apply the collective capabilities of the DOE Oak Ridge Facilities to finding scientific and technological solutions to problems of national importance. SDT serves as the facilitator between a sponsor and MMES' WFO program. This effort has resulted in an increased flow of DOE technology to both industry and other government agencies. These SDT teams are seeking non-DOE sponsors. The DoD and NASA have become two principal sponsors for WFO. SDT has taken the responsibility of matching ORNL capabilities with sponsor need and assembles MMES project teams to address sponsor goals. It removes administrative burdens from MMES technical personnel by monitoring project progress, financial status, and milestones. After the project has been completed, SDT maintains long-term continuity with sponsors for additional future work.

DATA REQUIREMENTS

Information Resources Management

The Information Resources Management (IRM) Section of the DSRD Program provides research and technical assistance to federal agencies in the planning, development, management and implementation of corporate information resources. DSRD's mission is to design, develop, and apply state-of-the-art information technologies and to provide solutions to problems affecting mission performance of the DOE and other federal agencies. MMES has successfully supported over 85 federal agencies to include the U.S. Army, Defense Logistics Agency, and Headquarters Army Materiel Command through its DSRD program. MMES has recognized the need to integrate and modernize IRM programs. The IRM section of DSRD is an excellent source of information resource management and can provide detailed informa-

tion on such topics as Data Administration, Data Dictionaries/Repositories, Database Administration, Enterprise Modeling, and Information Systems Development Methodology.

Y-12 Computer Integrated Enterprise Program

The Oak Ridge Y-12 Computer Integrated Enterprise Program was initiated in 1984 to facilitate needed modernization efforts, improve basic business processes, and leverage technology resources. This program manages limited resources available for investments in business improvements and information technologies to ensure investments directly support business goals, priorities and plans. Business system project managers from plant line organizations representing functional areas lead modernization planning and implementation activities. This provides the interface between the users and the service providers. Technology support is provided from the Computing, Telecommunications, Engineering, and Development Divisions at Y-12.

Specific strategies for business modernization included strategic planning, business area analysis efforts, use of commercial off-the-shelf software, and a standardized methodology based on information engineering. The information strategy plan defined a set of architectures providing common conceptual models of requirements for planning and control purposes and specified a long range implementation plan to define and sequence the initiatives required to realize the target architectures. A FY'91 strategy plan project updated the architectures to reflect recent changes to the Plant's business objectives and priorities. Common business activities and information needs are periodically redefined. The architectural information is reformatted into the form required by the information engineering methodology and the automated I-CASE tool.

In implementation of the strategic plan, limited success was achieved on separate business system projects. The primary focus for integration shifted from individual business systems to business areas. A business area represents a large portion of business functions within the plant which have common information requirements and typically include several highly integrated business systems. Emphasis is placed on the acquisition of commercial off-the-shelf software that is implemented without changes or modifications. Large comprehensive packages that cover the entire business area requirements are preferred. Current initiatives are underway in the health, safety, environment, and waste services; production management; facilities and equipment utilization; compliance management; and finance.

Many projects have been completed and quantifiable benefits have been realized. These include business systems providing better understanding of the business, better information systems and stable and more reliable data-

bases. Standardized systems, common training for users, application of information engineering tools, reusable code, and sharable data are resulting in faster development and more reliable systems. These systems are providing more flexibility in adapting business needs and returning real dollar savings. Future efforts will include construction of modular information systems and increased reliance on model based applications.

Information Center Concept

The Oak Ridge Y-12 Plant has created a corporate Information Center database to receive both classified and unclassified information from a variety of sources including production, manufacturing, personnel, environmental, laboratory results, certification and analysis databases. The Information Center database, a daily repository of all electronically derived data, is updated every day to provide VAX/VMS easy-to-use data access and reporting tools. A unique information Access Control System was developed based on a need-to-know philosophy because of security requirements at the facility and the sensitive nature of the data. The Information Center, while protecting its data, allows a user to access updated corporate data in a usable format without disturbing the facility's main system database and regular daily operations. It is expected that the Information Center will reduce software development costs by encouraging users to develop and maintain their own sources of data and applications.

Electronic Signature and Record Management System

As a project in the Work for Others Program, DSRD has developed a system to manage electronic records and an electronic signature capability. The electronic signature technology applies nationally accepted encryption standards using a manipulation detection code or checksum. This assures that the electronic signature cannot be forged, is authentic, is not alterable, and is not reusable. The electronic signature facility in the system provides for three levels of authentication which emulate the process of an individual signing a document, provides notary capability, and addresses the problem of alterable documents. Other features of the system include creating, managing, and querying electronic documents; creating and editing forms; creating document routings; auditing and managing versions of documents; monitoring and managing long-term document storage and disposition requirements; and safeguards against document falsification. System development methods provide for rapid development and incorporation of changes and updates. The software is public domain and fully transportable.

Based on the successful completion of the pilot development program, numerous benefits were identified. These include increased speed of information flow by centrally storing documents and automating work flow and tracking, faster access to documents, reduced data storage requirements, guaranteed integrity of data, and improved availability of information. Initial development costs were relatively low and new applications can be added quickly and cost effectively. Proposed enhancements to the system such as spreadsheet capabilities within documents, drawing and diagramming, and an imaging system, will extend the system to become a complete integration tool for resource management.

Electronic Document Management System

The DOE-Oak Ridge Electronic Document Management System (EDMS) provides a client/server environment that can be applied to any electronic document or drawing file control situation in which there are access and configuration control requirements. The system file manager core functions to manage the central repository document storage; manage document workflow, provide configuration control; provide search and retrieval queries; control access; log document access; and manage personnel who have access control. The EDMS presently manages over 12,000 documents and drawings, 2.4 billion bytes of information, and over 17,000 individual files. EDMS applications were engineered with Martin Marietta Energy Systems software and are applicable to a variety of commercial users, particularly those segments of the private sector, DoD, and federal agencies requiring both electronic document access and configuration control.

Data Systems Research and Development (DSRD) Program

The DSRD Program is a multi-site program within MMES. Its mission is to provide direct support to U.S. government agencies to design, develop, and apply state-of-the-art information technologies to provide modern solutions to problems affecting mission performance of the Department of Energy and other federal agencies. Some of these projects are performed as WFO projects and some are internal. Areas of expertise include research into advanced computing techniques, computer and communications security, future architectures, performance computing, information and technology standards, advanced database management prototypes, and configuration management studies. DSRD is extensively involved in technology transfer between the government and commercial sectors.

PREPARE REQUIREMENTS DOCUMENTS

Standard Generalized Markup Language (SGML)

The Publications Division of MMES recognizes that national and corporate information is an asset and has therefore initiated efforts to develop the expertise to bring these assets under control for the benefit of the company. The Publications Division of MMES established a Development and Production Group in 1987 devoted to the Standard Generalized Markup Language (SGML). This language has been specified as part of the CALS Initiative that addresses the difficulties of information assets growing to unmanageable proportions where problems include too much scientific and technical information for personnel to manage; the difficulty of sharing or reusing information; time-consuming and expensive search and retrieval; difficulty of moving information across computer platforms; and extensive information resident in technical reports, journals, procedures, and records.

SGML uses a different approach that is not format-dependent, but emphasizes information content which provides the basis for selecting software tools. Editing tools currently in use include Author/Editor, Checkmark, and IntelliTAG. Core technical tools include XTRAN, Rulesbuilder, and ARCSGML. Other support tools implemented by MMES include FORTRAN, TEX, and TagWrite. With these tools in place, the SGML team can now:

- Perform a comprehensive document analysis and generate document type definitions from scratch;
- Use MIL-M-38784 series and MIL-STD-28001 as a basis for application development;
- Perform high-level and low-level analysis of publishing environments, conversion applications, software testing and evaluation;
- Review the work of other vendors that have developed SGML applications.

The SGML Group began servicing the DOE in 1990, expanded to the Army and Defense Logistics Agency in 1991 and to other activities in 1992. The track record for accomplishments is new, but it has the foundation for strong information management capabilities.

QUALITY ASSURANCE

Y-12 Quality Information System

Because of the highly classified nature of the work done at ORNL, a need-to-know atmosphere developed where there

was a lack of communication between shops. Each shop that produced parts employed its own statistician and process engineer to monitor quality. Management was by exception, mainly centering on finding a problem and determining a solution. Process information which would allow product improvement was difficult to gather and had a long turnaround time. A better data handling system was required to meet the demand of changing production environments. Y-12 invested in a new Quality Information System known as SAS. This tailorable software package allows the user to tailor the program to meet specific requirements. Also, as the ORNL mission changed, this new Quality Information System was expanded to all production shops allowing quick and accurate sharing of information. SAS has dramatically improved product quality and shop efficiency. Machinists were trained, allowing the hands-on personnel to monitor their own performance and make necessary process adjustment quickly. Y-12 now has a standardized quantity information system which is user friendly. Statistics gathered with SAS have shown that product quality has steadily improved since its implementation.

Mechanical Inspection Services

The Y-12 Equipment Testing and Inspection Department, Quality Division, provides a variety of inspection and certification services for the Oak Ridge Y-12 Plant and other Martin Marietta Energy Systems Facilities in the Oak Ridge area. An eclectic assortment of inspections are available for a wide range of mechanical systems including energy, industrial equipment, materials handling equipment, furnaces, pressure, and vacuum systems. A group of 20 weekly inspectors, six hourly craftsmen, and three supervisors accomplish inspections and certifications required by regulation. This organization can perform both destructive and non-destructive testing using an assortment of techniques including but not limited to mass spectrometry, Halogen leak testing, Bubble testing, and Holiday (spark) testing. Appropriately credentialed personnel are available on staff to provide the necessary certifications. The capability provides a wide range of services available in a single, organizationally independent team.

SECTION 5

PROBLEM AREAS

5.1 DESIGN

TRADE STUDIES

Technology Transfer from National Laboratories

There has been a recent increased effort to transfer technology from national laboratories to private industry. Rapid transfer of technology from national laboratories is hindered for several reasons. Some contributing factors include: the role of national laboratories is often not understood by industry and the operation of national laboratories by contractors (from universities or private industry) causes confusion. Relations with laboratories are perceived to involve substantial government paperwork and delays.

Transfer and implementation of technology may be hampered for several reasons including:

- A "not invented here" syndrome and resistance to change by companies;
- Unavailable resources to transact and negotiate with laboratories;

- Technology acquired without a complete understanding of its implications;
- Dedicated staff to promote newly acquired technology;
- Insufficient patents and reports for technology transfer;
- Licensing and royalty agreements that not always serve the best interests of the nation and the companies involved.

Experiences with technology transfer by the staff at ORNL have indicated this is an area that requires further study to protect the nation's considerable investment in the development of new technology at the national laboratories. An area that requires particular attention is agreements which limit or restrict the use of new technology developed at taxpayer expense. One current practice which may be a problem is one that allows a company to acquire exclusive rights to a technology (at low cost) which the company does not further develop in a reasonable time frame. Other potential developers may be restricted from using the technology, hence no further development occurs.

APPENDIX A

TABLE OF ACRONYMS

APM	Automatically Programmed Metrology
CALS	Computer-Aided Acquisition and Logistics Support
CMT	Carbon Materials Technology
CRADA	Cooperative Research and Development Agreement
DOE	Department of Energy
DMIS	Dimensional Measurement Interface Specification
DSRD	Data Systems Research and Development
DYMCAS	Dynamic Special Nuclear Materials Control and Accountability System
EDMS	Electronic Document Management System
ET&I	Equipment Testing and Inspection
ES&H	Environmental, Safety, and Health
FARS	Future Armor Rearm System
FTIR	Fourier Transform Infrared Spectroscopy
I-CASE	Integrated Computer Aided Software Engineering
IDEF	Integrated Computer-Aided Manufacturing Definition Language
IFPUG	International Function Point User's Group
IGES	Initial Graphics Exchange Specification
IMIS	Inventory Management Information System
IRM	Information Resources Management
ISV	In Situ Vitrification
GTAW	Gas Tungsten Arc Welding
MCSA	Motor Current Analysis
MMES	Martin Marietta Energy Systems, Inc.
MODIL	Manufacturing Operational Development and Integration Laboratory
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
ORNL	Oak Ridge National Laboratory
ORP	Operation Readiness Process
PCB	Poly Chlorinated Biphenol
PVC	Poly Vinyl Chloride
RCRA	Resource Conservation and Recovery Act
RO	Reverse Osmosis
SAW	Surface Acoustic Wave
SCALE	Standard Computer Analyses for Licensing Evaluation
SDT	Space and Defense Technology Program
SGML	Standard Generalized Markup Language
SSC	Structures, Systems, and Component

TABLE OF ACRONYMS (Continued)

TQ	Total Quality
TLD	Technology Logic Diagram
VIM	Vacuum Induction Melting
WFO	Work for Others

APPENDIX B

BMP SURVEY TEAM

NAME	ACTIVITY	FUNCTION
Bob Jenkins (703) 746-3553	NAVSEA Washington, DC	Team Chairman
Amy Scanlan (206) 679-9008	BMP Representative Oak Harbor, WA	Technical Writer
Adrienne Gould (703) 696-8482	OCNR Arlington, VA	Technical Writer

DESIGN/TEST

Charles McLean (301) 975-3511	National Institute of Standards and Technology Gaithersburg, MD	Team Leader
Ben Kassel (301) 227-1355	Carderock Division Naval Surface Warfare Center Bethesda, MD	
Steve Ratz (317) 353-7151	Aircraft Division-Indianapolis Naval Air Warfare Center Indianapolis, IN	
Leonard Howell (205) 544-1453	NASA Marshall Space Flight Center Huntsville, AL	
*Larry Robertson (812) 854-5336	Naval Surface Warfare Center Crane Division Crane, IN	

PRODUCTION/FACILITIES-1

Tim LaCoss (518) 266-4566	U.S. Army Watervliet Arsenal Watervliet, NY	Team Leader
Jack Tamargo (707) 646-5788	Mare Island Naval Shipyard Mare Island, CA	
Nick Keller (812) 854-5331	Naval Surface Warfare Center Crane Division Crane, IN	

BMP SURVEY TEAM (Continued)

NAME	ACTIVITY	FUNCTION
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PRODUCTION/FACILITIES-1 (Continued)

*John Fischer (619) 939-1798	Naval Air Warfare Center Weapons Division China Lake, CA	
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Sylvia McFearin (703) 602-5374	NAVSEA Washington, DC	
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PRODUCTION/FACILITIES-2

Don Hill (317) 353-7221	Aircraft Division-Indianapolis Naval Air Warfare Center Indianapolis, IN	Team Leader
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Tom Kirchner (317) 353-7217	Aircraft Division-Indianapolis Naval Air Warfare Center Indianapolis, IN	
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*Angela Behr (317) 226-5634	Electronics Manufacturing Productivity Facility Indianapolis, IN	
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Cynthia Krist (309) 782-7861	U.S. Army Rock Island Arsenal Rock Island, IL	
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Jay Rarick (703) 704-1401	Fort Belvoir Ft. Belvoir, VA	
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MANAGEMENT/LOGISTICS

Richard Purcell (703) 271-0366	BMP Representative Washington, DC	Team Leader
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Larry Halbig (317) 353-3838	Aircraft Division-Indianapolis Naval Air Warfare Center Indianapolis, IN	
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CAPT Mike Pearson (703) 602-2123	Office of Assistant Secretary of the Navy (Research, Development and Acquisition) Product Integrity Washington, DC	
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Allan Mense (407) 452-5484	BMP Representative Washington, DC	
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*Denotes Environmental Team

APPENDIX C

NAVY CENTERS OF EXCELLENCE

Automated Manufacturing Research Facility (301) 975-3414

The Automated Manufacturing Research Facility (AMRF) – a National Center of Excellence – is a research test bed at the National Institute of Standards and Technology located in Gaithersburg, Maryland. The AMRF produces technical results and transfers them to the Navy and industry to solve problems of automated manufacturing. The AMRF supports the technical work required for developing industry standards for automated manufacturing. It is a common ground where industry, academia, and government work together to address pressing national needs for increased quality, greater flexibility, reduced costs, and shorter manufacturing cycle times. These needs drive the adoption of new computer-integrated manufacturing technology in both civilian and defense sectors. The AMRF is meeting the challenge of integrating these technologies into practical, working manufacturing systems.

Electronics Manufacturing Productivity Facility (317) 226-5607

Located in Indianapolis, Indiana, the Electronics Manufacturing Productivity Facility (EMPF) is a National Center of Excellence established to advance state-of-the-art electronics and to increase productivity in electronics manufacturing. The EMPF works with industry, academia, and government to identify, develop, transfer, and implement innovative electronics manufacturing technologies, processes, and practices. The EMPF conducts applied research, development, and proof-of-concept electronics manufacturing and design technologies, processes, and practices. It also seeks to improve education and training curricula, instruction, and necessary delivery methods. In addition, the EMPF is striving to identify, implement, and promote new electronics manufacturing technologies, processes, materials, and practices that will eliminate or reduce damage to the environment.

National Center for Excellence in Metalworking Technology (814) 269-2420

The National Center for Excellence in Metalworking Technology (NCEMT) is located in Johnstown, Pennsylvania and is operated by Concurrent Technologies Corporation (CTC), a subsidiary of the University of Pittsburgh Trust. In support of the NCEMT mission, CTC's primary focus includes working with government and industry to develop improved manufacturing technologies including advanced methods, materials, and processes, and transferring those technologies into industrial applications. CTC maintains capabilities in discrete part design, computerized process analysis and modeling, environmentally compliant manufacturing processes, and the application of advanced information science technologies to product and process integration.

Center of Excellence for Composites Manufacturing Technology (414) 947-8900

The Center of Excellence for Composites Manufacturing Technology (CECMT), a national resource, is located in Kenosha, Wisconsin. Established as a cooperative effort between government and industry to develop and disseminate this technology, CECMT ensures that robust processes and products using new composites are available to manufacturers. CECMT is operated by the Great Lakes Composites Consortium. It represents a collaborative approach to provide effective advanced composites technology that can be introduced into industrial processes in a timely manner. Fostering manufacturing capabilities for composites manufacturing will enable the U.S. to achieve worldwide prominence in this critical technology.

APPENDIX D

PROGRAM MANAGER'S WORKSTATION

The Program Manager's Workstation (PMWS) is a series of expert systems that provides the user with knowledge, insight, and experience on how to manage a program, address technical risk management, and find solutions that industry leaders are using to reduce technical risk and improve quality and productivity. This system is divided into four main components; KNOW-HOW, Technical Risk Identification and Mitigation System (TRIMS), BMP Database, and Best Manufacturing Practices Network (BMPnet).

- **KNOW-HOW** is an intelligent, automated method that turns "Handbooks" into expert systems, or digitized text. It provides rapid access to information in existing handbooks including Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168, SecNav 5000.2A and the DoD 5000 series documents.

- **TRIMS** is based on DoD 4245.7-M (the transition templates), NAVSO P-6071 and DoD 5000 event oriented acquisition. It identifies and ranks the high risk areas in a program. TRIMS conducts a full range of risk assessments throughout the acquisition process so corrective action can be initiated before risks develop into problems. It also tracks key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities in the development and acquisition process.

- The **BMP Database** draws information from industry, government, and the academic communities to include documented and proven best practices in design, test, production, facilities, management, and logistics.

Each practice in the database has been observed and verified by a team of experienced government engineers. All information gathered from BMP surveys is included in the BMP Database, including this survey report.

- **BMPnet** provides communication between all PMWS users. Features include downloading of all programs, E-mail, file transfer, help "lines", Special Interest Groups (SIGs), electronic conference rooms and much

more. Through BMPnet, IBM or compatible PC's and Macintosh computers can run all PMWS programs.

- To access **BMPnet** efficiently, users need a special modem program. This program can be obtained by calling the BMPnet using a VT-100/200 terminal emulator set to 8,N,1. Dial (703) 538-7697 for 2400 baud modems and (703) 538-7267 for 9600 baud and 14.4 kb. When asked for a

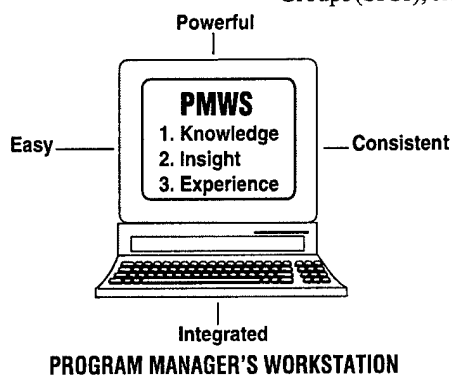
user profile, type: DOWNPC or DOWNMAC <return> as appropriate. This will automatically start the Download of our special modem program. You can then call back using this program and access all BMPnet functions. The General User account is:

USER PROFILE: BMPNET

USER I.D.: BMP

Password: BMPNET

If you desire your own personal account (so that you may receive E-Mail), just E-Mail a request to either Ernie Renner (BMP Director) or Brian Willoughby (CSC Program Manager). If you encounter problems please call (703) 538-7253.



APPENDIX E

NEW BEST MANUFACTURING PRACTICES PROGRAM TEMPLATES

Since 1985, the BMP Program has applied the templates philosophy with well-documented benefits. Aside from the value of the templates, the templates methodology has proven successful in presenting and organizing technical information. Therefore, the BMP program is continuing this existing “knowledge” base by developing 17 new templates that complement the existing DoD 4245.7-M or Transition from Design to Production templates.

The development of these new templates was based in part on Defense Science Board studies that have identified new technologies and processes that have proven successful in the last few years. Increased benefits could be realized if these activities were made subsets of the existing, compatible templates.

Also, the BMP Survey teams have become experienced in classifying Best Practices and in technology transfer.

The Survey team members, experts in each of their individual fields, determined that data collected, while related to one or more template areas, was not entirely applicable. Therefore, if additional categories were available for Best Practices “mapping,” technology transfer would be enhanced.

Finally, users of the Technical Risk Identification and Mitigation System (TRIMS) found that the program performed extremely well in tracking most key program documentation. However, additional categories – or templates – would allow the system to track all key documentation.

Based on the above identified areas, a core group of activities was identified and added to the “templates baseline.” In addition, TRIMS was modified to allow individual users to add an unlimited number of user-specific categories, templates, and knowledge-based questions.

APPENDIX F

PREVIOUSLY COMPLETED SURVEYS

BMP surveys have been conducted at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPNET. Requests for copies of recent survey reports or inquiries regarding the BMPNET may be directed to:

Best Manufacturing Practices Program
2101 Crystal Plaza Arcade
Suite 271
Arlington, VA 22217-5660
Attn: Mr. Ernie Renner, Director
Telephone: (703) 696-8483
FAX: (703) 271-9059

COMPANIES SURVEYED

Litton
Guidance & Control Systems Division
Woodland Hills, CA
October 1985 and February 1991

Texas Instruments
Defense Systems & Electronics Group
Lewisville, TX
May 1986 and November 1991

Harris Corporation
Government Support Systems Division
Syosset, NY
September 1986

Control Data Corporation
Government Systems Division
(Computing Devices International)
Minneapolis, MN
December 1986 and October 1992

ITT
Avionics Division
Clifton, NJ
September 1987

UNISYS
Computer Systems Division
(Paramax)
St. Paul, MN
November 1987

Honeywell, Incorporated
Undersea Systems Division
(Alliant Tech Systems, Inc.)
Hopkins, MN
January 1986

General Dynamics
Pomona Division
Pomona, CA
August 1986

IBM Corporation
Federal Systems Division
Owego, NY
October 1986

Hughes Aircraft Company
Radar Systems Group
Los Angeles, CA
January 1987

Rockwell International Corporation
Collins Defense Communications
Cedar Rapids, IA
October 1987

Motorola
Government Electronics Group
Scottsdale, AZ
March 1988

General Dynamics
Fort Worth Division
Fort Worth, TX
May 1988

Hughes Aircraft Company
Missile Systems Group
Tucson, AZ
August 1988

Litton
Data Systems Division
Van Nuys, CA
October 1988

McDonnell-Douglas Corporation
McDonnell Aircraft Company
St. Louis, MO
January 1989

Litton
Applied Technology Division
San Jose, CA
April 1989

Standard Industries
LaMirada, CA
June 1989

Teledyne Industries Incorporated
Electronics Division
Newbury Park, CA
July 1989

Lockheed Corporation
Missile Systems Division
Sunnyvale, CA
August 1989

General Electric
Naval & Drive Turbine Systems
Fitchburg, MA
October 1989

TRICOR Systems, Incorporated
Elgin, IL
November 1989

TRW
Military Electronics and Avionics
Division
San Diego, CA
March 1990

Texas Instruments
Defense Systems & Electronics Group
Dallas, TX
June 1988

Bell Helicopter
Textron, Inc.
Fort Worth, TX
October 1988

GTE
C3 Systems Sector
Needham Heights, MA
November 1988

Northrop Corporation
Aircraft Division
Hawthorne, CA
March 1989

Litton
Amecom Division
College Park, MD
June 1989

Engineered Circuit Research, Incorporated
Milpitas, CA
July 1989

Lockheed Aeronautical Systems Company
Marietta, GA
August 1989

Westinghouse
Electronic Systems Group
Baltimore, MD
September 1989

Rockwell International Corporation
Autonetics Electronics Systems
Anaheim, CA
November 1989

Hughes Aircraft Company
Ground Systems Group
Fullerton, CA
January 1990

MechTronics of Arizona, Inc.
Phoenix, AZ
April 1990

Boeing Aerospace & Electronics
Corinth, TX
May 1990

Textron Lycoming
Stratford, CT
November 1990

Naval Avionics Center
Indianapolis, IN
June 1991

Kurt Manufacturing Co.
Minneapolis, MN
July 1991

Raytheon Missile Systems Division
Andover, MA
August 1991

Tandem Computers
Cupertino, CA
January 1992

Conax Florida Corporation
St. Petersburg, FL
May 1992

Hewlett-Packard
Palo Alto Fabrication Center
Palo Alto, CA
June 1992

Digital Equipment Company
Enclosures Business
Westfield, MA and
Maynard, MA
August 1992

NASA Marshall Space Flight Center
Huntsville, AL
January 1993

Technology Matrix Consortium
Traverse City, MI
August 1990

Norden Systems, Inc.
Norwalk, CT
May 1991

United Electric Controls
Watertown, MA
June 1991

MagneTek Defense Systems
Anaheim, CA
August 1991

AT&T Federal Systems Advanced
Technologies and AT&T Bell Laboratories
Greensboro, NC and Whippany, NJ
September 1991

Charleston Naval Shipyard
Charleston, SC
April 1992

Texas Instruments
Semiconductor Group
Military Products
Midland, TX
June 1992

Watervliet U.S. Army Arsenal
Watervliet, NY
July 1992

Naval Aviation Depot
Naval Air Station
Pensacola, FL
November 1992

Naval Aviation Depot
Naval Air Station
Jacksonville, FL
March 1993
