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MANUFACTURING
METHODS &
TECHNOLOGY
**PROJECT SUMMARY
REPORTS**

(RCS DRCMT-302)

PREPARED BY

JUNE 1983

**USA INDUSTRIAL BASE ENGINEERING
ACTIVITY**

**MANUFACTURING TECHNOLOGY DIVISION
ROCK ISLAND, ILLINOIS 61299**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains summaries of 90 projects that were completed under the Army's Manufacturing Methods and Technology (MMT) Program. The MMT program was established to upgrade manufacturing facilities used for the production of Army Materiel. The summaries highlight the accomplishments and benefits of the projects and the implementation actions underway or planned. Points of contact are also provided for those who are interested in obtaining additional information.		



DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299

REPLY TO
ATTENTION OF:

DRXIB

8 July 1983

SUBJECT: Manufacturing Methods and Technology Program Project Summary
Report (RCS DRCMT-302)

SEE DISTRIBUTION (Appendix II to Enclosure 1)

1. In compliance with AR 700-90, dated 15 March 1982, the Industrial Base Engineering Activity (IBEA) has prepared the enclosed Project Summary Report.
2. This Project Summary Report is a compilation of MMT Summary Reports prepared by IBEA based on information submitted by DARCOM major subordinate commands and project managers. These projects represent a cross section of the type of efforts that are being conducted under the Army's Manufacturing Methods and Technology Program. Persons who are interested in the details of a project should contact the project officer indicated at the conclusion of each individual report.
3. Additional copies of this report may be obtained by written request to the Defense Technical Information Center, ATTN: TSR-1, Cameron Station, Alexandria, VA 22314.

1 Encl
as

JAMES W. CARSTENS
Chief

Manufacturing Technology Division

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INTRODUCTION

Background

The Manufacturing Methods and Technology (MMT) Program was established to upgrade manufacturing facilities used for the production of Army materiel, and as such, provides direct support to the Industrial Preparedness Program. The Manufacturing Methods and Technology Program consists of projects which provide engineering effort for the establishment of manufacturing processes, techniques, and equipment by the Government or private industry to provide for timely, reliable, economical, and high-quality quantity production means. The projects are intended to bridge the gap between demonstrated feasibility and full-scale production. The projects are normally broad based in application, are production oriented, and are expected to result in a practical process for production. The projects do not normally include the application of existing processes, techniques, or equipment to the manufacture of specific systems, components, or end items, nor do they apply to a specific weapon system development or a product improvement program.

MMT Program Participation

MMT Programs are prepared annually by DARCOM major subordinate commands. These programs strive for the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs.

Project proposals (Exhibits P-16) are submitted to the appropriate MMT Program Office. A list of offices is provided in Appendix I. Additional information concerning participation in the MMT Program can be obtained by contacting an office listed or by contacting Mr. James Carstens, AUTOVON 793-5113, or Commercial (309) 794-5113, Industrial Base Engineering Activity, Rock Island, IL 61299.

In anticipation of the lengthy DOD funding cycles, projects must be submitted in sufficient time for their review and appraisal prior to the release of funds at the beginning of each fiscal year. Participants in the program must describe manufacturing problems and proposed solutions in Exhibit P-16 formats (see AR 700-90, 15 march 1982, for instructions). Project manager offices should submit their proposals to the command that will have mission responsibility for the end item that is being developed.

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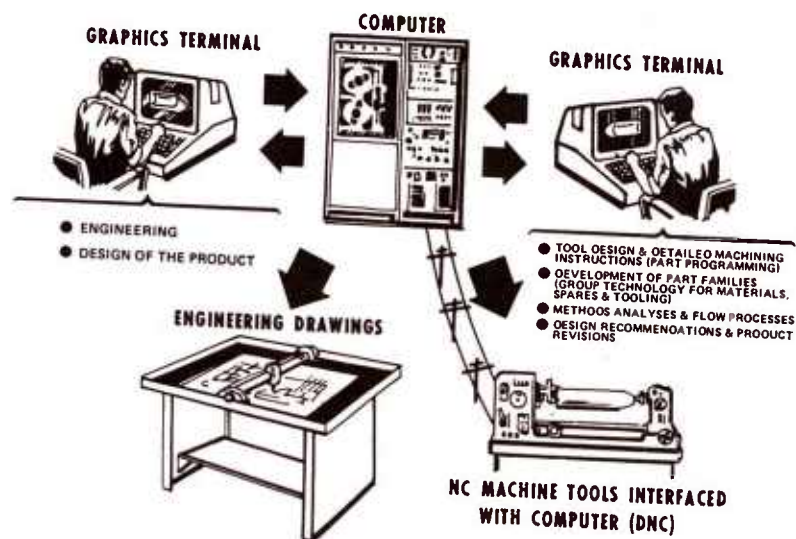
This report contains summaries of 90 completed projects that were funded by the MMT Program. The summaries are prepared from Project Status Reports (RCS DRCMT-301) and Final Technical Reports submitted by organizations executing the MMT projects. The summaries highlight the accomplishments and

benefits of the projects and the implementation actions under way or planned. Points of contact are also provided for those interested in obtaining additional information.

The MMT Program addresses the entire breadth of the Army production base and, therefore, involves many technical areas. For ease of referral, the project summaries are grouped into six technical areas. The technical areas are: CAD/CAM, Electronics, Inspection and Test, Metals, Munitions, and Non-Metals. A page of abstracts leads off each of these groups. Abstracts were prepared to highlight projects which achieved significant accomplishments.

The Summary Reports are prepared and published for the Directorate for Manufacturing Technology, DARCOM, by the Manufacturing Technology Division of the US Army Industrial Base Engineering Activity (IBEA) in compliance with AR 700-90. The report was compiled and edited by Mr. Andrew Kource, Jr. and ably assisted by Ms. Eileen Griffing and Ms. Sally Weckel with the typing and graphics arrangements.

COMPUTER AIDED DESIGN/ COMPUTER AIDED MANUFACTURING (CAD/CAM)



INFORMATIONAL FLOW IN A COMPUTER SYSTEM

ABSTRACTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
380 1071	Hybrid Integrated Computer Aided Design and Manufacturing (HICADAM)	C-2
<p>Hybrid microcircuits possess advantages in weight, volume, performance, power, and reliability but are difficult to design and build economically. This effort researched factors such as computer-aided layout, materials handling, manufacturing processes, and testing procedures and incorporated the information in Battelle's Electronics Computer Aided Manufacturing (ECAM) program. A hybrid circuit computer aided design system was installed at Hughes but cannot be tied to manufacturing without further development.</p>		
R81 1201	Computerized Production Process Planning for Cylindrical Parts	C-8
<p>Computerized production process planning (CPPP) offers a feasible alternative to the highly subjective process plans for machined cylindrical parts typically formulated manually. Computer Managed Process Planning (CMPP), a CPPP system, was upgraded to a production system and implemented at Pratt-Whitney, Sikorsky Aircraft and Hamilton Standard. CMPP will produce standard, consistent, efficient process plans at a reduced cost.</p>		
T78 5014	Improved Foundry Casting Processes Utilizing Computer Aided Flow and Thermal Analysis (CAD/CAM)	C-11
<p>The objective of the effort was to simulate the casting process and to produce a high quality and lower cost casting. The simulation technique used fluid flow and thermal analysis of molten metals and models of the mold pattern design. The CAD/CAM casting process was designed to be used either on a time-share basis or in a dedicated mode for a foundry computer system.</p>		
681 8120	Adaptive Control Technology (CAM)	C-14
<p>Cylindrical grinding, such as that used on large caliber cannon recoil slide surfaces, is inherently slow, requires a highly skilled operator, and is not quantitatively predictable. This project evaluated a patented control process called Energy Adaptive Grinding (EAG). EAG reduces specific energy by controlling power, wheel velocity, metal removal rate, heat, and grinding time. Results were very favorable and will be implemented in a follow-on effort.</p>		

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 3 80 1071 titled, "Hybrid Integrated Computer Aided Design and Manufacturing (HICADAM)", was completed by the US Army Missile Command in March 1982 at a cost of \$100,000.

BACKGROUND

The design and manufacture of hybrid microcircuits requires the integration of a number of skills including circuit design, circuit modeling, thermal analysis, parts selection, circuit routing, substrate screening and firing, component placement, circuit testing, packaging, burn-in, leak testing and final electrical testing. While hybrid circuits enjoy advantages in weight, volume, performance, power and reliability, they must be designed and built intelligently and economically to realize these advantages. Many of the skills named above can be enhanced through interaction of the designer and producer with a computer data base.

SUMMARY

An analysis of all design and manufacturing steps revealed areas where computer aided layout and process control could reduce hybrid circuit cost. Advancements were identified in computer-aided layout, materials handling, manufacturing processes, and testing procedures. When all these are synergistically combined into a computer integrated manufacturing system, a quantum improvement could result. But first, a common data base for design, manufacture and test is needed to make the three operations controllable from a single computerized system (see Figure 1). Also, a common data base employing the ICAM (Integrated Computer Aided Manufacturing) format would make the technology transferrable between firms.

The data base is controlled by a specification which insures its effectiveness as a design tool and its adequacy for manufacturing tasks. It can include logic, electrical, physical and management data.

Hughes Aircraft Company, Tucson Manufacturing Division, contracted to perform the analysis and describe a design/manufacturing capability. Hughes first surveyed hybrid specialty houses and systems manufacturers having hybrid circuit production capability. The survey asked firms how they designed and built hybrid circuits, what functions were computerized and how they related to the whole. Results of the survey are summarized in the Final Report.

HICADAM

HYBRID INTEGRATED COMPUTER AIDED DESIGN AND MANUFACTURING



Figure 1 - HICADAM Data Base

BENEFITS

The planning and data organization done in this HICADAM project were applied to the Electronics Computer Aided Manufacturing (ECAM) program by Battelle. Two years of investigation by Hughes were directly usable in the ECAM program since Hughes employed ICAM methodology and IDEF definitions worked out earlier as universal methodology.

A secondary benefit of the contract was a summary of additional MMT projects which may be needed before HICADAM can proceed. They include work in the following areas: hybrid data base specification, physical communications interface, automated parts identification, automated material handling system, component placement and routing, thick film ink characterization, micro-bridge production technology, semi-automatic probe screening system, automated camera and test probe system, automated substrate inspection.

IMPLEMENTATION

A hybrid circuit computer aided design system based on Computervision hardware and software is in place at Hughes Aircraft Co., Tucson, Arizona. But it cannot be tied to manufacturing process controls until several of the projects identified in the future mantech area are performed. The survey made as part of this contract showed that five firms have turnkey systems for computer aided design and four for computer aided manufacture of hybrid circuits.

The results of this analysis of hybrid circuit CAD/CAM were applied to the Electronics CAM Study being performed by Battelle's Columbus Laboratories.

MORE INFORMATION

The contract number for this project is DAAH01-81-D-A002/006. The Final Technical Report is titled, "Hybrid Integrated Computer Aided Design and Manufacturing" dated 19 Oct 81. The authors were Dean A. Keller and Rowland D. Conley. Mr. Gordon Little was project officer at US Army Missile Command, Huntsville, AL 35809, AUTOVON 746-3604 or Commercial (205) 876-3604.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 3 80 1075 titled "Electronics Computer Aided Manufacturing (ECAM)" was completed by the US Army Missile Command in March 1982 at a cost of \$300,000. This is the first year of a five-year effort.

BACKGROUND

Many firms producing electronic equipment for the Department of Defense have computer aided design systems which help them in the layout of components such as printed circuits, hybrid circuits, integrated circuits, panels, chasses, and cables. But most of these computerized methods are independent of each other, are written in different languages, and run on different computers. A few firms have developed interfaces on a sketchy basis, but are not tied in with manufacturing, inspection, or management information systems. What was needed was a top-down approach linking several systems into a computer-aided-design and computer-aided-manufacturing system operable within an architecture (framework) common to many firms in this arena. A Master Plan was to be generated to describe computer software requirements and identify developments needed to fill the gaps in technology and equipment.

SUMMARY

At the request of the US Army Materiel Development and Readiness Command and with Air Force and Navy funding, the US Army Missile Command wrote a "Technical Requirement" and ran a competitive runoff. The Command then entered into a contract with Battelle Columbus Laboratories to perform an investigation and define the scope of the problem, determine what DoD projects were already surveying the area, and develop an architecture for a generalized computer controlled system for the manufacture of electronic items mentioned above. Battelle was to evolve a Master Plan of actions to be taken, identify software needs, establish an architecture (diagram) of "As Is" and "To Be" factory models, and develop descriptions of additional tasks required.

Battelle established a prime/consortium coalition as called for in the contract, and using the Air Force Integrated Computer Aided Manufacturing (ICAM) methodology, evolved an architecture of electronics manufacture. The accompanying chart, Figure 1, lists the coalition members and their area of expertise. Each firm developed information and monitored several commodity areas. The main products of the commodity groups were process diagrams which describe "As Is" factory arrangements and other diagrams which show "To Be" factory arrangements.

	INTEGRATION	ADVISORY	PANELS, COVERS	CABLE & HARNESS	PRINTED WIRING BOARD	I.C.	HYBRID	WIRE-WOUND	ASSEMBLIES
AULT								•	
BOEING	•	•		x	•				•
COLLEGE CAD/CAM	•								
COMPUTERVISION	•								
GD	•			x				x	
GE	•								
HONEYWELL	•	•	•						x
HUGHES	•	•	•	•	x	x	x	•	•
IBM	•	•	•	•	•	•	•	•	•
MAGNAVOX	•	•					•	•	•
MCDONNELL DOUGLAS	•	•	•			•	•		•
MEC						•	•		
RCA	•	•	•	•					
ROCKWELL	•	•	x		•		•	•	•

• - INDICATES PARTICIPATION
 X - INDICATES TECHNICAL LEADERSHIP

Figure 1 - Activity Areas of Coalition Members

In Task 1 Battelle held meetings for each of the commodities and selected a chairman, defined the scope of interest for the group, assessed the degree to which ICAM dealt with the subject, reviewed related MMT projects and costs, identified technologies to be considered, reviewed ICAM architecture for relevance to this commodity, and prepared group plans using IDEF methodology.

Task 2 consisted of analyzing the current state of the art for each commodity and developing an "As Is" architecture. See Figure 2. It also included an analysis of new developments such as automation, group technology, improvements to manufacturing, and intelligent machines, etc. This led to the generation of "To Be" architectures for each commodity.

To accomplish the first half of Task 2, the commodity groups met and discussed current methods of manufacture at the plants represented by the members. They then consolidated these methods into a unified approach that was satisfactory to each member. Battelle staff then took the results from each group and with a top down approach consolidated the views into a composite "As Is" architecture for electronic manufacture.

Following each group's analysis of new methods and technologies, members generated "To Be" architecture for each commodity. They also developed a "factory view" which included design, manufacture, support and test of each commodity. This satisfied the second half of the Task 2 requirement.

Battelle staff then consolidated the results of these seven diagrams into a top down description of "To Be" architecture for all electronics manufacture. Battelle also developed and applied a productivity measure to each commodity's "As Is" and "To Be" architecture. The integration group identified support and integration functions that tie the commodities together.

Task 3 consisted of development of "To Be" factory descriptions and Master Plan lists of projects needed to realize the future factory. During the next phase this will result in thrust area roadmaps, project descriptions, and an explanation of project relationships.

To further develop the Master Plan and project list, the participants will identify the research programs, development projects and factory-floor demos needed to attain the future factory goal.

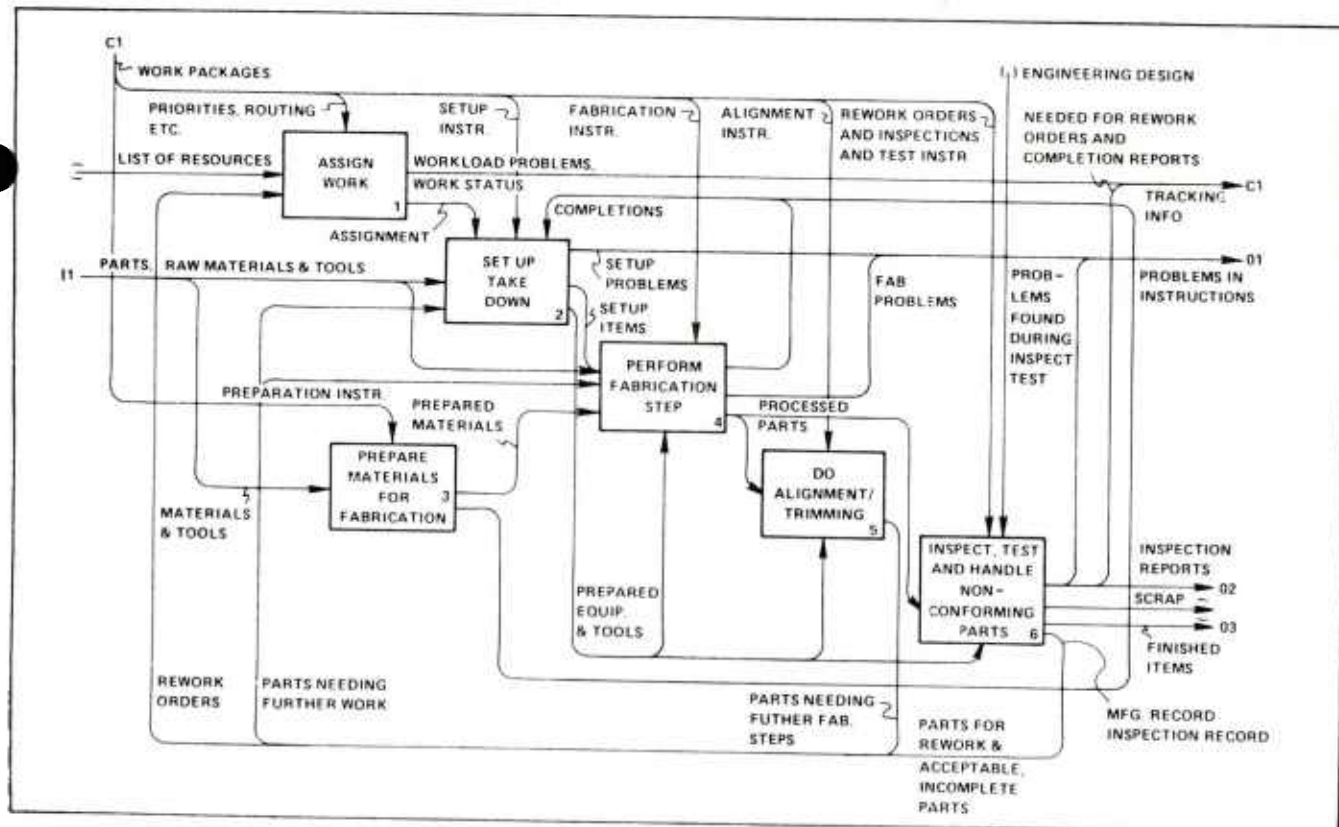


Figure 2 - Assemble Component Parts

Task 4 consists of preparing the Master Plan, a movie and slide presentation describing it, and a final report. In addition to identifying the projects, the teams and integration group will determine who will sponsor each project, write its description, and say when it should be funded. The Plan will also prioritize the projects, assess their technical feasibility, risk, and return on investment, estimate their cost, describe technology transfer, and plan implementation.

BENEFITS

The main product of the ECAM contract will be the Master Plan described above which will be available at completion of the FY 81 portion of the contract. It will contain the final prioritized project descriptions including objective, technical scope, estimated cost, duration, and expected benefits. The Plan will also include projects proposed by firms, universities, Electronic Industries Association, and CAM International.

MORE INFORMATION

Additional information may be obtained from Mr. Gordon Little, US Army Missile Command, DRSMI-RST, Huntsville, AL, 35898, AUTOVON 786-3604 or Commercial (205) 876-3604 or Dr. Alfred C. Robinson or Mr. Carl R. Soltesz, Battelle Columbus Labs, 505 King Avenue, Columbus, OH, 43201, Commercial (614) 424-5105. The contract was number DAAH01-81-A015-0001; Technical Report Number RS-R-82-1.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 81 1021 titled "Computerized Production Process Planning for Cylindrical Parts" was completed by the US Army Missile Command in September 1982 at a cost of \$233,750.

BACKGROUND

Machined cylindrical metal components are significant cost drivers in missile systems. Underlying the cost of these components are the process plans that detail how the parts are manufactured. These process plans are subjectively formulated and dependent upon the skill and expertise of the process planner.

Computerized production process planning (CPPP) offers an opportunity to overcome the shortfalls of manual procedures. Under previous MMT programs the desirability and feasibility of a CPPP system named Computer Managed Process Planning (CMPP) was demonstrated.

SUMMARY

The objectives of this project were to (1) upgrade the pilot CMPP system to a production system providing detailed documentation along with production oriented software; and (2) transfer the technology to industry.

The CMPP system is the product of ten years of development. Computer science and manufacturing engineering have been combined to form a unique system capable of generating process planning of high technology machined parts. A functional view of CMPP is provided at Figure 1; a typical part is depicted at Figure 2.

CMPP is manufacturer-independent; that is, it is designed to apply to a broad spectrum of manufacturers. The system performs three major functions: (1) it provides for constructing and maintenance of its data files, (2) computer models of cylindrical parts are constructed for use in process planning, and (3) process planning is performed. CMPP is written in Fortran and is currently implemented as a stand alone system.

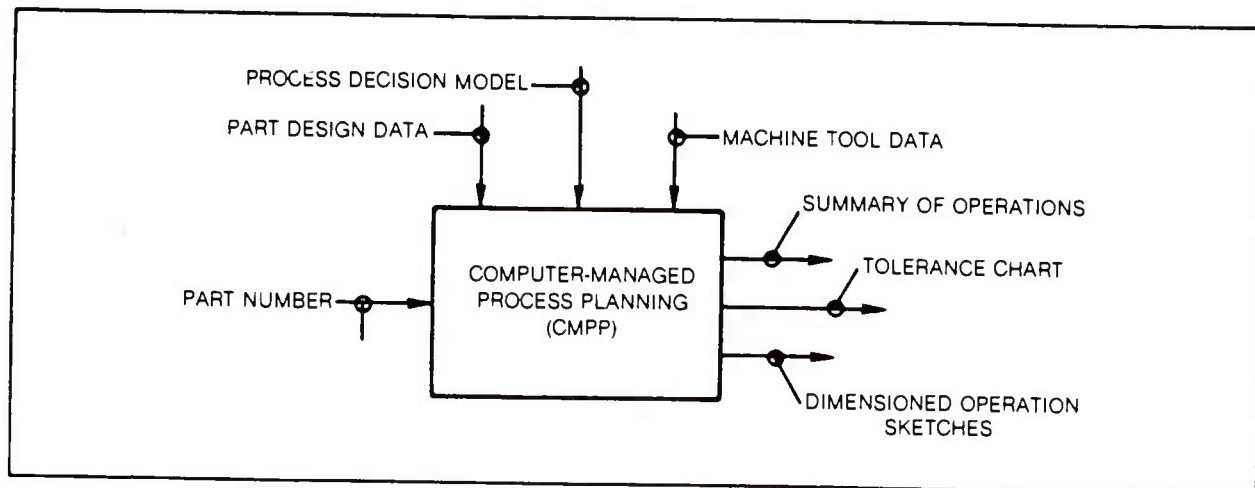


Figure 1 - Functional View of CMPP

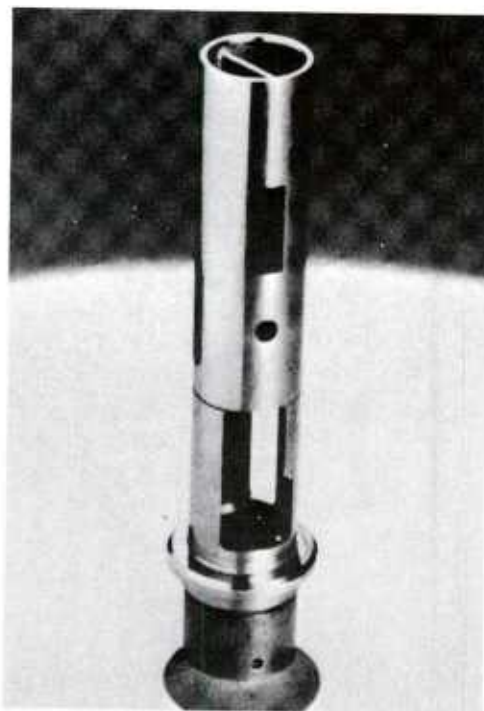


Figure 2 - CMPP Addresses Precision Cylindrical Machined Parts

BENEFITS

The CMPP system will:

- a. Reduce the "art" intrinsic to process planning to more of a "science."
- b. Produce standard consistent process plans.
- c. Reduce the cost of process plans.
- d. Improve the efficiency of process planning.

IMPLEMENTATION

The CMPP system has been partially implemented at three divisions within United Technologies Corporation; Pratt-Whitney, Sikorsky Aircraft, and Hamilton Standard. The system has also been applied on two military aircraft engines and on components used on the blackhawk helicopter, Navy lamp helicopter, CH53E helicopter, and F-16 and A-10 aircraft. Technical reports fully describing the CPPP concept and the CMPP software were prepared. A number of presentations and an end of contract demonstration were held.

MORE INFORMATION

Additional information can be obtained from Mr. Bobby Austin, US Army Missile Command, AUTOVON 746-2147 or Commercial (205) 876-2147. A motion film and slide presentation are available.

Summary report was prepared by James Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects T 78 5014 and T 81 5014 titled "Improved Foundry Casting Processes Utilizing Computer Aided Flow and Thermal Analysis (CAD/CAM)," were completed by the US Army Tank-Automotive Command in January 1983 at a cost of \$415,000 and \$50,000 respectively.

BACKGROUND

The casting process is wasteful of raw materials and energy. Less than 50% of the melted material is utilized in the end item cast configuration. The inefficiency of the process control results in a cost penalty to the casting, since the scrap and waste are charged to the individual casting. Prior industrial effort had centered on R&D studies to simulate heat flow and cooling curves using the finite difference method (FDM). A prior MMT Project T 77 5014 resulted in computer aided design techniques with a number of computer software procedures. The finite element method (FEM) was used to establish a model of the casting process for simple configurations. Samples were fabricated to evaluate predicted characteristics from these computer procedures.

The project was undertaken to extend prior MMT results to relatively complex parts for the advanced fluid flow and thermal analysis techniques.

SUMMARY

The objective of the effort was to simulate the casting process and to produce a high quality and lower cost casting. The simulation technique used fluid flow and thermal analysis of molten metals and models of the mold pattern design. A system of programs, UPCAST, was established by the prior MMT project. UPCAST provides for interactive design of a mold, for analysis with heat flow, and fluid flow techniques. Casting soundness can be predicted by using heat transfer plots and solidification maps.

The approach used on these two projects was to:

- (1) Utilize UPCAST for mold design.
- (2) Cast test plates and torsion bar housings at two production foundries, with thermocouple instrumentation on selected castings.
- (3) Improve and expand the computer programs for UPCAST.

A planned follow-on effort will extend or improve the operation of the computer programs and procedures. Casting soundness criteria will be determined from the analysis of data from castings for test plates and torsion bar housings.

Computer procedures for the casting solidification process have been completed for the no-bake sand process. Substantial effort was expended to improve the generality of the computer procedures. The FDM procedures were established for heat transfer analysis. The FDM procedures compliment the FEM procedures established by the prior MMT effort. Mesh generators were established for use with each method.

Eight stepped plate castings and one-hundred torsion bar housing castings were fabricated at the Blaw-Knox foundry in East Chicago, Indiana, with the no-bake sand process. Five different mold configurations were used. Six of the housing molds were instrumented with thermocouples at 18 locations, in order to obtain empirical cooling rate data. The casting pattern and the instrumentation of the stepped plate castings are illustrated in Figure 1.

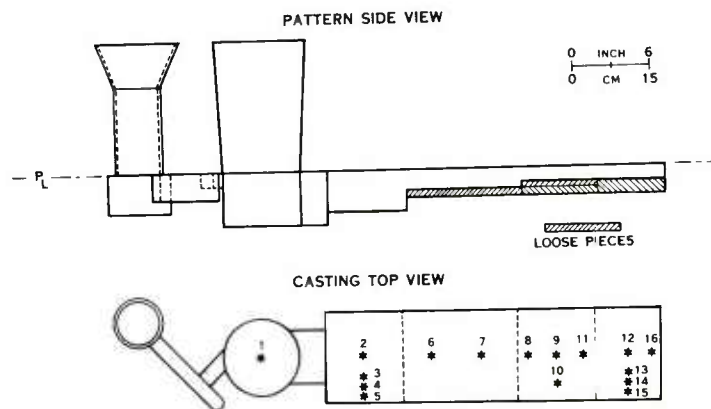


Figure 1 - Test Plate Pattern

Test plate castings and eight torsion bar housing castings were fabricated at the Lebanon Steel foundry in Lebanon, Pennsylvania, with the green sand process. Two of the housing molds were also instrumented with thermocouples at 18 locations.

The torsion bar housing castings were for the ABRAMS (M1) Tank and met all acceptance criteria.

BENEFITS

The anticipated benefits from this project are improved foundry castings. The tangible benefits will be (1) reduced scrap losses, due to better material utilization, (2) high quality castings, due to improved mold design. Intangible benefits will be (1) the foundry engineer does not require extensive programming experience to exercise the system, (2) some of the "black art" of pattern making will be reduced to documented computer algorithms and procedures.

IMPLEMENTATION

The CAD/CAM casting process is designed to be used either on a time-share basis or in a dedicated mode for a foundry computer system. Additional planned effort continues on MMT Project 4 82 5014. Preliminary results from this project are under evaluation for use at the foundries of Lebanon Steel, Blaw-Knox Mill Machinery, Deere & Company, Sivyer Steel, and Rock Island Arsenal.

MORE INFORMATION

Additional information on this effort is available from the project officer, Mr. Mike Holly, TACOM, DRSTA-RCKM, AUTOVON 786-6467 or Commercial (313) 574-5814.

Summary report was prepared by Steve McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 6 81 8120 titled "Adaptive Control Technology (CAM)" was completed by the US Army Armament Material Readiness Command in September 1982 at a cost of \$60,000.

BACKGROUND

Large caliber cannons require close machined tolerances on recoil slide surfaces. The only practical means of machining these surfaces is by cylindrical grinding which is inherently slow. Cylindrical grinding also requires a highly skilled operator to meet geometry and quality requirements while controlling process variables, wheel wear, metal removal rate, safety, heat, and metallurgical properties.

Inasmuch as the grinding process is an art rather than a science, it so far has defied efforts at quantitative "predictability." Therefore, the solution to the user problem of specifying the best process variables is not one that can be arrived at using handbook factors and calculations. Instead, the user determines grinding feed and speed standards empirically.

SUMMARY

The objective of this project was to reduce the art intrinsic to the grinding process to more of a science, and apply the results to gun tube recoil surfaces. An engineering evaluation was conducted relative to the application of a patented adaptive control process called Energy Adaptive Grinding (EAG) (also known as cold grinding). The EAG process controls power, wheel velocity, metal removal rate, heat, and grinding time automatically (see Table 1). This technique brings all the important grinding parameters under control eliminating the post process adaptive control currently performed by highly skilled operators of conventional CNC grinders.

The principle underlying this control theory is based on minimizing the power required to remove a unit volume of material. This is accomplished by measuring and controlling specific energy (SE):

$$\text{Specific Energy} = \frac{\text{Horsepower used}}{\text{Volume of metal removed per unit time.}}$$

CONVENTIONAL VERSUS COLD GRINDING PARAMETERS

Parameters	Grinding Method	
	CNC Convantional	Cold Grinding
Wheel RPM	Fixed	Changing
Wheel Wear Rate	Uncontrolled	Controlled
Wheel Surface Velocity	Uncontrolled	Controlled
Feedrate	Variable	Changing
Work RPM	Variable	Changing
Work Surface Velocity	Uncontrolled	Controlled
Metal Removal Rate	Uncontrolled	Controlled
Power Used	Uncontrolled	Controlled
Grinding Heat	Uncontrolled	Controlled
Grinding Time	Uncontrolled	Controlled
Truing Roll RPM	Uncontrolled	Controlled
Truing Feed Rate	Fixed	Changing
Relative Wheel Truing Velocity	Variable	Changing
	Uncontrolled	Controlled

Legend: FIXED (generally characteristic of machine)
VARIABLE (but fixed during grinding)
UNCONTROLLED (during grinding)
CONTROLLED (continously during grinding)
CHANGING (continously during grinding:
controlled indirectly)

Table 1.

Once SE is under control, the allocation of power in grinding can be controlled, sometimes increasing productivity over ten times (see Table 2).

DIVISION OF POWER IN GRINDING			
	Specific Energy	Haat (Parcantage)	Matel Ramovel (Percentage)
Conventional grinding varies uncontrollably over a range between:	40	96	4
	35	95	5
	30	94	6
	25	92.5	7.5
	20	90.5	9.5
	15	87.5	12.5
	10	81	19
Cold grinding is controlled at selectable values between:	8	76	24
	6	68	32
	4	53	47
	3	36	64
	2.5	24	76
	2	4	96

Table 2.

IMPLEMENTATION

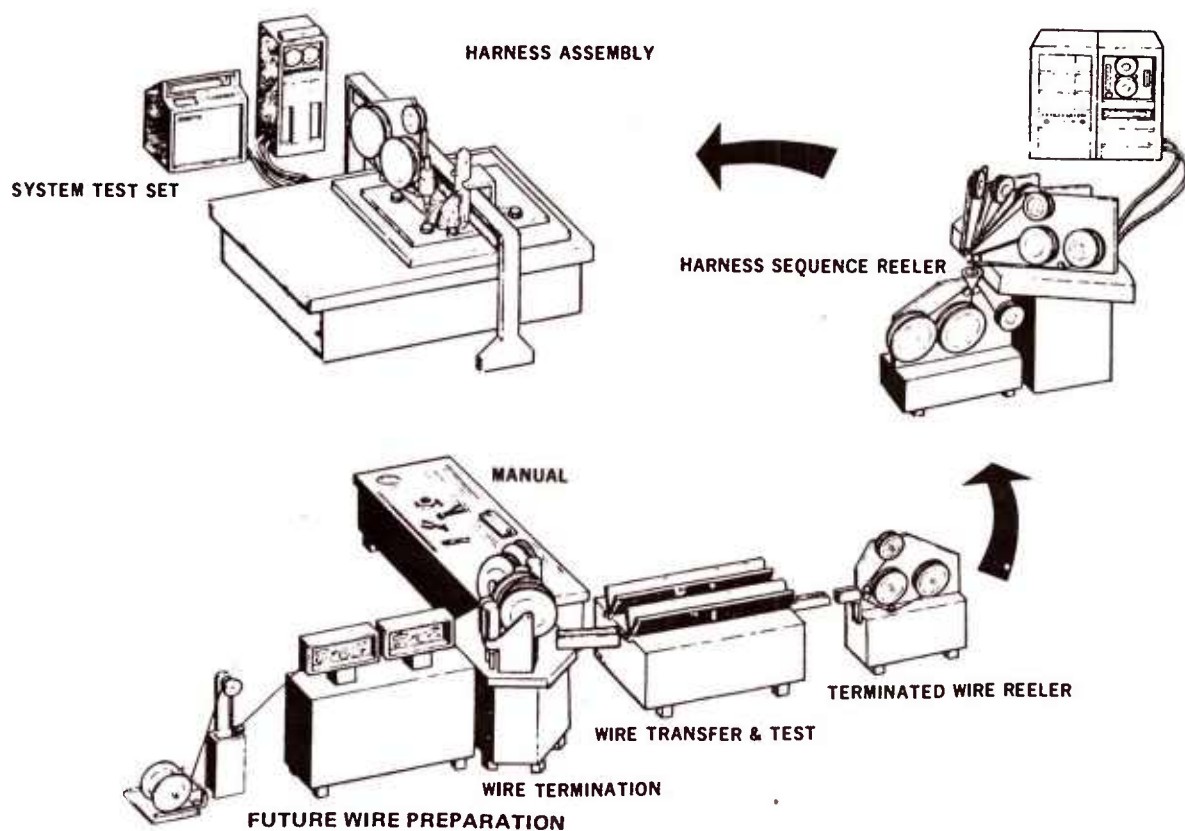
Results of the evaluation were very favorable and indicated that the EAG process should be used. A follow-on project is underway to implement the technology.

ADDITIONAL INFORMATION

Additional information is available from Mr. Gary Conlon, Watervliet Arsenal, AUTOVON 974-5737 or Commercial (518) 266-5737.

Summary report was prepared by James Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

ELECTRONICS



CONCEPTUAL APPROACH TO FIXING
ELECTRICAL CONNECTORS TO CABLES

ABSTRACTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
578 3907	Metal Nitride Oxide Semiconductor (MNOS) Timer Circuit for Electronic Time Fuzes	E-7

This project attempted to transfer less expensive civilian techniques to the manufacture of MNOS chips used in a military environment. Plastic packaging and the use of glassivation instead of nitride passivation were investigated with favorable results. The counter/memory and scalar/logic integrated circuits manufactured, packaged and tested on this contract will be used in the XM445 ET fuze for the Multiple Launch Rocket System.

880 0915	Group Technology Requirements Definitions, Electronics	E-11
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This project determined the fundamental characteristics of a Group Technology Electronics Classification and Coding System (ECACS). Although CC/GT systems have been very successfully oriented toward machined parts, none are available for electronics. Electronics manufacturers were surveyed to determine electronics areas suitable for inclusion in ECACS, and also advantages resulting from its use. Fundamental characteristics and a procurement specification have been developed for a GT/ECACS.

H80 5094	MMT for 8K Bit BORAM	E-13
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This project developed an 8 kilobit Block Oriented Random Access Memory (BORAM) device for data recording and signal processing. Chips were arranged in parallel for faster data rates, and improvements were made in nitride deposition and photoimaging. BORAM units are now used in the Marine Integrated Fire and Support System and the Air Force F16 Advanced Airborne Radar. FAA testing is underway for use in the Accident Information Retrieval System since the unit retains data when the power is off.

H77 9792

Production of Low Noise Figure Ion Barrier
Microchannel Plates (LNF/MCPs)

E-19

This effort solved several problems previously associated with image intensifier tube components for the aviator's night vision imaging system and night vision glasses. These included funneling input channel openings to reduce noise, reducing channel spacing for increased resolution, and applying an ion barrier film over the input channels for longer life. Improved microchannel plates are used in the AN/AVS-6 Aviator's Night Vision Imaging System and were made available to manufacturers for study and comparison.

R79 1041

Large Scale Integration Fabrication
Methodology Improvement

E-22

Acceptable custom integrated circuits needed for various projectile guidance systems had a final acceptance rate of 1-2 percent of total output. Topology modification, process modification, producibility and yield improvement, test method automation, and documentation were studied. Process control iterations and topology changes increased yield from 2% to 16% and improved test methods resulted in a 40% cost reduction on circuits for the Copperhead, Hellfire and Navy Guided Projectile programs.

R79 3372

Manufacturing Methods for Magnetic
Components

E-28

This effort investigated methods for lowering the cost and improving the reliability of manufactured miniature electromagnetic components for missile applications. Several efficient procedures resulted including liquid injection molding and "C" core bond welding techniques. The importance of protecting the wire from damage during storage and maintaining reduced voltage gradients was recognized. Various developed techniques were implemented in-house at Hughes Aircraft.

R80 3411

Manufacture of Non-Planar Printed Circuit
Boards

E-31

Non-planar printed circuit boards are an alternative to complex and expensive interconnected small circuit boards currently used in applications such as missiles. A spiral antenna accurate to 1/100 of a wavelength and a cylindrical circuit board were produced. The board was composed of flat, flexible layers held in place by a cast adhesive, and passed rigorous environmental and electrical tests. Pilot capability and equipment designs will be provided by a second year effort.

R80 3436

Development of Ceramic Circuit Boards and
Large Area Hybrids

E-33

Large scale hybrid microcircuits solve performance, packing density, and interconnect problems for military circuits, although they had undeveloped production processes and thus were extremely expensive. Ceramic substrate mounting procedures, new soldering compounds and procedures, and passivation layer deposition techniques were developed resulting in low non-recurring cost, controllable yields, and increased reliability.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 2 76 9771 titled, "MMT - Low Temperature Processing of Bulk Semiconductor Switches and Limiters," was completed by the US Army Electronics Research and Development Command in July 1979 at a cost of \$380,000.

BACKGROUND

High frequency microwave signal generators and modulators require high quality semiconductor switches and detectors in their input circuitry. These diodes can be manufactured only on high purity silicon and with newer processes that use lower than normal temperatures; 1000°C rather than 1300°C. High purity silicon can only be grown using purest starting material and accurately controlled growing and refining processes.

SUMMARY

Microwave Associates, now MACOM Inc., Burlington, MA, contracted with ERADCOM to perform the manufacturing technology development following several years of R&D at Rensselaer Polytechnic Institute. Contract work resulted in the standardization of processes and tolerances for producing high power bulk semiconductor limiter modules for use at X-band frequencies (8-12 GHz). Limiter modules were built that blocked the passage of a full 20 kilowatts of spike power; a PIN diode does the main limiting job, a low power varactor does clean-up isolation, and a detector diode biases on both the limiter and clean-up diodes. See Figure 1. Processes for manufacturing the bulk limiter diode are as described on the following page.

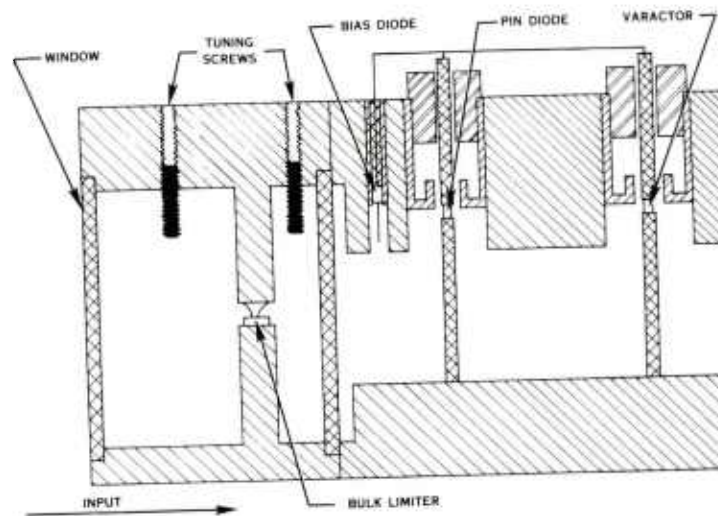


Figure 1 - Bulk Diode Limiter Cross Section

First, high resistivity silicon wafers are thinned to three mils by polishing and etching. The wafers are then phosphorous diffused at 1000°C for 30 minutes using a phosphorous chloride source. The phosphorous doped glass on the wafer is next etched in hydrofluoric acid and then 1000 Angstroms of silicon dioxide glass is grown on at 1000°C.

Both surfaces of the wafer are then photoprocessed to transfer a 0.75 mil checkerboard pattern of windows onto the wafer which are etched through the silicon dioxide and phosphorous doped silicon layers using buffered hydrofluoric acid. Next, boron is diffused into the window areas at 950°C for 20 minutes using a boron nitride source. The wafers are again etched in hydrofluoric acid to remove the glass from their surfaces.

Both surfaces are then metallized with 500 Angstroms of titanium-tungsten (10%-90%) alloy and 2000-3000 Angstroms of gold. One surface is then plated to 0.1 mil of gold and the other to 4 mils. The wafers are saw-cut into 40 mil squares and separated into chips. The chips are diffusion bonded to a gold wire, dipped into silicon etchant to form a mesa, and passivated with silicon nitride. They are then mounted in copper irises and tested for low and high level RF performance. This entire sequence of operations is outlined in Table 1.

Each bulk limiting diode is thereafter mounted in a module along with three different diodes as shown in Figure 1. Two tuning screws permit adjustment for broadband performance.

<u>OPERATION</u>	<u>PRODUCTION EQUIPMENT</u>	<u>RATE UNITS PER 8 HOURS</u>	<u>YIELD</u>	<u>FINISHED OUTPUT (100 Starts)</u>	<u>STATIONS</u>	<u>CONTROLS</u>
1.01 - Slice Silicon Ingot	Dual Micromatic	200 Wafers	95%	95	1	Micrometer - Thickness
1.02 - Polish Wafer	M/A Polisher	100 Wafers	95%	90	1	Standard Wafer
1.03 - Etch Wafer	Fisher Flood	1000 Wafers	95%	81	1	Visual
1.04 - Check Wafer Thkn	Dual Micromatic	1000 Wafers	95%	77	1	Micrometer - Thickness
1.05 - Phosphor Diffusion	M/A Diffusion Furnace	100 Wafers	95%	73	1	4 Point Probe - Resistivity
1.06 - Silane (SiO ₂)	CVD Reactor	100 Wafers	95%	69	1	Sloan Thickness Monitor
1.07 - Open Checker- Board Windows	Dark Room	10 Wafers	80%	55	1	Visual
1.08 - Boron Diffusion	M/A Diffusion Furnace	100 Wafers	95%	52	1	4 Point Probe - Resistivity
1.09 - Annealing	M/A Furnace	50 Wafers	100%	52 Wafers	1	---
1.10 - Metallization (Ti-W-Au)	MRC-900	50 Wafers	80%	48 Wafers	1	Visual
1.11 - Electroplate Gold	M/A Electroplating Bath	20 Wafers	95%	46 Wafers	1	DecTak - Thickness
1.12 - Define Contacts	Dark Room	20 Wafers	95%	43 Wafers	1	---
1.13 - Dicing	M/A Diamond Saw	4 Wafers	80%	160,000 Chips	1	---
1.14 - Electrical Check	Curve Tracer/Boonton	1000 Chips	50%	80,000 Chips	1	---
1.15 - Ball Bonding (5 mil Gold Wire)	M/A Ball Bonder	500 Chips	80%	60,000 Chips	1	Visual
1.16 - Epoxy Junction	Oven	---	90%	54,000 Chips	1	Visual
1.17 - Dice Approval	Curve Tracer/Boonton	500 Chips	90%	46,000 Chips	1	Capacitance & I-V
1.18 - Mounting Chip In Iris	Manual Mounting	200 Chips	60%	27,000	1	Visual
1.19 - Low Power Testing of Bulk Limiter	X-Band Line	500 Chips	20%	5,400	1	Electrical
2.0 - Tuning of Bulk Limiter	Manual	500 Chips	80%	4,300	1	Electrical Meets Spec.

Table I - Bulk Limiter Chip Processing

BENEFITS

The availability of solid state receiver protectors was the chief result of this contract. Previously, gas tube limiters were used and they had short operating lifetimes; cost of replacement gas tubes increased the life-cycle cost of user items and limited their effectiveness.

Before this program was contracted, the cost of a bulk limiting diode averaged \$250. The goal of the contract was a price of \$100 per diode but that was not attained because of the unavailability of large diameter high resistivity silicon. The price of the full limiter module was reduced from \$1,000 in R&D quantities to \$300 in larger buys. Also, the solid state module may replace a gas tube limiter which costs \$200-300 and had an average life of only 300-1000 operating hours. The new solid state limiter module costs more but has an indefinite life for a net savings of hundreds of dollars per installation. While the solid state device was being developed, gas tubes were improved to extend their life from 200-300 hours to 1,000 hours, and this has slowed the adoption of solid state limiters.

IMPLEMENTATION

Limiter modules are being used in the AN/TPN-18 Marine Ground Control Radar front end and are available for use in the AN/TPQ-36 Mortar Locating Radar.

MORE INFORMATION

Additional information on this project is available from Mr. George Morris, ERADCOM, AUTOVON 995-2825 or Commercial (201) 544-2825. The contract was number DAAB07-76-C-0039 and the final technical report is number DELET-TR-76-0039.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 5 78 3907 titled, "Metal Nitride Oxide Semiconductor (MNOS) Timer Circuit for Electronic Time Fuzes," was completed at Harry Diamond Laboratories for the US Army Armament Materiel Readiness Command in June 1982 at a cost of \$300,000.

BACKGROUND

Counter memory circuits used in variable time fuzes were more costly than their non-military counterparts because they did not make effective use of chip area, employed external components that could have been included on the chip, and required a hermetic package. Chips made with this MNOS technique for pocket-size computers are packaged in a plastic package and can be manufactured quite inexpensively. The intent of the project was to transfer these civilian techniques to a military environment.

SUMMARY

The objective of the program was to evaluate the processes, techniques and equipment needed to manufacture a special purpose integrated circuit (IC) used in the M587/M724 and other electronic time fuzes. The circuit must be producible at the rate of 110,000 per month at a cost of \$4 each after the second millionth unit.

Nitron, Inc. of Cupertino, CA, contracted to manufacture counter/memory chips using metal nitride oxide semiconductor (MNOS) techniques; Nitron had performed an R&D contract in this technology and was familiar with the processes. They were also a second source supplier of the counter/memory IC, and had done R&D on a new combination timer IC comprising both the counter/memory and a scaler/logic circuit.

Some of the effort included work on plastic packaging: attaching and wirebonding the chips to lead frames and molding around them in a multicavity mold to form 16-pin dual-in-line plastic packages. The devices then have their leads cut off and bent, and are tested automatically.

Phase II devices were protected with either a simple glassivation coating or a more expensive nitride passivation and were then molded into a package. This comparison of glassivation vs nitride passivation showed that the less expensive glassivation procedure will suffice.

Phase III and IV devices were gold wire bonded and molded into packages at a sub-contractor's facility (Norsk Engineering). The packaging yield on these units after screening test and prior to acceptance test was 84%; 7574 devices were started and 6384 devices passed the packaging test.

Some of the devices were tested for setback by being fired from a gun; results showed the integrity of the plastic packaging method.

BENEFITS

The circuit developed on this project was revised to meet MIL SPEC 38510B requirements by being housed in a hermetic ceramic package. It is used in the XM445 fuze for Multiple Launch Rocket System rounds; Vought Corp. is prime contractor for the missile and HDL is responsible for the fuze. Point of contact on the effort is Mr. Donald Hunter, AUTOVON 290-3710.

The circuit was not used in the XM587 fuze because Army decided not to type-classify that fuze. However, over 5,000 packaged circuits were delivered to HDL for test firing and for use in this and other prototype fuzes.

A methods handbook and final technical report to be delivered on this contract were not prepared because the contractor expended all funds before completion of the handbook and report.

IMPLEMENTATION

The counter/memory and scaler/logic integrated circuits manufactured, packaged and tested on this contract are used in the XM445 ET fuze for the Multiple Launch Rocket System.

MORE INFORMATION

Additional information may be obtained from the project engineer, Mr. Alan Reiter at Harry Diamond Labs, Adelphi, MD 20783, Attn: DELHD-DE-OT, AUTOVON 290-3720 or Commercial (202) 394-3720.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 5 79 3913 titled, "Mechanical Joining of Miniaturized Electrical Components," was completed by the US Army Electronics Research and Development Command, Harry Diamond Laboratories, in September 1980 at a cost of \$89,000.

BACKGROUND

Joining of leads to hybrid and integrated circuits for use in electronic fuzes was thought to require high heat that could cause failure of delicate components or formation of oxide coatings. Laser welding with its precise control and short duration was recommended for experimentation in fine joining to thereby prevent heat damage.

SUMMARY

Shortly after the project was started, its intent was shifted to welding copper foil to copper cups to form ampules which contain sulphuric acid and are used in small batteries. The work was made difficult by the fact that the ampules must be filled with acid before the foil is welded on. This was solved with accurate fixturing to hold the battery cups, to present the cup and diaphragm to the welder, and to move the welded assembly away from the weld area.

Complete batteries consisting of the ampule, plate and container were also welded. However, leaks occurred in these assemblies and this portion was not implemented.

HDL also welded anti-spin tabs to unattended jammer rounds; the tabs were not weldable using standard techniques. Welding schedules including spot size, pulse power density, and duration were worked out for several of these configurations.

A Design Guide was to have been prepared as a deliverable item on this project but the funding was expended before the work was completed. Some of the data for the Guide is available at HDL.

BENEFITS

Anti-spin tabs were welded onto unattended jammer rounds; a welding schedule including pulse power density and duration was standardized. HDL also procured a higher power neodymium YAG laser to supplement its lower power ruby laser.

IMPLEMENTATION

At the present time there is no intention to use laser welding of copper foil covers to copper battery cups because several have leaked.

MORE INFORMATION

Additional information may be obtained from the project engineer, Mr. Robert B. Reams, DELHD-R-CM-ME, Harry Diamond Laboratories, 2800 Powder Mill Road, Adelphi, MD 20783, AUTOVON 290-3010 or Commercial (202) 394-3010.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 8 80 0915 titled "Group Technology Requirements Definitions, Electronics" was completed by the US Army Armament Research and Development Command in December 1982 at a cost of \$60,000 (Tri-Service Program: Army - \$30,000; Navy - \$15,000; Air Force - \$15,000).

BACKGROUND

Classification and Coding/Group Technology (CC/GT) is rapidly becoming recognized as having a major influence on productivity and computer integrated manufacturing. A CC/GT system can be used as a common identifier for accessing integrated and multiple data bases. CC/GT can provide planners an insight into manufacturing requirements currently not available.

Present CC/GT systems have been oriented toward machined parts. As CC/GT moves out of the confines of the machine shop and into the area of electronics manufacture, a classification and coding system specifically designed for electronics must be developed; currently no such coding system exists.

SUMMARY

The objective of this project was to develop a description of the fundamental characteristics of a Group Technology Electronics Classification and Coding System (ECACS) including a procurement specification for configuring an ECACS. In order to identify the information an ECACS should generate, a survey of electronics manufacturers was conducted. Objectives of the survey were:

- Identify those areas, or families, within electronics design and manufacture, which would be candidates for ECACS.
- Identify the possible characteristics of those areas, or families, which would be essential to design and/or manufacture.
- Identify the characteristics of the test and evaluation processes associated with electronics design and manufacture.
- Identify those areas of greatest interest for applications of ECACS.
- Identify primary advantages perceived as the result of using an ECACS.

The survey was conducted via mailed questionnaires and on-site interviews. The data collected was analyzed and an ECACS specification was prepared.

BENEFITS

The fundamental characteristics of a Group Technology Electronics Classification/Coding System have been defined and a procurement specification prepared.

IMPLEMENTATION

A three-part final report was prepared documenting (1) the survey methodology and results, (2) the requirement definition, and (3) the procurement specification.

Recommendations were prepared to the DoD Electronics Computer Aided Manufacturing Program Manager and incorporated into that program.

MORE INFORMATION

Additional information and a copy of the final report is available from Mr. Nathaniel Scott, Jr., US Army Armament Research and Development Command, AUTOVON 880-6945 or Commercial (201) 724-6945.

Summary report was prepared by James Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project H 80 5094 titled, "MMT for 8K Bit BORAM," was completed by the US Army Electronics Research and Development Command, in December 1981 at a cost of \$80,000.

BACKGROUND

A random access memory unit was a good candidate for semiconductor memory application using the Block Oriented Random Access Memory (BORAM). It could be assembled of Metal Nitride Oxide Semiconductor (MNOS) devices in a multichip hybrid package. The project was directed toward establishing manufacturing and testing techniques for the multichip package.

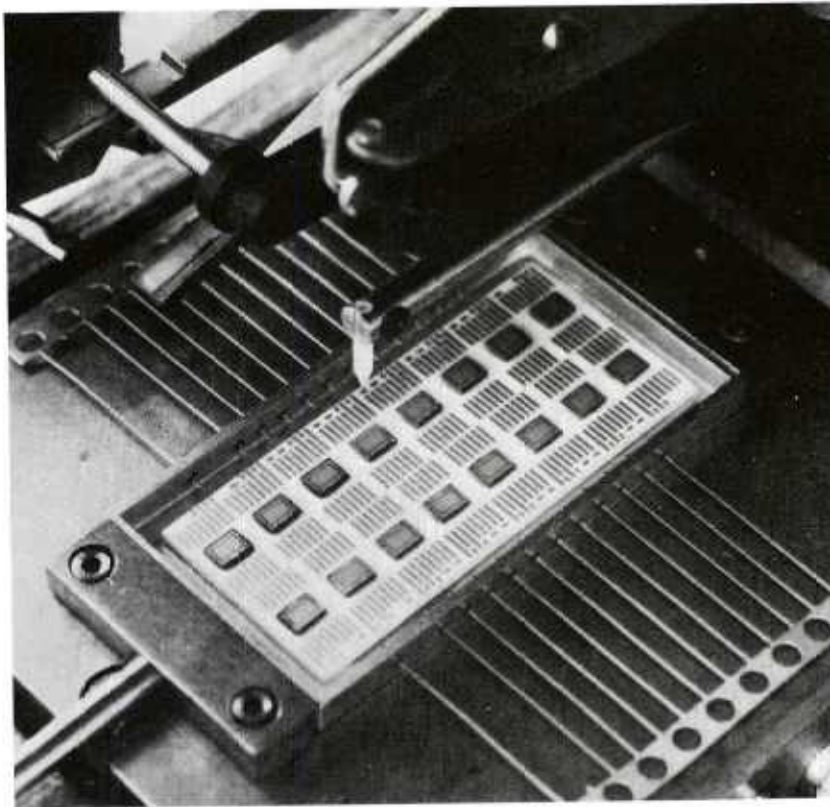
At the time the project was conceived, MNOS 2 Kilobit BORAM devices were no longer cost effective for mass memories and an 8 Kilobit device was needed for data recording and radar signal processing. The performance adequacy and reproducibility of MNOS BORAM devices had to be demonstrated in a military environment. A group of circuit boards containing these packages could replace a magnetic drum or disc in a field environment.

SUMMARY

Westinghouse Systems Development Division, Baltimore, applied MNOS technology to solid state computer secondary storage. Random access memory (RAM) chips built using MNOS technology did not have fast read and write times; to overcome this limitation BORAM chips were arranged to operate in parallel on blocks of data to provide fast data rates. Circuit and process problems were addressed and successive configurations reduced these difficulties.

Improvements were also made in nitride deposition and photoimaging. The thickness of nitride over the tunnel layer affects field stress in the layer and could lead to degradation of memory capability. Effort was expended to produce an adequate nitride layer by using low pressure chemical vapor deposition (LPCVD); run-to-run variability is now only $\pm 3\%$.

Bonding of chips to substrate pads was done by three methods, depending on production volume. Operator-controlled ultrasonic wire bonding using one-mil gold wire sufficed during prototype construction. Computer controlled ultrasonic wire bonding was used during production (see the accompanying figure). Tape carrier bonding proven on a parallel project will be used in future production. Tape mounted chips permit burn-in prior to assembly and are expected to reduce rework and failure rate during burn-in.



MNOS Chips Being Wire Bonded to Ceramic Substrate

Package sealing techniques were changed during the contract from soldering to welding, as soldering introduced splashes into the package causing problems later with solder balls and shorting. Welding was done with a parallel seam welder with almost 100% yield through hermeticity test.

One section of the Final Report details electrical and functional operation of the memory system; it will not be repeated here.

A substantial part of the contract effort went into development of test routines and test equipment for checking first the semiconductors, then the circuit boards, and finally the entire assembly.

BENEFITS

In addition to production engineering the BORAM unit, Westinghouse completed several versions of the memory package: a Marine Corp. secondary memory, an Air Force program storage unit, an Army airborne accident recorder, and a spacecraft recorder. Because the MNOS memory unit retains its data with the power off, it should find wide use in military equipment.

IMPLEMENTATION

BORAM units are now supplied by Westinghouse to Norden Division of United Technology Corp. for use in the Marine Integrated Fire and Support System (MIFASS) as a one megaword Mass Memory Unit and also to the Air Force for memory in the APG-66 Advanced Airborne Radar for the F-16. It is being

considered for program storage in the AN/ALQ-165 Airborne Self-Protection Jammer, and has undergone testing with FAA and Army Aviation Command as part of the Accident Information Retrieval System (AIRS).

During the contract, Westinghouse achieved a production rate of 500 16-chip hybrid circuits per month. This capability is available for manufacture of circuits for the above hardware items and other applications. A data sheet was distributed to military contractors to encourage additional use. A second source was established at Harris Semiconductor, Melbourne, Florida. The contract number was DAAK20-80-C-0259, and was run jointly by Army and Navy. The Navy project engineer was Mr. Roman Federok at Naval Air Development Center, Warminster, PA. The final technical report was sent to 70 Government offices and 30 industrial firms.

MORE INFORMATION

Additional information may be obtained from the project engineer, Dr. Herbert Mette, US Army Electronics R&D Command, AUTOVON 995-4995 or Commercial (201) 544-4995, or from Mr. Joseph Brewer at Westinghouse, Baltimore, MD, Commercial (301) 765-7457.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project H 76 9749 titled, "MMT for Thick Film Processing of Microwave Integrated Circuits", was completed by the US Army Electronics Research and Development Command and Harry Diamond Laboratories in June 1979 at a cost of \$360,000.

BACKGROUND

This project was funded to convert thin film deposition techniques into thick film printing technology for hybrid circuits. Present thin film methods are expensive due to processing time, component handling, the need for high vacuum equipment, and the requirement for controlled or inert atmosphere for sputtering.

Thick film technology can eliminate these shortcomings through use of in-line full or semi-automated production processes such as circuit printing, substrate firing (ink drying), sintering and improved testing.

SUMMARY

Rockwell International, Collins Radio Electronics Division at Dallas, Texas was awarded a contract to produce two thin film microwave sources (a Radiosonde Modulator/Transmitter, and FM Source) in thick-film circuitry.

Device characteristics are briefly described as follows:

A. Radiosonde Modulator/Transmitter

- | | |
|--|----------------------|
| 1. Frequency | 1680 ± 20 MHz |
| 2. Power Output | 65 mW |
| 3. Modulation | 100% AM 0 to 1835 Hz |
| 4. Frequency Stability
(-70°C to +70°C) | ± 2 MHz |

B. FM Source

- | | |
|---|--------------------|
| 1. Frequency | 1375 ± 25 MHz |
| 2. Power Output | 500 mW |
| 3. Modulation | FM 0 to 1 MHz rate |
| 4. Tuning Linearity
(50 MHz Bandwidth) | $\pm 2\%$ |

The two devices are shown in Figures 1 and 2.

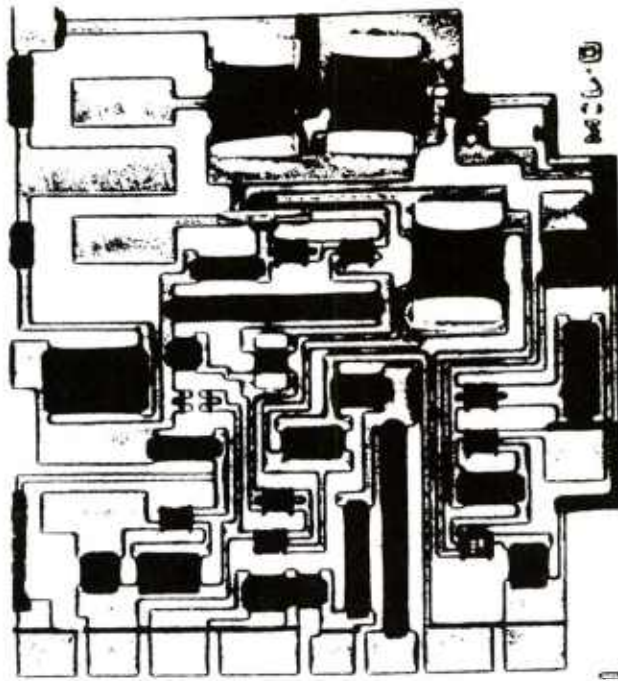


Figure 1 - Thick Film Microwave Radiosonde Modulator

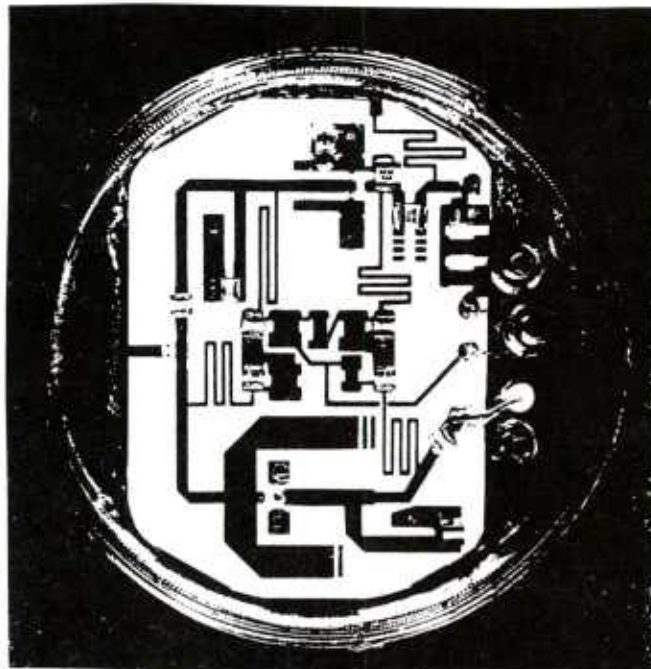


Figure 2 - Thick Film Microwave Integrated FM Source Circuit

Thick film conductor compatibility in high frequency circuits was examined. Metal inks and processing procedures that would attain optimum circuits and satisfy the specifications were evaluated. Three different bonding category inks, reactive, mixed, and frit, and three different composition alumina substrates were used.

All thick film patterns were screened through a 325 mesh screen with a .0005 inch emulsion. This procedure resulted in a fixed film thickness of

11-13 microns. Several electrical measurements were made. D.C. resistivity was performed on all conductors using a serpentine pattern with an aspect ratio of 436:1. A D.C. electrical continuity check for screened-through-holes related hole size to substrate thickness. It was seen that screened-through-hole processing is reliable provided hole diameters are equal to or greater than substrate thickness. High frequency measurements were made and Q vs frequency was documented.

It was determined thick film conductor adhesion was affected by substrate type, film thickness and firing profile. Tests showed Dupont 9308 PdAg and Dupont 9885 PtAu had satisfactory adhesion with manufacture profiles suggested and screening parameters chosen. Dupont 9791 Au was recommend for maximum Q and satisfactory adherence; however, gold bearing solders must be used for solder attachment of passive and active components. Either Dupont 9308 PdAg or Dupont 9885 PtAu was recommended for hybrid assemblies using soft solders.

All ten thick film radiosonde modulator/Transmitter engineering samples met power output, current, reference frequency, transfer characteristics and pulse width specifications over the full temperature range. Four units, however, did not meet the 4 MHz frequency stability requirements. They remained slightly out of spec between -70°C and -50°C.

The FM Source Engineering Samples had marginal results. Noteable exceptions were the high G (> 20,000g) shock test and modulation linearity (+ 2 percent) requirements which were not achieved. Exhaustion of funds led to the effort's termination. Pilot production rates were not demonstrated for either circuit.

BENEFITS

Although all goals were not attained, sufficient work was performed to advance the thick film technology to the point where subsequent applications will become much easier at these microwave frequencies.

IMPLEMENTATION

The Radiosonde Modulator/Transmitter was scheduled for application in the AN/AMQ-23 Weathersonde. The requirement for this equipment was withdrawn.

The FM Source had application in the parachute opening microwave proximity sensor. Anticipated procurement requirements for this equipment did not materialize.

MORE INFORMATION

Additional information may be obtained from Mr. James Kelly, CECOM, Ft. Monmouth, NJ, AUTOVON 992-4077, Commercial (201) 532-4077 or Mr. Bill Trueheart, Harry Diamond Laboratories, Adelphi, MD, AUTOVON 290-3110, Commercial (202) 392-3110. The contract was DAAB07-76-C-0026.

Summary report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project H 77 9792 titled, "Production of Low Noise Figure Ion Barrier Microchannel Plates (LNF/MCPs)," was completed by the US Army Research and Development Command, Night Vision and Electro-Optics Laboratory in August 1981 at a cost of \$600,000.

BACKGROUND

There was need for improved image intensifier tube components for the aviator's night vision imaging system and night vision goggles, and for improved methods and equipment for volume production of these components. This project dealt with processes for making better microchannel plates which are used in the above devices to amplify the light level of a viewed scene.

Three drawbacks of second generation image intensifier tubes attributable to microchannel plates are:

- a. Deterioration of performance due to poisoning of the photocathode by ion feedback from the MCP,
- b. Local intensity fluctuations at the output screen due to "noise" in the MCP, and
- c. Low resolution due to large 15 micro-meter center-to-center spacing of the channels.

SUMMARY

Galileo Electro-Optics Corp., Sturbridge, MA, contracted with Night Vision Labs to production engineer their methods for making microchannel plates and to overcome the problems listed above. Galileo's methods included monofiber drawing, multiwrapping, multifiber drawing, billet fusing, billet slicing, wafer finishing, chemical processing, channel funneling, MCP coating, film evaporation and electrical testing.

The purpose for establishing these improved methods was to produce improved microchannel plates needed to meet the more stringent requirements of image intensifier tubes for aviator's night vision systems.

Galileo performed the following activities:

- a. Modified glass fiber drawing and bundling techniques to permit assembly of microchannel plates having 10 micro-meter center-to-center spacing of fibers; an improvement over the 15 micro-meter spacing previously used.

b. Modified hydrogen reduction techniques to optimize electrical properties of the MCP material.

c. Designed and built holding devices for funneling input ends, for depositing magnesium oxide secondary enhancement coating, and for depositing quality aluminum oxide ion barrier films.

d. Optimized funnel etching conditions for uniform funnel configuration and improved batch processing results; obtained the high open area ratio desired.

e. Optimized magnesium oxide coating deposition technique.

f. Perfected aluminum oxide ion barrier film evaporation over funneled area in a batch process; barrier quality was excellent with few pinholes observed.

g. Solved problems with crazing of the lacquer used to support the aluminum oxide ion barrier deposit by returning to the original type of lacquer used; this type of lacquer has now become non-proprietary.

h. Optimized salvage operations for reclaiming microchannel plates with defective films or coatings.

i. Built a bakeable test station for mounting and testing two microchannel plates with one pumpdown; see Figure 1.

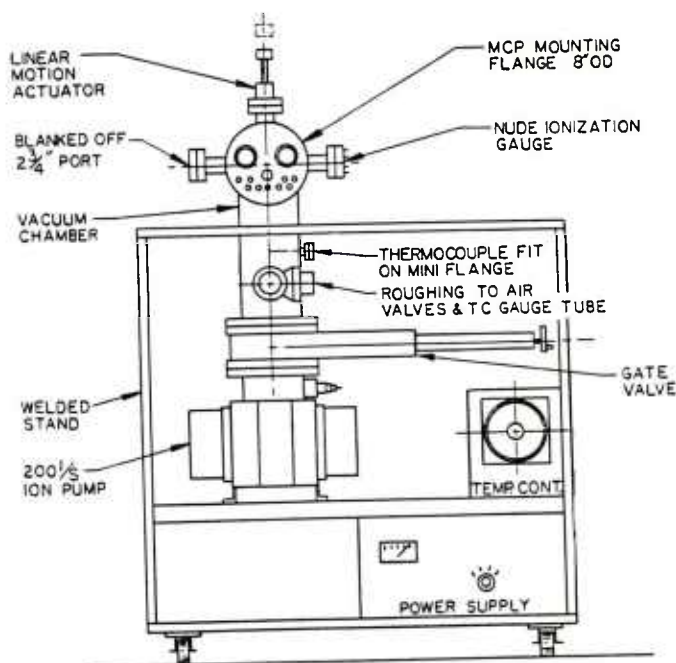


Figure 1 - Bakeable Test Station

BENEFITS

As a result of the development and optimization of the advanced methods listed above, Galileo established a capability for manufacturing ten microchannel plates per eight hour shift. The new MCPs have lower noise, increased resolution, and extended life.

A set of three bakeable demountable test stations were built to permit electrical and electro-optical testing. New procedures for noise figure and EEI measurement were developed. Vacuum bake for eight hours at 375°C and electron beam scrub of the microchannel plates is now possible in the test station.

The advantage of low noise figure microchannel plates is an improved signal-to-noise ratio obtained by funneling input channel openings to increase collection efficiency and by applying a high secondary emission coating to amplify the signal. Channel spacing was reduced by drawing finer fibers. This resulted in increased resolution. Extended tube life was obtained by applying an ion barrier film over the input channels to protect the tube cathode from MCP outgassing.

IMPLEMENTATION

Improved microchannel plates form part of image intensifier tubes used in the AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) and are available for use in the AN/PVS-7 Night Vision Goggles when they go into production in mid-1984. Improved MCPs have been provided upon request to several tube manufacturers for evaluation and comparison purposes.

MORE INFORMATION

Additional information may be obtained from Mr. Edward J. Bender, Army Night Vision & Electro-Optical Lab., DELNV-SE, Ft. Belvoir, VA 22060, AUTOVON 354-1624 or Commercial (703) 664-1624.

The contract was number DAAB07-77-C-0589. Dr. Joseph L. Wiza, Manager of Advanced Detector Technology at Galileo, was program manager at Galileo.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 79 1041 titled, "Large Scale Integration Fabrication Methodology Improvement", was completed by Martin Marietta Corp. for the US Army Missile Command in February 1982 at a cost of \$1,000,000.

BACKGROUND

Two custom integrated circuits needed for guidance systems in the Copperhead, Hellfire, Laser Seeker and Navy Guided Projectile had very poor yield during early production. They appeared to be dependent upon processing procedures and somewhat on topology. These circuits, the detector preamplifier and the limit-sum amplifier, had problems with noise, gain balance, cross-coupling, dynamic range and stability. Acceptable units comprised only 1-2 percent of total output and this made their cost prohibitive. Also, with the duration of testing required, sufficient units could not be obtained to satisfy production needs. All factors indicated that yield had to be increased from 1-2 percent to 7-15 percent.

SUMMARY

Martin Marietta Corp., Aerospace Division addressed the problem of preamplifier and limit-sum amplifier circuit unavailability by encouraging its suppliers to look at five phases of work: topology modification, process modification, producibility and yield improvement, test method automation, and documentation. These phases will be addressed briefly below.

Harris Semiconductor, RCA, and Martin Marietta, the three suppliers of the preamplifier, each worked on its own configuration. Harris then shifted to a Martin-designed preamplifier and with process improvements, increased yield to 5%. Thereafter, Harris worked on its limit-sum amplifier and automatic test methods and subsequently reduced its cost 40%.

Martin Marietta used its own funds to modify the Harris preamplifier at Martin's Microelectronics Center and sent the topological layouts to RCA for wafer processing. RCA had problems with both the Martin preamplifier design and its own design and the work was shifted to Harris. The preamplifier is shown in Figure 1 to illustrate its complexity. It is shown wired into a TO-8 package in Figure 2.

The limit-sum amplifier was originally designed and produced by Harris Semiconductor and its revision for better producibility was accomplished there with the aid of computer simulation. The large scale integrated circuit was modeled through temperature extremes and component tolerances to spot problems before the circuit was built in silicon. Circuit capabilities were discussed with using engineers in relation to program needs, and circuit requirements modified to be more realistic.

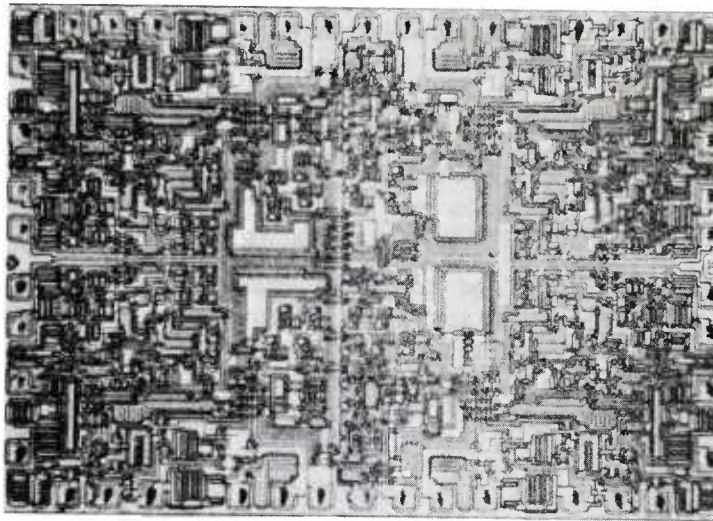


Figure 1 - Martin Marietta Preamplifier Chip

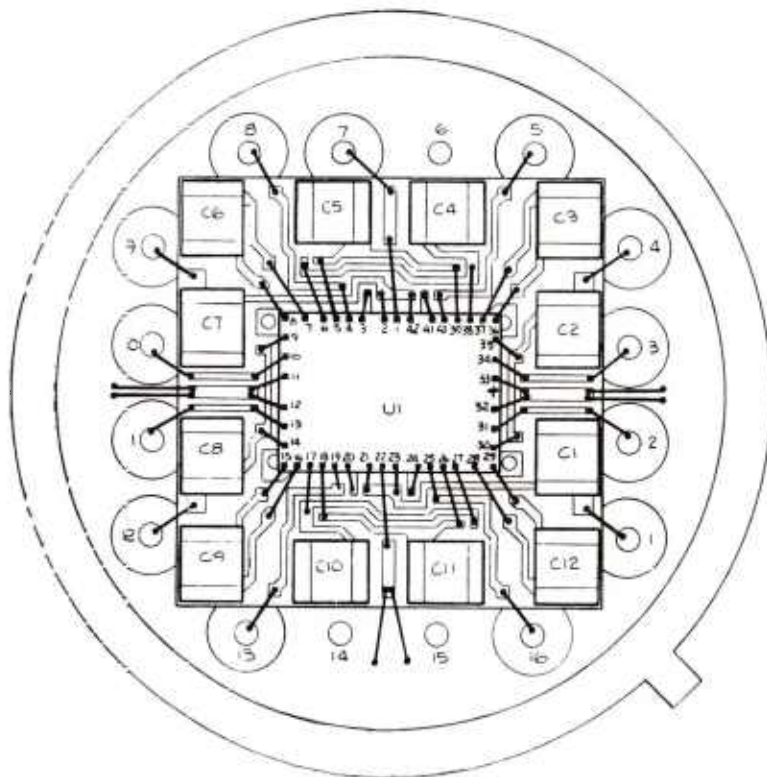


Figure 2 - Internal Package Layout

It was determined that widespread utilization of the technology developed under an MMT project would not happen unless the Army takes actions to encourage the utilization of the project results. Suggested actions were:

1. Utilize a standard format for preliminary identification of potential MM&T projects that will encourage government and industry personnel to document project ideas.

2. Screen potential projects from the standpoint of technical feasibility, commercial viability and likelihood of implementation prior to preparation of P-16's.

3. Perform in-depth assessments of the feasibility and benefits of potential MM&T projects prior to submission to higher authorities for funding.

4. Include in contract technical requirements for MM&T projects, explicit tasks to generate information on process operations, operating parameters, costs, equipment designs and application potential.

5. Closely involve potential users of the technology and decision makers that influence that utilization in the information flow concerning progress and results of the project.

6. Disseminate the project results widely through press releases, articles in trade publications and appropriate brochures.

7. Routinely survey potential technology users, particularly those receiving information on projects, concerning actual utilization of results.

8. Continue assessments of future missile manufacturing technology needs and the identification of major MICOM thrust areas in this regard.

The truly significant manufacturing technology resulting from the MICOM MM&T projects with Litton is the fast warm-up cathode materials and fabrication processes. Because of the uniqueness of the fast warm-up capability to missile applications, it is doubtful that this technology will see widespread use outside of this field. However, its use by PATRIOT has been successful, and it appears that other future missile radar applications will materialize.

In order to achieve the most wide-scale utilization of this technology, the following actions were recommended:

1. Distribute copies of the project final reports to:

- TWT manufacturers
- Other microwave tube manufacturers
- Missile prime contractors
- Other microwave system manufacturers (e.g., radar, communications and electronic countermeasures)
- Appropriate DoD organizations
- Suitable MICOM project offices and laboratories
- Universities active in microwave device research

2. Prepare an article about the project for publication in an appropriate trade magazine.

3. Contact recipients of project data on a one-on-one basis to determine if they are interested in using the technology.

BENEFITS

These actions will help insure that MICOM's MM&T program will remain properly focused and useful. This is particularly true if program managers maintain an "implementation" orientation throughout project planning, execution and follow-up.

IMPLEMENTATION

Some of the suggestions are performed as an integral part of the Manufacturing Technology Program.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Bobby Parks, MICOM, AV 746-2147 or Commercial (205) 876-2147. The contract number was DAAK40-78-C-0283.

Summary report was prepared by Dan Richardson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 79 3372 titled, "Manufacturing Methods for Magnetic Components", was completed by the US Army Missile Command in February 1982 at a cost of \$410,000.

BACKGROUND

Electromagnetic devices represent a substantial portion of the cost of present and planned missile systems. The current and projected design are also requiring these magnetic devices meet reduced weight and volume specs by factors of 3 to 6. Application of the current manufacturing processes, which has been essentially unchanged for 50 years, is inadequate for these newer devices resulting in an expensive product with marginal reliability. This project is the second and last fiscal year of the effort.

SUMMARY

This effort investigated and evaluated existing methods and defined improvements for the manufacture of low cost, highly reliable miniature electromagnetic components for missile applications. This second phase of the effort concentrated on interconnection techniques, tooling and structural parts.

Interconnection Technique

This area was subdivided into wire insulation stripping and bonding methods. The most common method of insulation stripping is to melt the insulation with a soldering iron or a flame. The melted insulation then serves as a flux for the soldering operation. This method can cause serious problems, dissolution and altered annealing, for fine and ultrafine wire sizes. Other methods of wire stripping investigated were abrasive, chemical, air abrasive and laser. No improved method of wire stripping resulted from these investigations.

The fragility of fine and ultrafine wires require that they be bonded to a heavier wire for external connections. Eight methods for joining the fine wires to the heavier intermediate lead were investigated. Parallel gap welding, ultrasonic bonding, thermosonic bonding and lead foil crimping were rejected due to either no bonding or incomplete bonding. Laser welding resulted in a satisfactory fusion of the wires but it is a difficult operation and special fixturing would be required for production quantities. Conductive adhesives can provide suitable bonding, however, the material is difficult to apply and flexing in the bond area results in cracking and peeling of the adhesive. Skeining, where the wire is folded back and forth

on itself and twisted to form a larger multistrand conductor, provides a satisfactory method but requires a solder strippable wire insulation. This solder strippable (low temperature) insulation is not allowed for most high reliability applications.

Molding

The three methods investigated for encapsulating parts were vacuum form molds, slush molds and a simple aluminum liquid injection mold. Vacuum form molding was rejected due to the inability to maintain desired thicknesses. Slush molds, made from low melting temperature metal, were unsatisfactory because removing the mold subjected the part to undesirably high temperatures. A system concept utilizing automatic metering, mixing and filling was defined. The liquid injection molding techniques show the most promise for large production quantities.

Structural Parts

A high resistance coating technique was defined for the bobbin shields. This method, if developed, could result in a simplified method for producing the equipotential surface.

Core Banding

A means of welding the core band was developed that prevents loosening due to solder creep experienced with conventional banding. For this procedure, a pull tab is welded to the band, and the band is wrapped around the core. The tab and the band are placed in the tensioning machine and the band is impulse welded at the overlap when the proper tension is reached. The end of the band and the tab are then cut off and welded down to complete the operation.

BENEFITS

Several improved procedures for manufacturing miniature electromagnetic components were developed. The most significant include: the importance of protecting the wire from damage during storage, importance of reduced voltage gradients, liquid injection molding techniques and the welding of "C" core bands.

IMPLEMENTATION

Several of the techniques were implemented in-house at Hughes Aircraft. The end-of-contract demonstration and distribution of reports containing recommendations were used to transfer the developed technology.

MORE INFORMATION

Additional information may be obtained from Mr. Richard Kotler, Missile Command, AUTOVON 746-2065 or Commercial (205) 876-2065. A final report titled "Manufacturing Methods and Technology for Electromagnetic Components" Contract DAAK40-78-C-0271 describes the findings in detail.

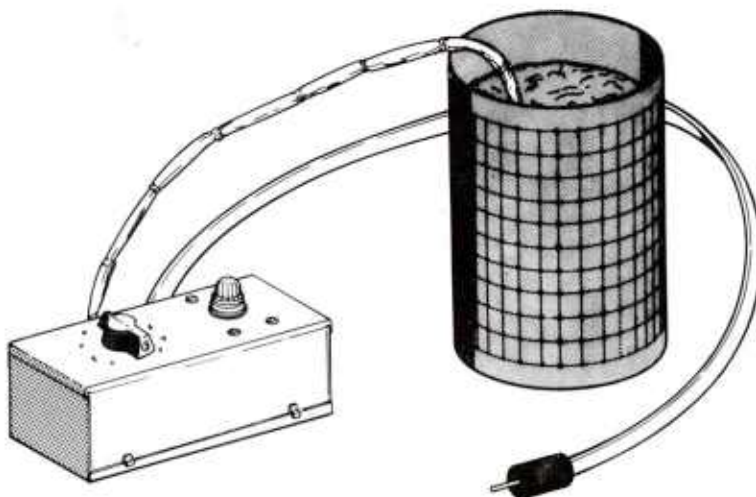
Summary report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 80 3411 titled, "Manufacture of Non-Planar Printed Circuit Boards", was completed by the US Army Missile Command in September 1982 at a cost of \$220,000.

BACKGROUND

Most of the technology for manufacturing and populating electronics circuit boards in large production quantities is applicable only to flat boards. For some applications, such as missiles, this restriction results in the use of many small circuit boards with complex and expensive interconnection systems. The ability to economically produce non-planar circuit boards would result in less complex and more reliable electronics packages.



Completed Cylindrical Circuit Board

SUMMARY

This is the first year of a planned two year effort. The project encompassed two tasks: a spiral antenna and an eight layer cylindrical circuit board.

An antenna configuration analysis was completed and the material selection criteria was established. Manufacturing processes and performance data were developed for three versions of this antenna. Prototype units were surface accurate to 1/100 of a wavelength and additively plated to within 0.001 inch as required.

Five potential constructions were evaluated for manufacture of the cylindrical circuit boards. For the first method the innermost pre-etched layer is wrapped around a mandrel. The subsequent pre-etched layers are registered with the first layer by the use of tooling pins and bonded with adhesive layers. After curing, the board is drilled with a four axis NC drill. This, followed by an elaborate exposure system, made it a costly and complex method of producing boards. The next approach was to use an unreinforced polyimide supported copper-clad substrate. These flexible layers were bonded using B-staged glass-supported polyimide adhesive layers. This approach was also abandoned because the layers were still too stiff and cracked or delaminated when wrapped.

The third method was thermo forming polysulfone copper clad laminates. This system looked promising, however, the product is no longer available due to the lack of a market. This approach was abandoned.

The fourth method was injection molded polysulfone. This method eliminates the costly drilling operation but requires expensive tooling and processing of each layer in the cylindrical configuration. The method was abandoned as being too expensive.

The fifth approach was to use flexible materials during the processing. The flexible layers are processed while flat in much the same manner as a conventional board. The flat layers are then etched, except for the outer layers, and laminated. The outer layers are then processed and the circuit drilled. A bonding tool and cast adhesive are then used to form the board into the required circular shape. The cylindrical board produced was subjected to and successfully passed environmental and electrical tests to verify integrity. The follow-on project will optimize the manufacturing processes and provide the pilot capability required to manufacture 16 of the disk antenna and 20 cylindrical circuit boards.

BENEFITS

The materials and processes for producing non-planar circuit boards were established. Environmental and Electrical testing were completed to verify product capabilities.

IMPLEMENTATION

The second fiscal year of this effort will provide the pilot capability and equipment designs that are suitable for a production environment.

MORE INFORMATION

Additional information may be obtained from Mr. Robert Brown, MICOM, AUTOVON 746-5321 or Commercial (205) 876-5321. An interim report titled "Manufacturing Methods and Technology for Non-Planar Printed Circuit Boards" was written that describes this portion of the effort (Contract No. DAAH01-81-C-A777).

Summary report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 80 3436 titled, "Development of Ceramic Circuit Boards and Large Area Hybrids," was completed by the US Army Missile Command in September 1982 at a cost of \$450,000.

BACKGROUND

The requirement for more capability in electronic control systems has resulted in the need for more complex micro-components and a requirement for denser packaging systems. The most practical means of satisfying the performance, packing density, and interconnect problems for military circuits is to use large scale hybrid microcircuits. Since large hybrid microcircuits are relatively new, their configuration and production processes are not fully developed and as a result the devices are unnecessarily expensive.

SUMMARY

Two methods of producing the hybrid circuits were investigated during the first phase of this program. The first method was a more conventional hybrid in a can technique using Stinger-Post as sample electronics. The first phase of the effort completed the industry survey and defined the process and repair procedures. This phase of the effort fabricated and tested sample devices. Technical achievements were enhanced in the area of environmental restraints when employing large metal hybrid packages.

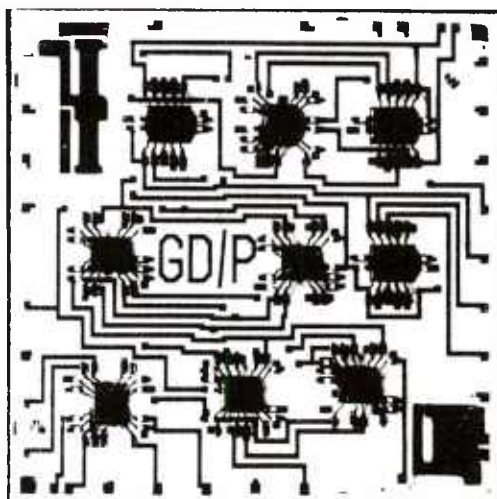


Figure 1 - Hybrid Microcircuit

The mechanical shock testing, bomb pressure testing and centrifuge testing were evaluated using current MIL Standard Specifications. Due to the large physical size of these devices, this testing can damage the part. Modifications to these environmental specifications have been proposed in areas that will not degrade device field reliability.

The second approach used a ceramic substrate for mounting the micro-circuit chips. A passive layer is deposited over the device for environmental protection. Technical advancements were made in the areas relating to chip attachment. The mounted chips were able to withstand mechanical shock testing to 20,000 'g's, acceleration to 13,000 'g's, and thermal shock testing. New soldering procedures and solder compounds were established for mounting the ceramic chip carriers.

BENEFITS

The developed processes include the advantages of low non-recurring cost, controllable yields and increased reliability. High packaging densities on substrates up to 4" x 4" can be accomplished with weight and cost savings.

IMPLEMENTATION

Implementation of these procedures is being accomplished for the Stinger-Post missile system. Implementation was not completed on the Navy guided projectile due to design changes which eliminated the candidate board and the inability to demonstrate adequate mechanical strength for that program.

MORE INFORMATION

Additional information may be obtained from Mr. Paul Wanko, US Army Missile Command, Redstone Arsenal, Alabama, AUTOVON 746-7097 or Commercial (205) 876-7097.

Summary report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 78 3453 titled, "Improved Production Techniques for Ground Laser Locator," was completed in February 1983 by the US Army Missile Command and the US Naval Weapons Center at a cost of \$211,000.

BACKGROUND

Lithium niobate electro-optic Q-switches have been used in military and commercial laser ranging and designation systems for a number of years. Figure 1 shows an exploded view of a Q-switch. As more systems using the Q-switches go into large scale production and higher power systems are being developed two major problems are apparent:

- (1) Available manufacturing capability is not adequate to meet projected requirements.
- (2) Increases in power levels will require the development of surface damage resistant anti-reflection coatings.

A lack of purchasing specification consistency, little knowledge of cost sensitivity specifications, and no generally accepted test procedures for quality assurance have resulted in little support for improved Q-switch manufacturing technology. A project was established at the Naval Weapons Center to solve the problem of providing the Q-switch production capacity at a unit cost expected with higher volumes of sales.

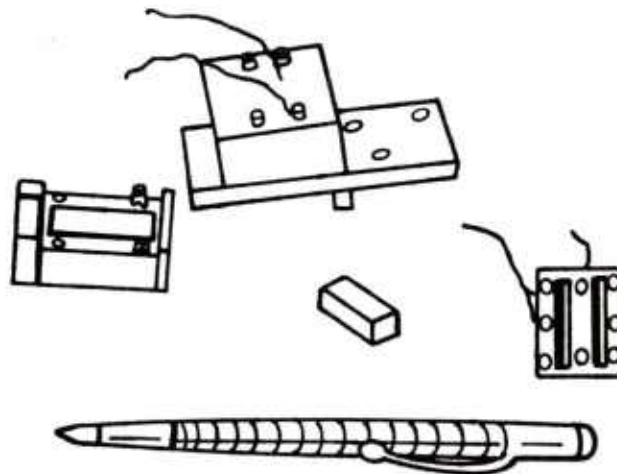


Figure 1 - Q-Switch Assembly

SUMMARY

Crystal Technology Inc. was contracted to evaluate and demonstrate improved high production rate manufacturing methods for the production of high damage threshold lithium niobate Q-switches. This project was managed by the Naval Weapons Center and complements the effort to provide the production capacity for the projected requirements.

One of the areas of interest was larger lithium niobate crystal growth. The single crystals are grown using the Czochralski technique. By increasing the boule diameter to 3-inches, it was calculated that up to 24 Q-switches could be produced with relatively little increase in labor. This would be a great improvement over the 10 Q-switches that could be cut from the 2-inch diameter crystal. One of the growth stations was modified for 3-inch crystals. Other 2-inch crystals were made as well to insure that enough Q-switches were available for the rest of the project. Although optical quality Q-switches were cut from the 3-inch boules, the yield was much lower than that from the 2-inch crystals and significant improvement was not demonstrated for crystal growth.

In general, Q-switches are only fabricated from material in the top two inches of the boule, regardless what length of the boule appears to be of optical quality. This is because strain is usually higher in the lower portions of the crystal. During this project, the upper four inches of the boules were evaluated to see if usable sections of the boule were being automatically discarded. This was found to be the case and it was determined that some of the material presently being rejected could profitably be carried down the manufacturing line before making a final selection.

A newly purchased, rugged, high precision saw and goniometer were evaluated to see if orientation during cutting could be maintained to sufficient accuracy to eliminate hand lapping from the fabrication procedure. The saw enabled cutting the sides of individual Q-switches to within ± 3 min. of the required orientation to the z-axis and to hold the orientation while cutting an entire batch of Q-switches. The hand lapping machine was converted to a surface grinder to bring sides into final finish. If the alignment on cutting is slightly off, the surface grinder can correct the entire batch. Batches of 30 to 50 can be handled routinely. This insures the polished faces are held to ± 6 min.

The face polishing method did not radically change. A batch of eight in a fixture are polished at one time. Parts subjected to damage can be reworked in the same fixture without deviating from the standard operating procedures.

Two AR coatings were tested and approved for specific systems. The C-5 coating is employed where the lowest reflectivity is needed and Q-switched power densities up to 300 MW/cm^2 are encountered. The I-3 coating is employed where resistance to extremely high optical power densities is needed and somewhat higher reflectances are acceptable. A newly developed T-6 coating which is proprietary to Crystal Technology combines very low reflectivity with a far higher damage threshold than previously obtained. With further testing and approval for use, it is expected to provide increased benefits over other coatings.

During this project, 340 Q-switches were cut from 19 crystal sections. Quality control tests during fabrication reduced the total to 275. Another 82 were lost because of coating quality, mishandling, wavefront distortion, Z-axis alignment or extinction ratio, yielding a total of 193 Q-switches.

BENEFITS

During this project, a manufacturing facility was developed which is capable of producing up to 250 lithium niobate Q-switches per month. All hand operations have been converted to machine processes, permitting lower manufacturing costs as well as improved quality and yield. Q-switches produced with these processes have been qualified for use by most major US manufacturers of military ranging and designator systems.

IMPLEMENTATION

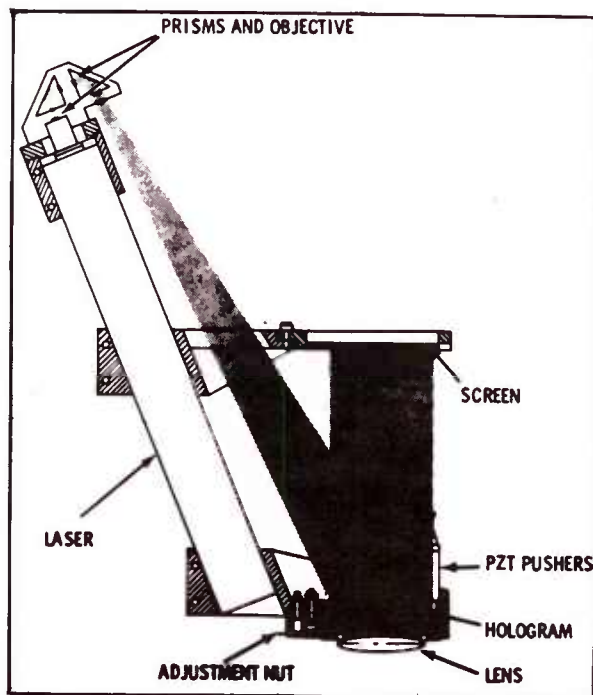
Crystal Technology is currently using all of the results of this project in the production of lithium niobate Q-switches. Many companies are purchasing these Q-switches to support TRAM, A6, GLLD, GVLLD, MULE and DIVAD. Since August 1982, the Q-switch cost savings for DIVAD are \$150 each, and for GVLLD are \$69 each.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Delmar Bobberpuhl, NWC, AUTOVON 437-3723 or Commercial (714) 939-3723. The contract number was N60530-80-C-0111. The report was NWC Technical Memorandum 4948.

Summary report was prepared by Dan Richardson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

INSPECTION AND TEST



OPTICAL HOLOGRAPHIC TEST EQUIPMENT

ABSTRACTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
R78 3376 R80 3376	Testing Electro-Optical Components and Subsystems	I-2

The objective was to establish a facility and the associated equipment to verify aspheric optical components. The technique used to establish this verification compatibility is computer holography where a light pattern (hologram) appears to come from the perfect reference asphere. The holowriter facility and equipment is available for use by any government agency or contractor engaged in government work.

680 8054	Improved Manufacturing Techniques and Quality of Optical Scratch and Dig Standards for Fire Control Systems	I-6
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Military specification MIL-O-13830 defining manufacturing criteria and in-process inspection procedure for optical elements is no longer applicable to current production. This project investigated available high volume manufacturing methods for stable, reproducible optical standards compatible with National Bureau of Standards instrumentation. The photolithographic process shows potential for reducing calibration, inspection, maintenance, and litigation costs after completion of the follow-on effort and standards revision.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects R 78 3376 and R 80 3376 titled "Testing Electro-Optical Components and Subsystems" were completed by the US Army Missile Command in March 1982 at a cost of \$675,000.

BACKGROUND

The Army's requirements for aspheric optics have increased in recent years. By using diamond-turning machining techniques, aspheric metal mirrors with almost any arbitrary shape can be produced. However, there were not any acceptable measurement methods to verify the shape of these optics. Spheres and flats are tested routinely by optical interferometric comparison with reference spheres or flats. When asphere deviates dramatically from the reference sphere, the interferometric method is not appropriate. The asphere fringes become unresolvable and the information is irrevocably lost.

SUMMARY

The objective of this effort was to establish a facility and the associated equipment to verify aspheric optical components. The technique used to establish this verification capability is computer holography where a light pattern (hologram) appears to come from the perfect reference asphere. The generation of these fine resolution holograms is accomplished by a step and repeat procedure where a small section of the computer generated hologram pattern is optically demagnified and imaged on a photosensitive plate. A computer controlled x-y table is used to step to a new location, the computer displays a new section of the hologram pattern, and the process is repeated. The exposure of small sections of the photosensitive plate requires extreme position accuracy. This is accomplished by allowing the x-y table to step to the new location to "rough in" the position. An error signal from a position interferometric drives the CRT display for fine position accuracy.

The equipment is designed to compensate for possible problems with stability, vibration, temperature drift and humidity changes. The sensitivity of the equipment requires it be placed on an air suspended granite table in an environmentally controlled room, Figure 1.

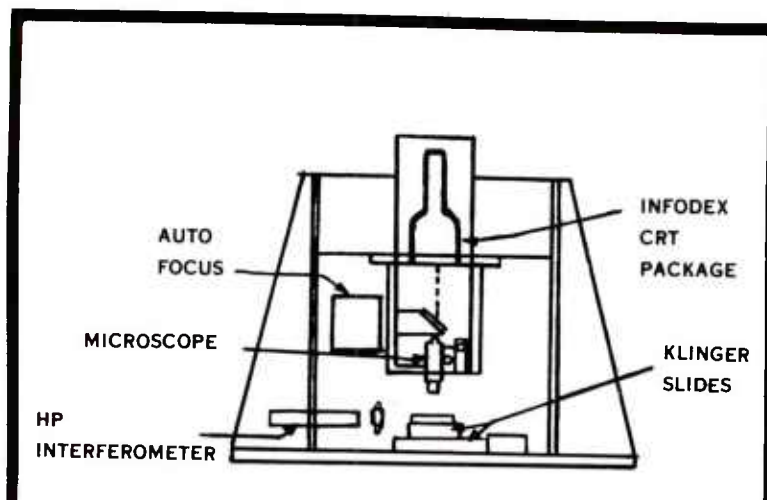


Figure 1 - Granite Table

BENEFITS

The results obtained from this effort demonstrated that the computer holography technique can be used to verify aspheric optical shapes.

IMPLEMENTATION

The holowriter facility and equipment is available for use by any government agency or contractor engaged in government work. This facility is located at Aerodyne Research Incorporated, Billerica, MA, and may be used for a nominal fee which covers labor, materials, computer time and maintenance.

MORE INFORMATION

Additional information concerning this effort is available from Mr. W. Friday, AUTOVON 746-8611 or Commercial (205) 876-8611.

Summary report was prepared by Del Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 5 80 4266 titled, "Magnetic Power Supply Manufacturing, Inspection and Test Process Development", was completed by the US Army Armament Research and Development Command, in November 1982 at a cost of \$345,000.

BACKGROUND

The recent M456AI Heat cartridge improvement program included: (1) repositioning the power supply from the nose of the round to inside the fuze housing and, (2) using a magnetic pulse generator power supply. As a result, the development of manufacturing, inspection and testing methods to produce the magnetic power supply were required. This type of power supply, even though used in other munitions, has not been produced in the quantities and size required for artillery, tank or mortar ammunition. The production rate requirements for these power supplies are 360 per hour.

SUMMARY

This effort was initiated to develop a semiautomated manufacturing, inspection and testing process to produce the magnetic pulse generator power supply. This report covers the first phase of the two-phased effort which developed the assembly stations' detail design, assembly line functional layout and process flow, Figure 1.

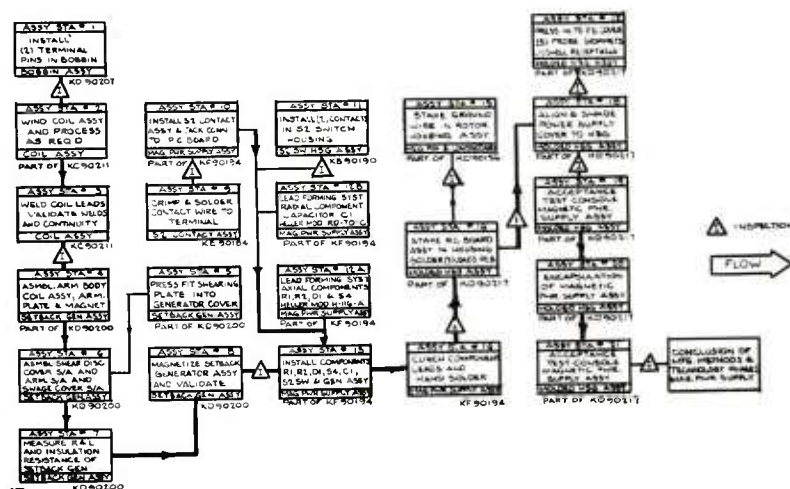


Figure 1 - Phase I--Flow Chart

In the development of this process, the following component design and assembly processes used in the product development program were found not to be fully suitable for high-volume production and were altered accordingly.

- o The setback generator design had many producibility shortcoming. These shortcomings were eliminated by redesigning the coil assembly and resistance welding the coil leads to the bobbin pins.

- o The coil winding machine was modified to wind eight coils simultaneously rather than one.

- o A magnetic charger and special Gaussmeter were purchased and modified to allow 24 set back generator assemblies to be validated during one charging cycle.

- o The printed circuit board assembly was redesigned and repackaged.

In addition, the following new equipment items were identified to ensure the quality and reliability goals of the magnetic power supply:

- o Centrifuge timing test console.
- o Electrical acceptance test console.
- o Release mechanism assembly tester.

Phase II of this effort entails the fabrication of the required equipment, installation, and debugging of the manufacturing inspection and testing process to produce the magnetic power supply. This phase of the effort is currently in process.

BENEFITS

The benefit realized by the Army from this phase of the effort is a manufacturing, inspection and testing process design to produce the magnetic power supply at a rate of 360 per hour.

IMPLEMENTATION

The results of this project are being used in phase II of the effort in the equipment fabrication, installation and process debugging. A technical report, ARLCD-CR-82051 dated November 1982, titled "Magnetic Power Supply Assembly of M509A2E1 Fuze (Phase I)" is available.

MORE INFORMATION

Additional information may be obtained from S. Israels, ARRADCOM, AUTOVON 880-5591, or Commercial (201) 328-5591.

Summary report was prepared by Del Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 6 80 8054 titled "Improved Manufacturing Techniques and Quality of Optical Scratch and Dig Standards for Fire Control Systems" was completed by the US Army Armament Research and Development Command in February 1983 at a cost of \$185,000.

BACKGROUND

Military specification MIL-O-13830 defines manufacturing criteria and in-process inspection procedures for optical elements. The requirements and testing procedures of MIL-O-13830 have not kept pace with present day technology in properly defining and assigning readily measurable acceptance testing parameters and in establishing objective manufacturing criteria for optical elements.

A substantial amount of money and effort has been spent on the subject of optical scratch defects by the DoD and private industry. The Aerospace Industries Association of America, the US Army Munitions Command, the American National Standards Institute and the National Association of Photographic Manufacturers have each published their own proposed revision to MIL-O-13830A. ARRADCOM has previously funded R&D and MM&T work in an effort to revise MIL-O-13830. MM&T Project 6 77 7744 resulted in a study that detailed areas in MIL-O-13830 that were no longer meaningful and should be removed or needed further investigation.

SUMMARY

This project was the first part of a two year effort, the goal of which was to investigate the available manufacturing methods capable of the high volume production of stable, reproducible optical standards and to determine the initial design parameters of the scratch pattern. The present methods of manufacture, diamond scribing and photolithography with chemical etching, lack the control needed to assure reproducibility, have low yields, and require 100% inspection with time consuming and subjective visual techniques.

The National Bureau of Standards (NBS) is developing a theoretical computer model to study the phenomenon of light scattering through scratch type artifacts and is building special instrumentation to quantify measured scattering properties of scratches. The theoretical understanding of scratch scattering is being used in the design and specification of scratch configurations. One criteria being used in the evaluation of scratch fabrication techniques is compatibility with the NBS instrumentation. This would permit the instrument to be used in final acceptance inspection of procured scratch standards.

A preliminary evaluation of the fabrication techniques for the standards was conducted. This was a psychophysical study in which 15 inspectors from 5

optics manufacturers and the government qualitatively evaluated 8 standards, each manufactured with a different process. The processes and their statistical ranking are shown in Table 1 where 1 is the highest and 8 is the lowest.

<u>Category</u>	<u>Mean Ranking</u>
Molded Plastic (KODAK)	2.53
ARRADCOM STD.	2.76
Laser Scribe (Quantronix)	4.26
Chemical Etch	5.06
Diamond Scribe	5.36
Laser Scribe (ESI)	5.40
Embedded Bubble	5.46
Embedded Fibre	5.80

TABLE 1 - Ranking of Scratches

It is felt that the high rating given to the ARRADCOM standard is biased in part by the fact that the inspectors recognized it as the MIL-O-13830 standard. The Army has been the custodian of the master MIL-O-13830 which is universally used by the optics industry. Frankford Arsenal was the sole manufacturer of the standards for 30 years and since its closing, much expertise has been lost. The standards are referenced for each procurement action and are supplied as GFE.

The three highest rated fabrication processes, excluding the ARRADCOM standard, were further evaluated to establish how the characteristics of each process can be specified and controlled. The molding process requires a master mold, the characteristics of which are very difficult to specify and inspect. A trial and error process would be required to produce a scratch in the mold with a specific apparent visual strength. The molding process is highly repeatable and can produce extremely fine surface features.

Laser scribing has difficulty with specification and control also. The visual appearance of the scratch artifact is highly sensitive to the individual kerfs. The kerfs are dependent on the spatial energy distribution, the power level and the substrate coating. A general applicable manufacturing procedure could not be established. Again, a trial and error process would be necessary to visually match the trial scratch artifacts against the standards.

The two fabrication methods just discussed suggest that all scratch standard fabrication be carried out on government owned and controlled equipment. This is regarded as undesirable because the government would like to refine and define all techniques and equipment so that it could get out of the standards business and let non-government standards groups handle it.

The photolithographic process appears to be the most likely to achieve the required repeatability and control. This process is wide spread in the high volume solid state electronics industry that has refined the process to a resolution of approximately one micron. The photolithographic process is completely compatible with NBS instrumentation. The companion etching process is the key question now. The alternatives which will be explored are chemical etching, plasma etching or ion beam etching.

BENEFITS

The quantifiable benefits which DoD will accrue upon successful completion of this effort are:

- (1) lower calibration costs due to construction which allows automatic measurement of "visual impact" readings.
- (2) reduced inspection costs due to more accessible, lower cost standards which is presently not the case.
- (3) an increased standards production base due to non-government manufacturers with lower cost fabrication processes.
- (4) decreased maintenance cost due to more durable construction and packaging of the standards.
- (5) elimination of the heavy ARRADCOM workload of calibration/maintenance/certification of the standards every 12 months.
- (6) reduced litigation costs in government-vendor disputes due to the optics industry accepting the new standards with calibration traceable to NBS.
- (7) inclusion of a mirrored section of each scratch which will reduce disputes involving coated optical mirrors.

IMPLEMENTATION

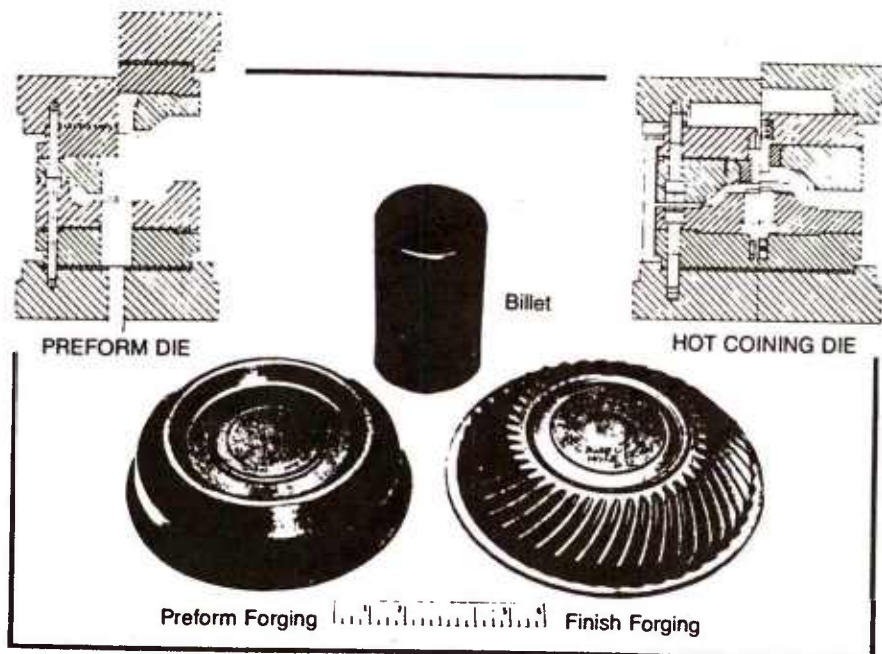
After completion of 6 81 8054, ARRADCOM, DRDAR-QAF-I, will prepare the necessary ECP to revise MIL-0-13830 and Drawing #7641866 to include the new process.

MORE INFORMATION

Additional information may be obtained by contacting Mr. John Salerno, ARRADCOM, AUTOVON 880-3210 or Commercial (201) 724-3210. The contract number was DAAK10-81-C-0308.

Summary report was prepared by Dan Richardson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

METALS



TWO-HIT FORGING PROCESS

ABSTRACTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
178 7199	Laser Hardening of Gears, Bearings and Seals	ME-5
179 7199		
180 7199		

The objective of this effort was to develop an energy efficient method of heat treating gears and bearings of Army engines and helicopter components. Information developed in the gear and bearing work was to support the work on seals. The major portion of this effort addressed the spur gear laser surface hardening program. The intent was to replace aircraft quality accessory drive carburized gears with laser hardened gears and achieve significant cost savings.

381 1086	Cobalt Replacement in Maraging Steel for Rocket Motor Components	ME-10
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Maraging steel is an alloy which is heavily dependent on cobalt for developing its physical properties. Cobalt is becoming increasingly difficult and expensive to obtain because the United States must import almost 100% of its requirements. This project was the first phase of a three-phase effort to establish a manufacturing methodology for producing high strength, cobalt free maraging steel.

R79 3136	Improved Manufacturing Processes for Compliant Bearing Gyros	ME-13
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Current seeker head gyros are expensive due to the extensive and accurate machining required during production. This project established a pilot production line for a modified gyro design having a compliant layer air bearing gap. Eight gyroscopes were built and a checkout station completed. This gyro is being considered for future Copperhead and Hellfire buys due to its estimated \$434 cost, a \$966 savings per unit over existing models.

576 6472	Alternate Processes for Fabrication of Precision Parts for MT Fuzes	ME-18
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Pinions are usually manufactured by machining from solid round stock using automatic hobbing machines. These machines, as well as their precision carbide cutters, are now available only from foreign sources. The project was to develop alternate methods and processes for manufacturing pinions that would use domestic equipment and skills. A successful alternative method of manufacturing pinions was developed using hydrostatic extrusion, drawing, and machining.

681 8001

Rapid Flow Plating of Small Caliber Gun
Tubes

The interior surface of 50-caliber gun barrels is currently production plated with chromium to improve wear resistance. Rapid chromium plating of small caliber gun tube ID surfaces can be accomplished with high current densities under high solution flow conditions. The deposition rate can be increased 10 to 60 times by providing forced, rapid solution flow at the plating surface. The objective of this project was to optimize process parameters and develop techniques for the rapid chromium plating of small caliber gun tubes.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 178 7155 titled "Cost Effective Manufacturing Methods for Improved High Performance Helicopter Gears" was completed by the Aviation Research and Development Command in August 1982 at a cost of \$410,000.

BACKGROUND

The demand in helicopter operation for greater reliability of high performance gears at lower cost has required that improved processing and evaluation techniques be instituted. MMT efforts of prior years have emphasized the optimization of heat treatment of gears made of commercially available AISI9310 and modified VASCO X2 steels. As a result of these efforts, heat treatment and processing variables such as carburizing, austenitizing and tempering procedures have been developed. However, to insure effective implementation, it is required that quality control be incorporated when specifying steels for high performance gear applications. Accordingly, one aspect of this multi-year effort is to use computerized ultrasonic nondestructive testing in every stage of processing. This control, coupled with improved metal production processes and unique fabrication methods such as ausrolling and cold finish rolling should result in significant improvement in quality, reliability and cost.

SUMMARY

Current high performance, helicopter gear manufacturing processes use individual tooth grinding as the final shaping and finishing operation. This is an expensive, time consuming operation. Also, significant material defects can pass through the existing quality assurance process without detection.

This effort was entered into with the objectives of restructuring the manufacturing process, inserting and economically evaluating more revealing inspection processes and replacing individual tooth grinding with an ausrolling/cold finishing automated procedure. It will also investigate the use of the cold finishing method in the restoration/refurbishing of surface damaged teeth.

This first phase project, under the FY78 funding, accomplished the following tasks:

1. Base line roller contact fatigue specimens and companion load rollers were machined, carburized, hardened, tempered and finish ground. Roller contact fatigue testing will continue under FY80 funding.

2. The electrostatic precipitator (smoke-eater) was installed and is operational. A warm oil circulation system was checked out and is performing satisfactorily at required ausroll temperatures (400°F).

3. The gear roller load frame was modified to provide more clearance for rapid insertion and attachment of the pre-rolled gear and shaft assembly upon transfer from the gear assembly bath to the gear roller machine.

4. Strain gages were mounted on all four posts of the die set for measuring horizontal strain and load magnitudes transmitted to the gear during rolling operations.

5. Five of the initial carburized gears representing five different hobbed pin diameters were measured for tooth spacing, size over pins, bore roundness and pitch diameter runout. The gears were then bored to 2.6927/.6920-inch diameter and charted for tooth involute and lead error.

6. Insert plugs were machined and fitted to the gear bores. A fixture for positioning and assembling the pre-rolled gear to a bearing shaft under hot oil was built. Trial runs of oil immersed gear assembly operation and transfer of the assembly to the gear roller machine were underway at project completion.

7. Ausrolling of quenched gears will commence immediately after satisfactory assembly procedures are established, under the FY80 funding.

BENEFITS

The prototype ausrolling equipment is now operational and ready to proceed with this effort.

IMPLEMENTATION

The results of this first phase project will be implemented in the continuing effort.

MORE INFORMATION

Additional information may be obtained by contacting Mr. E. Kinas at the Army Materials and Mechanics Research Center, AV 955-5270 or Commercial (617) 923-5270.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 178 7199, 179 7199 and 180 7199 titled "Laser Hardening of Gears, Bearings, and Seals" were completed by the US Army Aviation Research and Development Command in January 1982 at costs of \$180,000, \$180,000 and \$121,200, respectively.

BACKGROUND

Gear teeth are currently surface hardened by case carburizing. This process is expensive since it requires much energy, masking, quenching dies, and final grinding. The races of ball bearings are through hardened, which results in the lack of impact strength and fracture toughness needed for durability. The M-50 material used in bearing races cannot be case carburized nor induction hardened. The information derived from the bearing and gear work was to be used to support the planned work on seals. The new manufacturing process would reduce costs by eliminating masking before and stripping after heat treatment; it would reduce the energy required to heat treat and eliminate the quenching process with the attendant quenching dies; and it would potentially eliminate a grinding operation.

SUMMARY

The primary objective of this effort was to develop an energy efficient method of heat treating gears and bearings of Army engines and helicopter components. Information developed in the gear and bearing work was to support the work on seals.

The major portion of this effort addressed the spur gear laser surface hardening program. The intent was to replace aircraft quality accessory drive carburized gears with laser hardened gears and achieve significant cost savings.

Two low alloy steels were considered for use in this program. Preliminary work was conducted on AMS 6419 steel, commonly known as 300M. This steel is a modification of AISI 4340 with higher carbon, molybdenum and silicon. It is a premium quality consumable electrode vacuum melted steel suitable for aircraft accessory gearing. Figure 1 shows the hardness profile of a 300M specimen laser hardened and tempered at 300°F. The temperature is the lowest tempering temperature that is used in aircraft gearing application. As seen from Figure 1, 300M does not retain R_{C60} hardness after a 300°F temper. Therefore, 300M was not given any further consideration in this program.

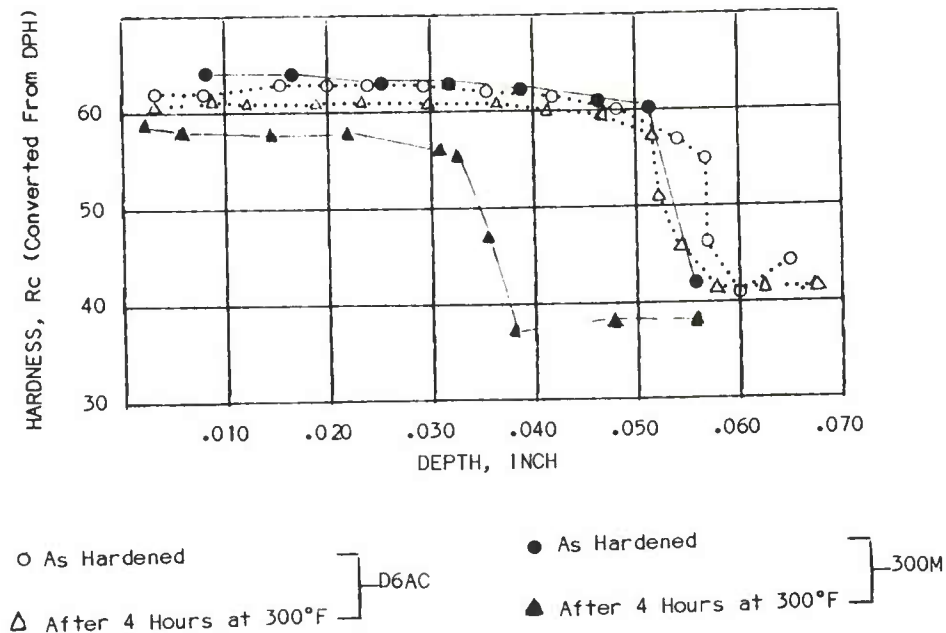


Figure 1 - Hardness Profile

The second material selected was D6AC per AMS 6431. It is a low alloy steel of premium quality produced by consumable electrode vacuum melting. It has higher carbon and molybdenum than 300M and therefore was expected to yield $R_c 60$ minimum hardness after 300°F temper. The hardness profile of D6AC is shown in Figure 1 and it demonstrates that it does not meet the minimum hardness requirement after tempering.

The heat treat condition of steel prior to laser hardening has a significant effect on the case properties. For this reason, all specimens were normalized, hardened, and tempered before laser hardening.

One set of experiments was conducted on D6AC steel to compare the laser hardened case hardness with that obtained by conventional hardening followed by oil and water quench. The results clearly demonstrated that the laser hardened case is harder than that obtained by conventional heat treatment.

The results of evaluation of test gears showed that the problem of tempering of the west flank exists when the east flank is within the desired case depth range. An auxiliary means of cooling the gears is necessary to obtain R_c minimum surface hardness on the west flank.

The repeatability of the process used was not adequate to consistently produce a case depth in a tolerance band of .008 to .010 inch. The presence of recast layer on several teeth of the prototype gears dictates that they will have to be finish ground. There was also a lack of case depth uniformity from end face to end face. This problem was not discovered until late in this program.

BENEFITS

In spite of termination of this program prior to a successful completion, several benefits can be realized which are the basis for the following conclusions.

Laser hardening of D6AC provides a surface hardness that is higher than that achieved through conventional hardening followed by oil or water quench. The flank-root-flank method of laser hardening a gear tooth has the disadvantage of back side tempering. The accuracy with which each tooth is positioned for laser hardening is extremely important. For production applications, a highly precise indexing mechanism would be required.

Spot hardening of the gear teeth, with the optics used in this program, had the disadvantage of incomplete coverage from end face to end face for the .375-inch wide gears. The inconsistencies in laser hardening observed in this program indicate that in a production mode this process would require some special quality assurance provisions. Comparative cost analysis indicated that laser hardening cost was approximately 38 percent of the cost of carburizing. The cost benefit is primarily due to the elimination of labor intensive operations and the reduction of costly furnace time.

IMPLEMENTATION

The program was terminated due to technical difficulties encountered and the expense required for system modification to overcome the problems. There was no logical course of action for pursuing the contract objectives within the present funds available. Since the program was terminated prior to its successful completion, the results could not be implemented.

MORE INFORMATION

Additional information may be obtained from Mr. Bruce Park, AVRADCOM, AV 693-1625 or Commercial (314) 263-1625.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 178 7285 and 179 7285 titled "Cast Titanium Compressor Impellers" were completed by the US Army Aviation Research and Development Command in February 1982 at costs of \$135,000 and \$300,000, respectively.

BACKGROUND

Current titanium compressor impellers are produced by machining the flowpath and blade surfaces from an oversized forging. This results in a substantial loss of material and expensive machining operations. Typically, about 75 percent of the initial forging is machined away and machining operations generally constitute about 66 percent of the total impeller cost. By investment casting the impeller to near-net shape, material utilization is dramatically improved and machining operations are minimized. Hot-isostatic pressing and heat treatment of the castings improves the mechanical and fatigue properties to a level attractive for dynamic applications.

SUMMARY

The major objective of this program is to develop and demonstrate a pilot production process for investment casting titanium centrifugal compressor impellers to near-net shape. The compressor impellers will be produced and tested to completely evaluate the economic advantages of the selected casting technique and processing against life cycle costs of the conventional forged and machined compressor impeller.

A sample of compressor impellers was received from two vendors and further processed by heat treating, chemical machining, and bead blasting. Table 1 summarizes the variable foundry practices and heat treatments used. Specimens were sectioned from the hubs, prepared as high cycle resonant fatigue specimens, macro-etched, and metallographically examined. Data included ambient and elevated temperature tensile and stress-rupture properties, fatigue limits, macro structure and micro structure. This data was then related to the various processing parameters and foundry practices used.

With a few exceptions, the data seem to show that the most effective heat treatment is obtained by quenching as rapidly as possible from a temperature of 1750° or above. This data only represents two years of a 5-year program. A detailed analysis of the entire processes developed will be available in the final year of this project.

HEAT TREATMENT *	STO		HIGH O2	COREO		TIP EXT.		LOW PREHEAT
	PCC	TITECH	TITECH	PCC	TITECH	PCC	TITECH	PCC
1 *	8-1	S/N 24	S/N 1				S/N Y	
2 *	8-2	S/N 16	S/N 2					
3 *	8-3	S/N 18	S/N 4					
4 *	8-4	S/N 19	S/N X	10-3	S/N 21			
5 *				10-1		7-1	23	9-1
6 *				10-2	S/N 10	7-2		9-3
7 *						7-3	22	
8 *		20					17	
9 *	8-5					7-5		9-2. 9-5

Table 1 - Casting Parameters
And Heat Treatment

- 1 * AS HIPEO
2 * POST-HIP STA: 1750 F/30 MIN/RAPID AIR COOL OF ARGON MUFFLE:
AGED 1100 F/4 HR./VAC
3 * POST-HIP STA: 1850 F/30 MIN/RAPID AIR COOL OF ARGON MUFFLE:
AGED 1100 F/4 HR./VAC
4 * POST-HIP STA: 1850 F/30 MIN/RAPID WATER OUECH OF ARGON MUFFLE:
AGED 1100 F/4 HR./VAC
5 * POST-HIP STA: 1800 F/30 MIN/RAPID WATER OUECH OF ARGON MUFFLE:
AGED 1100 F/4 HR./VAC
6 * POST-HIP STA: 1750 F/30 MIN/RAPID WATER OUECH OF ARGON MUFFLE:
VARIABLE AGE
7 * POST-HIP STA: 1775 F/30 MIN/RAPID OUECH OF ARGON MUFFLE:
VARIABLE AGE
8 * AS HIPED AGEO ONLY 1100 F/4 HRS./VAC
9 * POST-HIP STA: 1750 F/30 MIN/RAPID WATER OUECH OF ARGON MUFFLE:
AGED 1100 F/4 HRS./VAC

BENEFITS

This represents two years of a 5-year program. Anticipated benefits upon the successful completion of this program will enable the Army to procure titanium centrifugal compressor impellers at reduced cost compared to forged impellers. In addition, the results of this program will have direct application to other titanium centrifugal compressors.

IMPLEMENTATION

After completion of this program, an Engineering Change Proposal will be prepared by Solar Turbines, Inc. for introduction of cast titanium impellers into T62T-40 production. Detroit Diesel Allison will introduce cast impellers in the GMA500 during development testing to qualify the parts prior to initial production.

MORE INFORMATION

Additional information covering this project may be obtained from Mr. M. Galvas, Applied Technology Laboratory, US Army Research and Technology Laboratories, AVRADCOM, AV 927-2771 or Commercial (804) 878-2771.

Summary Report was prepared by Wally Graham, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 381 1086 titled "Cobalt Replacement in Maraging Steel for Rocket Motor Components" was completed by the US Army Missile Command in October 1982 at a cost of \$300,000.

BACKGROUND

Current high performance rocket motor components utilize maraging steel in large quantities. Maraging steel is an alloy which is now heavily dependent on cobalt for developing its physical properties with most compositions containing about 9% cobalt. Cobalt is becoming increasingly difficult and expensive to obtain because the United States must import almost 100% of its requirements from politically sensitive areas of the world. This critical strategic material requirement could not be fulfilled during mobilization. Recent R&D efforts have produced small heats of cobalt-free maraging steels with nearly equivalent physical properties.

SUMMARY

This project was the first phase of a three-phase effort to establish a manufacturing methodology for producing high strength, cobalt free (Free-Co) maraging steel rocket components.

The initial vehicle for evaluating the Free-Co material was the fabrication of TOW launch motor cases. The effects of various forging/annealing temperatures on the mechanical properties of the material were evaluated relative to forging, drawing, and shear forming operations. Manufacturing characteristics and mechanical properties were compared to those obtained with cobalt containing 18Ni 300 grade maraging steel which is now used in the TOW launch rocket motor cases. The mechanical properties of specimens generated from fully processed motor cases were typically 292 ksi yield strength, 300 ksi ultimate tensile strength, and 6% elongation in a 1-inch gage length. This compares with a typical tensile strength of 330 ksi and less than 1% elongation in a 1-inch gage length for specimens generated from 18 Ni 300 maraging steel. The shear forming procedures used to fabricate 100 TOW configuration parts from Free-Co material were identical to those used for production TOW hardware; and the heat treat shrinkage coefficients for the Free-Co TOW hardware were determined to be essentially the same as those exhibited by the cobalt-bearing 18 Ni 300 grade maraging steel. This is an important aspect since it implies that no changes in process planning would be required if a switch were made to Free-Co from 18 Ni 300 maraging steel for production TOW. The machinability study conducted at Metcut Research, Cincinnati, Ohio, indicated that the Free-Co alloy exhibits an overall

machinability slightly less than the corresponding cobalt-bearing grade of maraging steel. This phase of the program requires additional investigation since the contractor's in-house experience with machining actual parts from Free-Co did not confirm Metcut's data.

A total of 50 Free-Co TOW rocket motor cases was delivered to the Army Missile Command for further evaluation. Figure 1 outlines the complete process used in fabricating the TOW rocket motor cases during the first phase project.

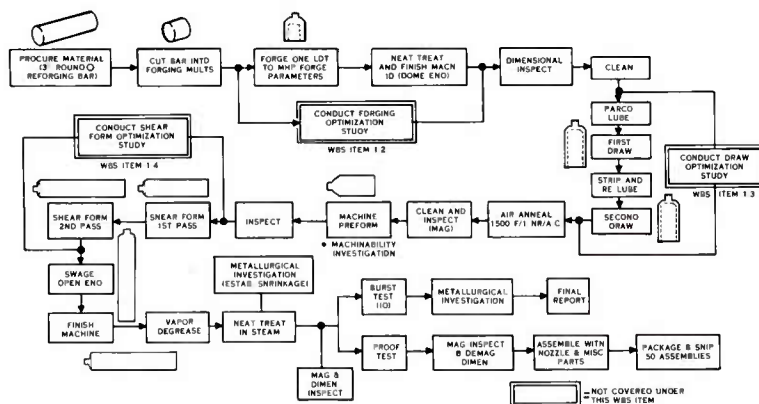


Figure 1 - Free-Co 250 TOW Motor Case - Process Flow Chart

Another facet of this project was to extend the Free-Co manufacturing technology to other potential rocket motor applications of larger (14 inch) diameter, through an investigation of scaled-up Free-Co hardware. This portion of the program encompassed forging, shear forming of cylinders (to wall thicknesses of 0.100 to 0.143 inch), Electron Beam welding, and mechanical properties evaluation, including fracture toughness testing. Some of the most significant findings of this program were:

1. The Forging Optimization Program, conducted in sections from the 8" RCS billet, confirmed the results obtained previously in 3" diameter reforming bar. The Free-Co alloy appears to be non-sensitive to "C-Curve Embrittlement" and, therefore, may be forged with high forging temperatures (2100°F).
2. It was demonstrated that shear forming reductions of nearly 80% could be achieved without the need for inter-stage annealing operations.
3. Electron beam welding of cylinder sections was successfully accomplished, with no difficulties. Post weld inspection by X-ray and penetrant confirmed the excellent weldability of this material.
4. Post shear form annealing at 1500°F and aging at 900°F for 4 hours resulted in yield strengths greater than 255 ksi, and tensile ultimate strengths greater than 265 ksi, with 4 to 8 percent elongation.
5. Fracture toughness testing of specimens generated from the shear spun cylinders indicate that the Free-Co material possesses excellent toughness and crack growth rate characteristics.

BENEFITS

This project paved the way for the next phase, which is already underway. The excellent test results experienced to date indicate a high probability of success in achieving the required physical properties of the cobalt containing maraging steel.

IMPLEMENTATION

The results of this project are being carried forward in the continuing effort.

MORE INFORMATION

Additional information may be obtained by contacting Mr. William Crownover at US Army Missile Command, AV 746-5821 or Commercial (205) 876-5821.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 79 3136 titled, "Improved Manufacturing Processes for Compliant Bearing Gyros", was completed by the US Army Missile Command in February 1981 at a cost of \$350,000.

BACKGROUND

Gyros for seeker heads of the type pictured in figure 1 are expensive to manufacture due to the extensive and accurate machining required to produce these precision devices. An improved concept of gyro operation wherein the air bearing gap and caging capability are provided by a compliant layer has been developed. The second and final phase of this effort was to establish a pilot production line, prototype gyros and an automated checkout system.



Figure 1 - COPPERHEAD Seeker

SUMMARY

The first fiscal year defined changes to the gyro assembly to enhance producibility. These included:

- o Adding 2 steel rings to the rotor to facilitate dynamic balancing.
- o Making part changes to allow a molded magnet.

- o Using a multi-cavity mold that permits interchangeability of the compliant layers.

This second phase of this effort produced a pilot production line on which eight compliant bearing gyroscopes were built. Existing balancing machines were inadequate for these gyros since the commercially available units all require structurally rigid bearings. American Hoffman was contracted to produce the balancing machine for these air bearing gyros. An automated checkout station for the completed gyro was also designed and built.

A prototype gyro was cannon launched at Redstone Arsenal at a "G" level of 9,937. Performance was checked before and after the launch with no degradation in performance as a result of the launch.

BENEFITS

The estimated cost to manufacture the compliant bearing gyro is \$434 each. Cost to manufacture the current COPPERHEAD gyro is \$1400 each, therefore, a considerable cost savings can be realized if this process is implemented.

IMPLEMENTATION

The compliant bearing gyro is being considered for the fourth buy of COPPERHEAD in late FY84. It is also being considered for the stabilization gyros in HELLFIRE.

MORE INFORMATION

Additional details relative to this effort may be obtained from Mr. W. G. Robertson, MICOM, AUTOVON 746-6151 or Commercial (205) 876-6151.

Summary report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 579 1903 and 580 1903 titled "Die Cast Tailcone and One-Piece Skin for BLU-96/B" were completed by the US Army Armament Research and Development Command in December 1981 at costs of \$450,000 and \$1,176,000, respectively.

BACKGROUND

During engineering development of the Navy's FAE II weapon system, a major component of the weapon, the tailcone, was designed and fabricated as a sand casting. This is the normal method of fabrication used for prototype or limited production because design changes can be made at minimal cost. However, it is usual that once the design is fixed and ready for high volume production, permanent mold casting is used. Permanent mold casting permits production of more uniform castings, closer dimensional tolerances, improved mechanical properties, and lower cost.

Because of the large size of the tailcone diecasting (weighing approximately 92 lbs), see Figure 1, a modification to existing commercial die casting capabilities was required.

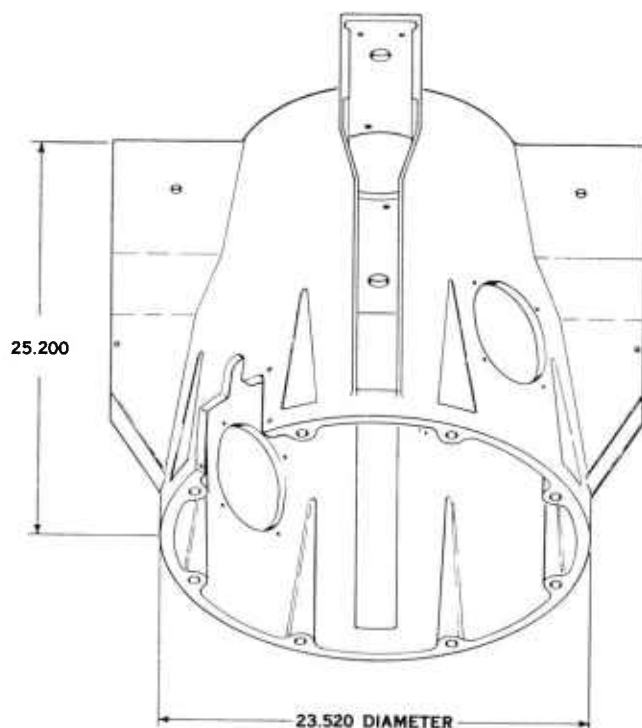


Figure 1 - Tail Cone

SUMMARY

The two main objectives of this project were to: (1) develop die cast tooling and process for the tailcone, and (2) develop a manufacturing process to produce the three-section cylindrical skin in one piece. The main challenge facing the application of die casting technology to the tailcone was to achieve a high integrity casting of dimensions and weight greater than anything previously manufactured as a die casting.

The cast steel holding dies were so large, 22 feet high, 6.5 feet deep and 20 feet wide, that it was necessary for them to extend around and beyond the tie bars of the 3,000 ton machine. These were then machined to accept the major impression blocks which were manufactured of forged steel. The die casting machine and related auxiliary equipment were modified so that sample castings were produced. The castings were found to be dimensionally acceptable with only minor die corrections required prior to beginning Low Rate Initial Production (LRIP). The castings were the largest parts ever cast for a weapons system at 92 pound trim weight. The die corrections were made prior to storage of the die, awaiting initiation of LRIP. Test samples were cast and trimmed for use in the final test of BLU-96 weapons as well as final tailcone acceptance testing.

Final acceptance included recommendations for improved die venting to ensure 100% minimum tensile properties during production sampling inspections. The culmination of this effort has truly advanced the state-of-the-art for die casting by successfully demonstrating that the world's largest die casting can be satisfactorily produced from the world's largest die-casting die. This was the first casting die completely designed by a computer.

In order to roll the skin in one piece, a special two roll machine was designed and built. The machine satisfactorily produced samples for acceptance testing as well as items for assembly into hardware for final test of the BLU-96/B weapons. The skins produced by this machine were found to be dimensionally and mechanically acceptable. Flight testing and the resultant improved weapon performance demonstrated the successful achievement of the project.

BENEFITS

Savings of nearly \$50,000,000 could be realized during the production of 100,000 units. This was the first casting die successfully designed by a computer.

IMPLEMENTATION

Equipment resulting from this project will be used in initial production facility for FAE II BLU-96/B weapons. Meanwhile, the dies and equipment have been stored away awaiting funding for the FAE BLU-96/B. The technology learned is available for other weapons systems.

MORE INFORMATION

Additional information may be obtained by calling the Project Officer, Mr. Donald Herigstad, AV 880-4081 or Commercial (201) 880-9011.

Summary Report was prepared by Wally Graham, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 576 6472 titled "Alternate Processes for Fabrication of Precision Parts for MT Fuzes" was completed by the US Army Armament Research and Development Command in January 1981 at a cost of \$400,000.

BACKGROUND

Large quantities of pinions made from AISI 416 stainless steel are used by all of the Services in various types of mechanical timing devices. An uninterrupted supply of this critical hardware is essential to maintaining an effective state of military preparedness. Pinions are currently manufactured by machining from solid round stock using automatic hobbing machines. These machines as well as their precision carbide cutters are now available only from foreign sources. Two factors make it undesirable to continue this dependency on foreign-made equipment. One is the potential vulnerability to international politics which could adversely affect the accessibility of new equipment and spare parts. A second is the general business decline within the watch industry which now threatens the future availability of pinion machining equipment and the associated manpower skills.

SUMMARY

This situation prompted an in-depth study in the early 1970's of the production base for manufacturing precision pinions within all branches of the military. Based on the results of this study, the decision was made to develop alternate methods and processes for manufacturing pinions that would utilize domestic equipment and skills.

Candidate processes were selected and feasibility programs conducted. Based on the results, hydrostatic extrusion was selected for further development. Figure 1 shows the essential difference between conventional and hydrostatic extruding.

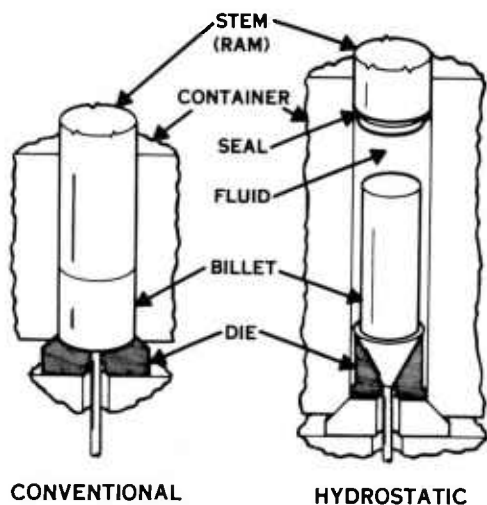


Figure 1 - Schematic Diagram Showing Essential Features of Hydrostatic and Conventional Extrusion Processes

The major portion of this program was directed towards optimizing procedures and parameters for extruding pinion stock suitable for drawing to target dimensions and machining into finish pinions. It was determined that the pressure requirements to extrude pinion stock depended mostly on temperature effects, billet lubrication factors, and critical features of die design. Adjustments in these process variables and extrusion procedures permitted stock for the M564 and M724 pinions to be extruded successfully at a 3:1 ratio (billet to extrusion cross sectional areas) at pressures low enough to obtain acceptable die life. Problems associated with stick-slip that plagued earlier extrusion efforts were minimized by appropriate changes in extrusion speed, billet lubrication, and die design. The extruded M564 stock from these trials was cold-drawn in a single pass to target profile dimensions specified for this pinion. The M724 stock was also drawn to target dimensions. Finished pinions were then machined from selected drawn lengths of the M724 stock on an automatic screw machine, and supplied to the Army for further testing and evaluation. On the basis of the development work conducted in this program, the following conclusions were made:

1. A successful alternative method of manufacturing pinions for mechanical fuzes has been developed which consists of hydrostatic extrusion, drawing, and machining.
2. Extrusion tooling and process parameters have been optimized for warm hydrostatic extrusion of M564 and M724 pinion stock suitable for drawing and machining into finished pinions.
3. Extrusion of up to 130 meters (425 ft) of precision M724 pinion stock in repetitive runs through a single die demonstrated satisfactory performance of the extrusion process and tooling in a prototype-production run on laboratory equipment.
4. A manufacturing cost analysis indicates that this alternative approach should produce pinions at a cost competitive with that for the current process of hobbing.

BENEFITS

This alternative manufacturing method can eliminate U.S. dependence on foreign hobbing equipment and the special tungsten carbide cutters required for hobbing. In addition, it can alleviate the shortage of critical set-up skills needed to operate this equipment.

IMPLEMENTATION

Although the developed process is competitive with existing technology, it is not sufficiently advantageous to justify the replacement of existing facilities on a peacetime volume basis. However, the technology is available for implementation should the need arise.

MORE INFORMATION

Additional information may be obtained by contacting Mr. D. J. Reap of the Armament Research and Development Command at AV 880-5097 or Commercial (201) 724-5097.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 681 7990 titled "Improved Fabrication and Repair of Anodes" was completed by Watervliet Arsenal in September 1982 at a cost of \$98,000.

BACKGROUND

A lead plating facility for the manufacture of anodes is necessary to meet the Watervliet Arsenal cannon tube chrome plating requirements. Dependence upon contractor supplied melted-on lead clad anodes has proven unacceptable from a cost and lead-time standpoint and lacks the quality required for chrome deposit. A facility is required with the capability to repair specific portions of damaged anodes as well as producing new full length anodes.

SUMMARY

This project is the last of a multi-year effort to establish a facility to lead plate anodes of varying lengths and diameters as well as to repair portions of damaged anodes. The chromium plating of a cannon is a difficult task due to the abnormal size of the piece to be plated and the equipment required to process the cannon. The close tolerances specified, both in diameter and along the length of the cannon tube, necessitate an anode which has an even and concentric coating of lead.

Watervliet Arsenal has relied on commercial vendors to apply the lead coating. The cost of repairing damaged anodes is almost as costly as the purchase of a new anode.

The most logical alternative was to develop an in-house capability to apply the lead coating at a lower cost and within a shorter time frame. The method by which this coating was to be applied was by an electrodeposition process that is easily controlled and maintained. When properly balanced, a fine grained lead coating can be deposited to a thickness acceptable for use in chromium plating. The lead-tin fluoborate bath is the most attractive, commercially available plating solution. Available lead plating solutions cannot be used without considerable modification due to the higher deposition rates and longer plating times required. A plating system was modified to include a micro-processor that has the capability of monitoring and controlling the solution flow, solution pH and depletion of additives. The control program establishes the sequence of valve and pump states required for the lead plating of the anode. Evaluation of the operation showed uniform, continuous lead cladding at a deposition rate of 0.005 inch/hr. with a zero taper over the active length of the anode.

BENEFITS

The reduction of lead-time in the preparation of anodes and the ability to repair anodes that would otherwise be scrapped will result in significant cost savings.

The cost of melt-on cladding is \$17,434 per anode as compared to \$1,239 per anode for electrodeposited lead. The lead-time for contractor supplied melted-on lead clad anodes is approximately 100 days versus 4 days for in-house lead electrodeposition. The electrodeposition process also improves the quality of the coating in that it is uniform and does not contain voids and inclusions.

IMPLEMENTATION

The lead plating facility is located in the manufacturing area of the Operations Directorate at Watervliet Arsenal. The process has been optimized and is being used to lead plate anodes.

MORE INFORMATION

Additional information is available in DRDAR-LCB-RT final technical report titled "Improved Fabrication and Repair of Anodes" dated 27 Dec 82 or from the Watervliet Arsenal Project Officer, Mr. T. Pochily, AV 974-5717 or Commercial (518) 266-5717.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 681 8001 titled "Rapid Flow Plating of Small Caliber Gun Tubes" was completed by the US Army Armament Research and Development Command in January 1983 at a cost of \$132,000.

BACKGROUND

The interior surface of 50-caliber gun barrels is currently production plated with chromium to improve wear resistance. The gun barrels are mounted vertically in a sufficiently deep chromium plating tank and an insoluble anode is mounted axially inside each gun barrel. The gas produced at both the anode and gun barrel causes convection in the electrolyte which increases the plating rate and helps to control the electrolyte temperature in each gun barrel. However, plating rates are limited to about 0.001 in. per hour. Thus, two hours are required to plate the 0.002 in. minimum thickness of chromium required. A system with a substantially higher plating rate offers the advantage of a higher throughput of gun barrels, hence increased productivity.

SUMMARY

Rapid chromium plating of small caliber gun tube ID surfaces can be accomplished with high current densities under high solution flow conditions. The deposition rate can be increased 10 to 60 times by providing forced, rapid solution flow at the plating surface. The objective of this program was to optimize process parameters and develop techniques for the rapid chromium plating of small caliber gun tubes.

This project consisted of two tasks. Task A involved an evaluation of throwing power or the change in thickness of the chromium electroplate with the contour along a cross-section inside of a 50-caliber gun barrel. Task B involved the establishment of a test plating line by constructing the electroplating apparatus and experimentally operating it to demonstrate its viability.

In Task A, the evaluation of the electroplate properties along the bore for a number of plating parameters was inconvenient. A large number of tubes would be required which would have to be stripped for reuse. Also, sectioning (destructive inspection) of the tubes would be required to examine thickness variations. Therefore, a simulation technique was necessary for screening a range of experiments. It was estimated that a flow rate of 20 ft/sec represented a practical maximum value. Three grooves with dimensions of the rifling in the 50-caliber guns were machined around the circumference of the

cylinder which was mounted on a threaded shaft between two retaining sections. Several experiments were run with this system and smooth, uniform deposits were obtained from a bath containing 250 g/l of CrO_3 , 2.5 g/l of H_2SO_4 at 45°C .

With a cylinder diameter of 0.25 in., a rotation speed of 18,340 rpm was needed to attain a 20 ft/sec equivalent linear velocity. A carbon brush and slip ring arrangement was used to bring current from the power source to the rotating rod. This arrangement provided more consistent results and the higher current efficiencies expected at high shear velocities as compared to experiments using a 1.0 in. diameter cylinder.

Cylindrical specimens were plated using solutions with a sulfate catalyst and a mixed catalyst. The deposits from the mixed catalyst bath were found to be slightly harder than those from the sulfate catalyst bath. As a result of these laboratory evaluations, it was concluded that either bath tested could be used for the plating of gun bores. In the interest of simplicity, the bath containing only the sulfate catalyst was chosen for gun-bore plating trials.

Task B included the design of a plating system that was predicated on the use of a 0.375 in. diameter insoluble anode positioned axially in the section of the gun barrel to be plated. A schematic diagram of the flow system is shown in Figure 1. The internal surface area to be plated was approximately 50 in^2 . The system was designed to provide 1000 amperes between the anode and gun tube. The gun was positioned vertically with the breech end at the bottom. A 100 gallon plastic-lined steel tank held the plating bath. A pump capable of delivering 60 gals/min was mounted on the tank. A range of flow velocities from 1.5 to 21.6 ft/sec was evaluated. Current densities of 1.5, 2.75, and 3 amp/ cm^2 were applied for varying times. Adhesion of the deposit was tested and it did not flake or spall on any of the tubes. The bore diameters were measured and the results showed the fast-rate plated tubes were within tolerance and were tapered properly.

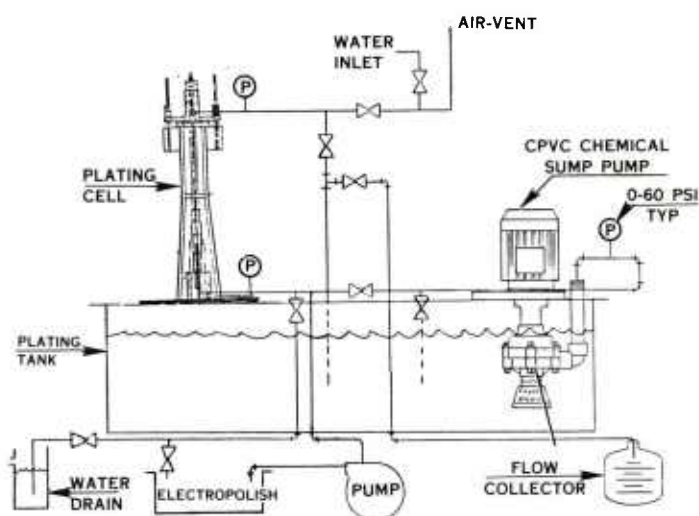


Figure 1 - Lead Plating Facility Diagram

BENEFITS

Smooth, adherent chromium can be electroplated inside the bore of 50-caliber gun barrels by the rapid flow plating process. About 0.003 inch of chromium was deposited in the bore in a period of about 12 minutes when a current density of 1.5 amp/cm² was used. The rate of deposition was about 15 times that for conventional plating. Taper of the bore toward the muzzle end could be accomplished by adjusting the current and electrolyte flow conditions.

IMPLEMENTATION

The work accomplished in this project on the optimization of process parameters for rapid flow chromium plating for a single barrel system (50 caliber) will be continued. The follow-on program will be a part of the Small Arms Weapons New Process Production Technology Program, Project No. 682 7985, Task D. A 3-barrel prototype plating system will be designed, fabricated, and optimized using the rapid flow plating process.

MORE INFORMATION

Additional information may be obtained from G. R. Lakshminarayanan, ARRADCOM, AV 880-5746 or Commercial (201) 328-5746.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 678 8043 titled "Improved Machining Procedures for Dovetails" was completed by the US Army Armament Research and Development Command in July 1980 at a cost of \$88,031.

BACKGROUND

The coupling of large caliber cannon tubes to the recoil mechanisms is accomplished through the slide ways. The slide rails are attached to cast steel or nodular iron hoops which have been shrunk onto the cannon tube. The slide rails are attached to the hoops through dovetail slots that are machined into the hoops. The dovetail slot configuration is used to provide maximum contact area between the rail and hoop and thus give the assembly high strength. (Figure 1).

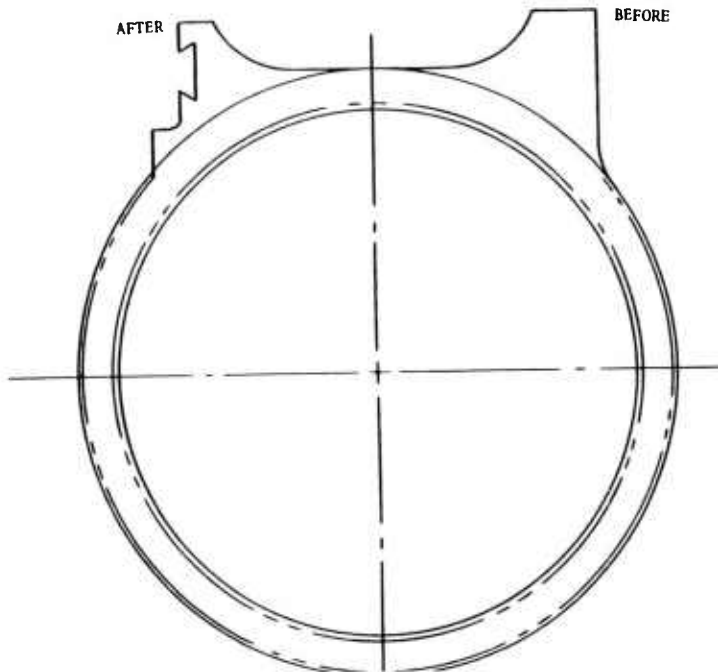


Figure 1 - Hoop Configuration Before and After
Dovetail Operation

Current production methods use a number of milling cuts to obtain the final configuration within the close tolerances required. High speed steel mills make a series of rough and finish cuts. Because this has to be accomplished in a series of passes, there is a possibility of mismatching the assembly surfaces.

Common industrial methods of dovetailing include broaching and milling. Broaching greatly reduces machining error, but it requires very expensive specialty equipment with little conversion capability and high tool maintenance costs. Milling allows the use of readily available equipment but requires frequent tool maintenance and operator intervention.

SUMMARY

The goal of this project was to develop a process that would simultaneously minimize the possibility of machining error and effect a substantial cost savings. An evaluation of the dovetailing process was conducted, including review of the number of cuts required, amount of stock removed, tolerances, and size and weight of the machined component. Based on this and additional studies, milling was chosen as the most practical means of production.

A relatively new procedure using two cross axial milling heads was adapted to produce the dovetail. (Figure 2).

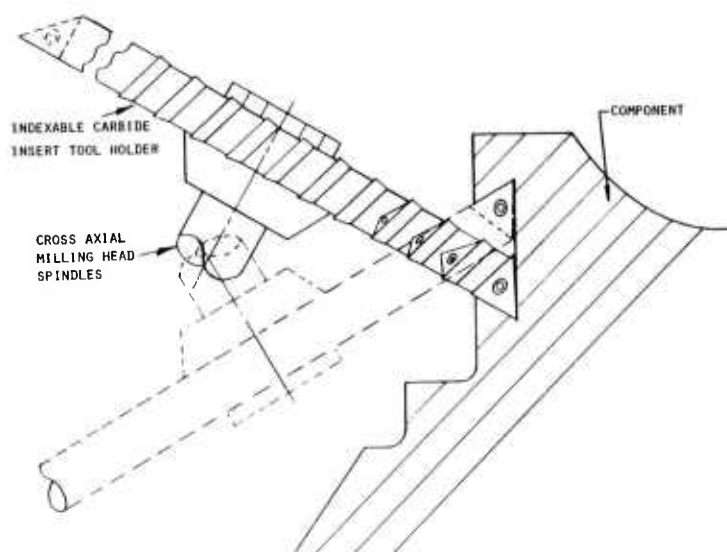


Figure 2 - Proposed Method of Machining Dovetails

The spindles of these milling heads will accommodate large diameter tool holders capable of securing indexable carbide inserts ground to the required configurations. These cross axial milling heads will be part of an interchangeable system mounted by means of a mechanical lifting device. When that portion of the operation is completed, the heads will be removed from the machine and stored.

The milling machine will be CNC controlled with a stationary worktable and two traveling columns to allow simultaneous machining of both sides of the tube/hoop assembly. Initially, the vertical and horizontal centerlines will be established with a series of rough and finish cuts. Next, a one inch slot will be milled in each side of the hoop, establishing the depth and vertical location of the dovetails. The cross axial heads will be mounted and the dovetails will be roughed in a single pass and finished in a subsequent pass.

A specification was prepared for the purchase of equipment to permit the rough and finish machining of the dovetail configuration and preliminary operation on the tube/hoop assembly.

BENEFITS

The machine design specified by this effort replaces no fewer than five Ingersoll milling machines previously used to perform the operations. The time standard will be reduced from 33.41 hours per piece to approximately 5 hours.

IMPLEMENTATION

The equipment and techniques generated as a result of this project will be acquired under project MOD 680 8015 REARM.

MORE INFORMATION

Additional information on this project may be obtained from Mr. Gary Conlon, AUTOVON 974-5611 or Commercial (578) 266-5611.

Summary Report was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project T 79 5045 titled, "Spall Suppressive Armor for Combat Vehicles (Phase I)", was completed by the US Army Tank Automotive Command (TACOM) in June 1980 at a cost of \$150,000.

BACKGROUND

The detonation of an impacting HEAT or a near-miss HE projectile can shatter a lethal volume of metal spall from the interior surfaces of lightly armored vehicles. Woven plastic/fiber composite liners have demonstrated a capacity to reduce crew exposure to spalling. Successful installations of composite liners have involved custom fitting and mechanical attachment of large panels.

The economic basis for conducting this project was to improve the utility of ballistic liners. By establishing manufacturing parameters and novel attachment techniques for a sectional liner system, versatile installation in various vehicles would be made possible. A pattern of mass-produced tiles could yield a level of crew protection comparable to that provided by custom fitted panels at lower cost.

This project, the first year of a two-year program, was conducted through in-house effort at TACOM and contractual effort at FMC Corporation, Ordnance Division, San Jose, CA.

SUMMARY

The contractor's investigations were centered on the construction and installation of prototype armor kits for the interior of the M113A1/A2 Armored Personnel Carrier. Development of the kit, utilizing Kevlar 29/PVB-Phenolic panels, was conducted through the analysis of the internal structure of the vehicle. The most critical areas of personnel vulnerability were determined. Those areas were then studied for the integration of the best ballistic protection at reasonable cost.

For effective spall suppression, the liner was required to withstand a 50 psi pressure differential. The 50 psi criterion was determined by prior ballistic testing.

Overhead liners were attached directly to the ceiling. Ramp and ramp door liners were attached in direct contact with the inner plates of both. Because of the magnitude of the calculated anchoring forces, the idea of using an adhesive anchoring system was abandoned. The idea of using a pattern of prefabricated tiles was also abandoned. The use of screws for the attachment of custom panels was chosen. Optimal spacing of attachment screws

provided sufficient liner deflection while ensuring uniform fastener loading. Side wall liner panel assemblies were installed in sliding track mounts which were mechanically attached to the ceiling at their top edge and to the sponson lip at their bottom edge. Figure 1 illustrates the installed positions.

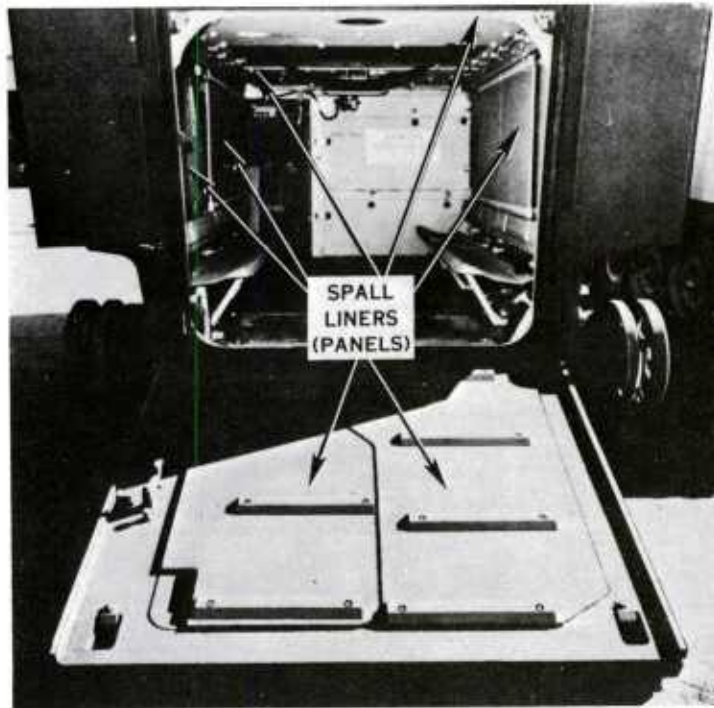


Figure 1 - Carrier Interior and Exterior

The modification or relocation of existing carrier components was avoided wherever possible. The armor kit contained 107 components (not counting assorted screws, washers, shims, nuts and rivets) and weighed 714 pounds.

BENEFITS

No manufacturing benefits were derived from this project since most of the work was devoted to the installation of armor kits for a product improved M113A1/A2 Carrier. However, the work that was accomplished did result in the delivery of three complete sets of armor and installation hardware. The armor will be subjected to a series of road tests and ballistic evaluation during the second year of the program.

IMPLEMENTATION

Since this project did not expand known composite manufacturing technology, the prospect of translating a new technique into a practical production setting does not exist.

MORE INFORMATION

Additional information on this project is available from Mr. Avery Fisher, TACOM, AUTOVON 786-5443 or Commercial (313) 574-5443. The technical report from the contractor is number 12259, "Spall Suppressive Armor System for M113A1/A2 Armored Personnel Carrier."

Summary report was prepared by Gaylen Fischer, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project T79 5090 titled "Improved and Cost Effective Machining Techniques (Phase II)" was completed by the US Army Tank-Automotive Command in July 1982 at a cost of \$446,000.

BACKGROUND

Many tracked vehicle components are expensive and require long lead times to produce. This is typically the result of poor manufacturing system performance particularly when the choice of the machining technology used is made without the benefit of specific machining data. This lack of data often leads to the selection of suboptimal tooling and inefficient machining parameters. This results in longer lead times, poor scheduling, and higher manufacturing costs.

The purpose of the three-year effort is to develop improved and cost effective combinations of cutting tools, cutting fluids and machining conditions such as speed, feed, and depth of cut for each of the important machining operations and specific grades of alloy steels, cast irons, and other materials used for TCV components.

Phase I entailed developing cost effective face milling, end milling, turning, drilling, reaming and tapping technology on difficult to machine parts which included armor plate flame cut surfaces and base material, cast armor, high temperature engine alloys, and alloys used in high production for chassis and engine parts such as 4140, 4340 and 17-4 PH.

SUMMARY

This effort consisted of planning machining tasks, conducting machining tests, selecting cost-effective machining conditions, and developing a machinability handbook.

Data was generated for machining operations for various combinations of test conditions. These included 40 primary alloys, 31 micro-structure types, 21 methods of heat treatment, 49 cutting tool materials, and 10 turning and face milling inserts. Ten different classes of cutting fluids were also utilized.

A data storage and retrieval system was developed for the data from this and other machinability studies. Features of the system include interactive access and data analysis, modeling capabilities, data sorting and searching, and listing capabilities.

The input machining conditions, work material, cutting tool and depth of cut are entered into the data analysis package along with the output test results, and measured tool life. The data is then passed to the report generating package which maintains listings of the original test data. The predicted tool life values are merged with the data from previous reports so a handbook of recommended starting points for cutting conditions can be maintained.

BENEFITS

Data obtained during this project will enable selection of the most efficient and least expensive tooling for machining operations. The cost of expensive and time consuming trial operations will be eliminated in the majority of machining set-ups. Further, lead time and scheduling manufacture of components will be improved and total manufacturing cost will be reduced.

IMPLEMENTATION

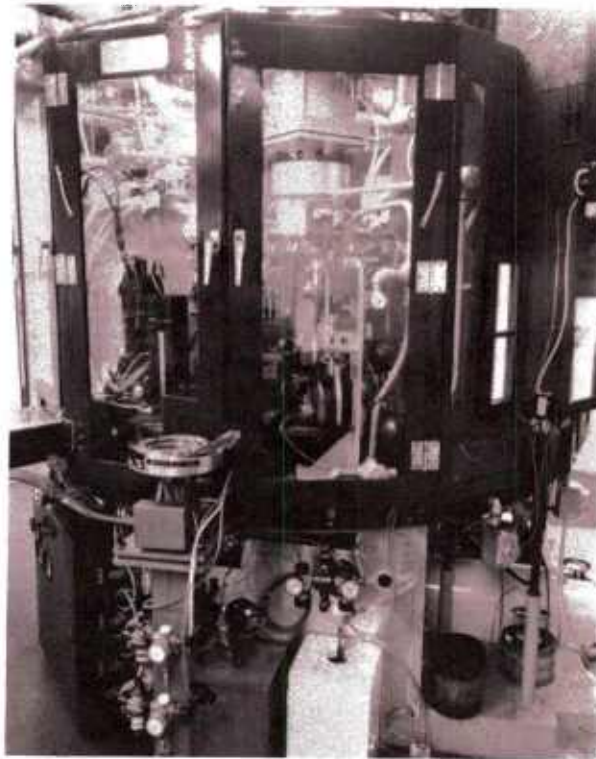
Data is being transferred to machining contractors through briefings and machining problem solving at manufacturing plants. A machinability handbook will also be made available to Government contractors at the conclusion of Phase III for the efficient utilization of machining data.

MORE INFORMATION

Additional information may be obtained from Mr. S. Sharma, TACOM, AUTOVON 786-8711 or Commercial (313) 573-8711.

Summary Report was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MUNITIONS



IOWA AAP DETONATOR LOADER

ABSTRACTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
381 1050	Low Cost Braided Rocket Motor Components	MU-5
<p>This project devised the technology to fabricate Rocket motor cases utilizing braided fiberglass/resin composite on a breakdown mandrel. The development of an optimum end closure, hardware attachment methods, and non-destructive testing methods was highly successful. Four-ply braided tubes were destructively tested and demonstrated few irregularities. Project findings will be implemented in a follow-on effort.</p>		
378 3228	Production Methods for Extrudable HTPB Propellant	MU-8
<p>The objective of this project was to reduce manufacturing costs and increase production rates by eliminating several of the current motor production stages and automating the propellant grain manufacture, loading and curing. The result was an economical manufacturing process for producing VIPER training rounds.</p>		
R80 3294	Production Process for Rotary Roll Forming	MU-11
<p>The high production volumes and similar shapes of tactical rocket motor cases make them ideal candidates for generic manufacturing processes. This project evaluated a variety of nozzle forming processes and demonstrated the cost-effectiveness of spinning with a fully automatic control cycle. The formed nozzles showed good thickness control and repeatability. Further development will be undertaken in the follow-on project.</p>		
579 4064	Automated Load Assemble and Pack Operations for 105mm Tank Cartridges	MU-20
<p>The objective of this project was to improve item quality, achieve labor savings, shorten lead times, lower end item cost, and achieve higher production rates. The approach was to design, build, and install an automated line to load and assemble a family of 105mm tank cartridges. The designed system is expected to produce any of six types of 105mm tank rounds at a rate of 10 rounds per minute. An estimated annual savings of \$4.5 million can be achieved through the total system under peacetime production requirements.</p>		

577 4281-A08
578 4281-A08

Cavitation Removal of Explosives

MU-26

This project investigated cavitating water jet technology as a method for removing explosive from rejected projectiles. An experimental facility utilized the CAVIJET cavitating fluid jet process to examine the effect of translation and rotation rates, pressure, and nozzle size and type on explosive removal from 105mm projectiles. The system appears to offer a 27% potential cost savings, a 95% probability of safety, and greater versatility than current techniques.

580 4288

Explosive Safe Separation and Sensitivity Criteria

MU-29

This project developed safety criteria for explosive production facilities based on tests at Milan AAP. Areas investigated included safe spacing of projectiles under loading plant conditions and at different stages of assembly. The tendency of various propellant types to explode was evaluated. The findings were incorporated in the design of load-assembly-pack lines at Milan and Mississippi AAP.

576 4303
577 4303

Acceptance of Continuously Produced Black Powder for Artillery, Mortar, Rocket Systems

MU-32

This project was designed to assure reliable performance of black powder produced by the continuous process. Special powder lots were prepared and an apparatus constructed to measure the flame spreading rate through a loosely packed bed of black powder. The flame spreader will reduce analytical testing of powder and should prove useful as a diagnostic tool during modern facility proveout.

579 4312
580 4312

Injection Molding for Production Explosive Loading

MU-34

Melt-pour loading of small munition items results in excessively large amounts of riser scrap in relation to the amount of explosive actually loaded. Injection loading by syringe action was successfully developed for loading BLU 63 bomblets with cyclotol 70/30. Horizontally dispensed syringe injection of 75/25 octol into anti-armor cluster munitions also produced high quality casts. The prototype equipment and procedure developed reduced scrap rates from 200-400% to 10% and reduced personnel exposure to hazardous materials.

577 4462	Modernized Forced Air Dryer (RAD) For	MU-37
578 4462	Multi-Base Propellants	
579 4462		

The objective of this effort was to establish a prototype facility and design criteria to modernize the present FAD houses. Design criteria for similar facilities at both Radford and Sunflower AAP were developed. Federal and state regulations for organic vapor emissions will be met which will significantly improve the environmental quality by reduction in hydrocarbon and NG emissions.

580 4462	Modernized FAD For Multi-Base Propellants	MU-40
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The objective of this project was to install, debug, and evaluate the modernized FAD bay and the associated pollution abatement and solvent recovery systems. The project demonstrated the propellant drying capabilities of the modified FAD bay operating at reduced flow rate and increased load. Also, it demonstrated the capability of the associated pollution abatement to meet federal and state regulations.

578 4466	Evaluation of TNT, Cyclotol, Octol With	MU-42
579 4466	ARRADCOM Melt-Pour Facility	

This project evaluated the current ARRADCOM Composition B continuous melt-pour line for the loading of TNT slurries and the development of an automated feed/mixing system for molten/flake TNT. Prototype equipment was fabricated and 155mm, M549 projectiles were filled with TNT slurry resulting in piping and defect free casts. The mixer system eliminated the need for cast probing and reduced slurry preparation time.

579 4508	Process Improvements for Pressable RDX Compositions	MU-48
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Severe dusting problems were encountered in the A-7 RDX drying operations at Holston AAP. A four-step modification process included enclosing the discharge area, a recycling system for the dried product, and piping for clean filtered water in the scrubbers. An operation mode utilizing water from the filtrate distribution tank in the scrubbers and hydrocyclone was chosen resulting in the capability of drying A-7 explosive to 2% moisture at a rate of 1401 lb/min.

576 6200

Small Caliber Ammo Process Improvement
Program

MU-51

This project supported the development of new and improved methods for producing 5.56mm to .30 caliber ammunition. Areas of emphasis included reduction of scrap, improved functioning of part detectors, and a Process Quality Control Computer System. Integration runs and a ten million piece test run were performed on the installed SCAMP module. The information obtained is being used for updating several additional SCAMP lines.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 3 81 1050 titled, "Low Cost Braided Rocket Motor Components" was completed by the US Army Missile Command (MICOM) in May 1982 at a cost of \$430,000.

BACKGROUND

Army production goals have dictated a reevaluation of current rocket motor component materials and fabrication processes. Because tactical missile cases for the General Support Rocket Systems (GSRS) and the Stinger comprise up to fifty percent of the propulsion system costs, a manufacturing technology effort was considered essential to permit further cost reductions. Recent research has led to the concept of braiding a fiber-glass/resin composite onto an accurately dimensioned mandrel. The purpose of the manufacturing technology effort was to optimize the conceptual process for an integrally braided case/nozzle configuration.

Project work was accomplished by in-house effort at MICOM and contractual effort at McDonnell Douglas Astronautics Company, Titusville, Florida.

SUMMARY

The contractor was required: (1) to evaluate braiding materials and braiding mandrel designs and establish preparation procedures for both, (2) to establish automatic braiding and resin application techniques, (3) to establish optimum end closure and integral hardware attachment methods, and (4) to apply nondestructive test methods for screening critical braiding and bonding defects. Each of these requirements was achieved.

A brief investigation of substitute braiding materials led to the selection of the benchmark material, S glass yarn. Attempts to braid with significantly cheaper E glass and S glass roving materials were unsuccessful. Based on the comparison among mandrel types it became evident that a break-down mandrel was the most cost effective approach for this program. Its external surface was TEFLON coated to reduce clean up after braiding.

An automated resin application process, designed to apply the resin onto the glass prior to the glass contacting the mandrel, was selected. The system consisted of two reciprocating ring spray machines which utilized airless spray guns. The epoxy spray pattern was not aimed directly at mandrel, but three inches to either side of the glass/mandrel interface. This approach maximized fiber wetting and eliminated all resin application time. The resin applicators and the braider are shown in Figure 1.

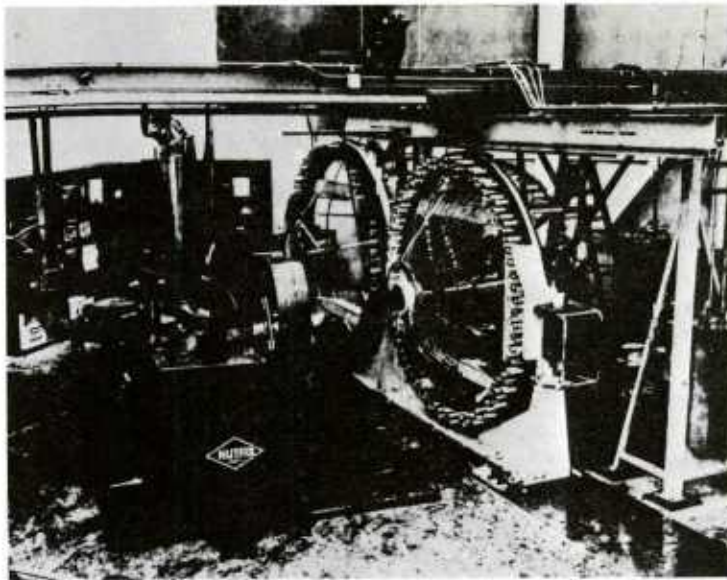


Figure 1 - Braider and Automatic Resin Applicators

The braider was completely automated. A McClean Anderson N-101 micro-computer was installed to control the McDonnell Douglas braider. The original mandrel drive system motors were replaced by servo motors to provide faster start/stop capabilities and microcomputer compatibility.

The selection of the breakdown mandrel allowed the nozzle to be braided-in-place, thus becoming an integral part of the rocket motor case. The head end had to be left open to permit the extraction of the mandrel. The head end closure retainer, therefore, was adhesive bonded to the braided tube after final cure. A fin body assembly was bonded to the aft end of the motor case. Motor case configuration is shown in Figure 2.

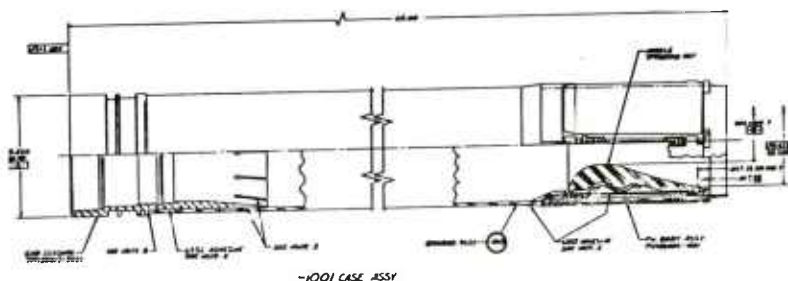


Figure 2 - MMT Rocket Motor Case

Evaluations of nondestructive testing devices were based on their abilities to detect defects in samples with known anomalies. The braided samples contained built-in voids, porosity, delaminations, foreign objects, cracks, interlaminar separations and broken fibers. A fluoroscopic imaging system readily found delaminations, separations, and foreign objects but none of the other defects. An infrared scanner system found voids, delaminations, cut fibers, foreign objects and areas of unmixed catalyst. Ultrasonic testing yielded negative results. Spectrophotometer testing was found useful in locating and rejecting composites manufactured with improperly mixed resin and catalyst or without sufficient total cure time. Holographic testing was considered but not tried due to high cost. The infrared scanner and fluoroscopic imaging systems were the most promising but neither could reliably detect defects smaller than 1/8 inch.

Four-ply braided tubes, 32 inches long by 5 inches inside diameter, were prepared for use as destructive test specimens and subjected to environmental and hydrostatic burst tests. Few irregularities were detected during this test series. Two 64-inch long motor cases complete with integral nozzles, bonded end closures, and fin body mockups served as the verification test items. The minimum burst requirement was 3500 psi. Both items failed where the fin body was bonded to the case but both surpassed the requirement by at least 2220 psi before failure occurred.

BENEFITS

The project has demonstrated a useful technique for the automated manufacture of braided motor cases which meet performance requirements. The interim technical report includes preliminary processing specifications, quality control data, material requirements, and equipment requirements.

IMPLEMENTATION

Implementation of the project will be deferred until the completion of the follow-on MMT project, 382 1050. The follow-on project will demonstrate the concept on full scale motors, will deliver production components for test firing, and will provide final manufacturing procedures.

MORE INFORMATION

Additional information on this project is available from Mr. William S. Crownover, MICOM, AUTOVON 746-5821 or Commercial (205) 876-5821. The interim technical report by the contractor is RK-CR-82-6, "Manufacturing Methods and Technology for Low Cost Braided Rocket Motor Components."

Summary report was prepared by Gaylen Fischer, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCNT-302)

Manufacturing Methods and Technology Project 378 3228 titled "Production Methods for Extrudable HTPB Propellant" was completed by the US Army Missile Command in February 1980 at a cost of \$200,000.

BACKGROUND

The current production of high volume, solid composite, small caliber rocket motors involves a number of time consuming and costly steps. For example, the propellant is batch mixed, cast into the motor, cured, and trimmed. A mandrel must also be inserted to provide the proper grain geometry and later removed after curing the propellant from 7 to 14 days. An earlier project demonstrated that some classes of small rocket motors could be injection molded. It was also suggested that some parts of the process could be automated.

SUMMARY

The objective of this program was to reduce manufacturing costs and increase production rates by eliminating several of the current motor production stages and automating the propellant grain manufacture, loading and curing. The most practical approach appeared to be to match quick-cure propellant technology to automated processing equipment.

The basic effort had two primary technical thrusts: (1) propellant formulation and (2) processing studies. Under the propellant formulation studies, an HTPB propellant was selected which was within the state-of-the-art with respect to ballistic and physical properties. It contained a minimum of 86% by weight of solids, and had a burn rate equal to or greater than 0.5-inch/second at 1000 psia. This propellant was chemically modified so that the cure rate was compatible with the injection molding process for the manufacture of propellant grains. Once the cure system was optimized, the propellant was characterized for ballistic, mechanical, processing and safety properties. The cure system used in this basic propellant was verified as effective in the VIPER propellant formulation.

The processing studies used an inert propellant formulation and progressed to live propellant as the final process evolved and all safety hazards were identified. The key processing parameters were established and analyzed against the propellant cure and safety characteristics. The effects of variables on the manufacturing process were determined and the finalized process demonstrated in a series of runs designed to demonstrate reproducibility. Live rocket motors were loaded and tested at Atlantic Research and six live motors delivered to USAMC. An analysis was performed to determine the potential cost savings in Viper motor production.

In Phase II, the VIPER Trainer Rocket Motor was selected as the subject for further characterization and pilot production. See Figure 1.

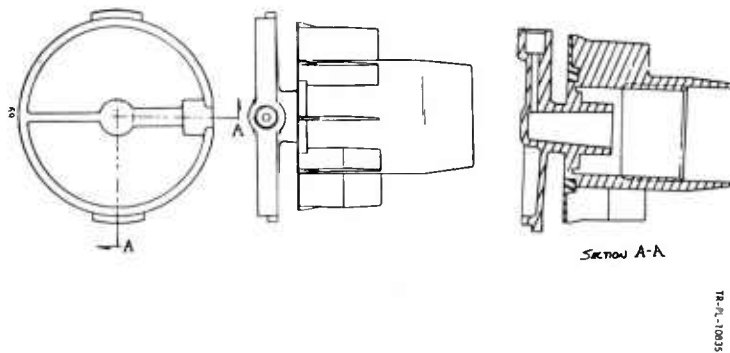


Figure 1 - VIPER Trainer
Propulsion Unit Nozzleless
Fin/Retainer Assembly

Propellant characterization tests were performed to evaluate pot life, flow, cure and mechanical properties of quick-cure modified Arcadene 358 used in the rocket motor.

A detailed design for prototype equipment to be used for loading VIPER trainer propulsion units was created to utilize the type process demonstrated in the basic effort. The components of the prototype equipment were procured, fabricated, assembled, and the equipment checked out to assure that performance and safety requirements were met. As it turned out, VIPER trainer rounds proved to be a poor choice since this motor case is only about 3/4 inch diameter and is closed at one end. This dictated that the several operations of the original automated process all be performed through one 0.75" opening. This led to the use of fragile parts which could not endure the combined thermal and mechanical stresses imposed upon them.

Even so, the process finally selected for loading VIPER trainers was an automated one. The distinction between the selected process and the one originally intended is that the selected process consists of automating conventional processing steps. The originally intended process would have injection molding of the propellant in a manner similar to injection molding of plastics.

In the selected process, motor cases on a conveyor pass under a device which automatically dispenses the correct amount of uncured propellant into each tube. The conveyor then moves each case to a station where a mandrel is inserted, and the case is quickly heated to 350°F for a very few minutes to cure the propellant. The motor is cooled rapidly and the mandrel is removed, completing the loading cycle. All the above steps are performed on automated equipment.

In addition to a process for loading VIPER trainer rounds, the project demonstrated that injection molding of quick-cure propellants is a feasible production method for small rockets where adequate openings into the case are available.

BENEFITS

This project resulted in an economical manufacturing process for producing VIPER trainer rounds. Economy will result from automation of processing steps and from the elimination of a large hardware inventory associated with conventional processing and cure technology. Areas of application include the loading of any small size, high production rate rocket motor which can utilize quick-cure propellant.

Cost reductions will be a function of the total number of rocket motors produced and of production rate. Automated equipment will require more capital investment but will reduce the unit cost of motors. The hardware inventory reduction will be a function of production rate. There will also be savings in energy costs due to the very short cure cycle.

IMPLEMENTATION

The result of this project was a process and facility for the production of VIPER trainer rounds. Based on the technology developed in this project, the contractor designed, fabricated, installed and checked out a production facility capable of large scale production of trainer rounds. Subsequently, however, the VIPER project office, for reasons unrelated to the process or quality of the round, decided not to produce the trainer round. The facility remains available and could be started up on short notice if needed.

MORE INFORMATION

Additional information on this project is available from Mr. Henry C. Allen, MICOM, AV 746-1841 or Commercial (205) 876-1841.

Summary Report was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project R80 3294 titled "Production Process for Rotary Roll Forming" was completed by the US Army Missile Command in February 1983 at a cost of \$300,000.

BACKGROUND

Motor cases for tactical rockets have at least two factors in common: high production volume and a similar shape, although the sizes vary. Therefore, generic manufacturing processes have general applicability to these systems. The use of a low cost mill product, such as line pipe, and a high volume manufacturing technology would provide a significant reduction of production costs applicable to the entire group of tactical rockets currently being manufactured or planned for production.

Line pipe, in particular electrical resistance welded (ERW) mechanical tubing or pipe, can be purchased as a standard mill product, and subsequently heat treated to achieve mechanical properties equivalent to SAE 4340 or titanium alloys, on a strength-to-weight basis. ERW pipe and tube possess excellent wall thickness control. The thickness control and cost make this material particularly amenable to precision forming processes and the reduction of tactical rocket manufacturing cost.

SUMMARY

The objective of the first phase effort was to evaluate, justify, and specify the optimum processing sequence, with full nozzle forming, for manufacturing rocket motor cases from mill products. Cost analyses, forming trials, and other required analyses were performed to justify and specify the lowest cost process. The Subscale Process Verification concluded with delivery to MICOM of twenty formed tubes using the justified, optimum process. The results of the program effort and MICOM's evaluation of the delivered cases will provide justification for MICOM approval of an Option 1: Full-Scale Process Demonstration.

The target motor case dimensions are shown in Figure 1. This design was established with MICOM approval as a representative product, produced from 8-5/8-inch diameter AISI/SAE 1035 steel ERW mechanical tube. Actual diameter dimensions and tolerances are functions of the processing sequences, and consequently of cost, and were treated as variables for cost trade-off considerations.

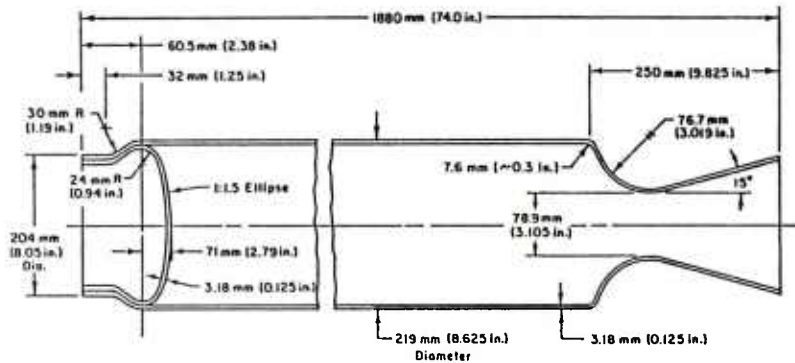


Figure 1 - Experimental Motor Case Target Design

The following nozzle forming processes were considered:

- (1) Rotary roll forming
- (2) Shrink forming
- (3) Radial forging
- (4) Explosive forming
- (5) Spinning:
 - ° Single-roller
 - ° Three-roller

The following variants of the spinning process, which evolved during the program, were also considered:

- (1) Incremental radial infeeds with each of a series of axial traverses.
- (2) Continuous radial infeeds of form tools with no axial traverse.
- (3) The potential cost impact of improved machine controls.

The results of this first of a two-phase program have demonstrated that spinning with fully automatic cycle control is the most cost effective and essentially risk-free approach to nozzle forming. The automatic cycle, either electro-mechanical or CNC, was determined to be necessary to achieve good thickness control (approximately ± 0.005 inch) and overall process or form repeatability. Because of the requirement for heat treatment after forming, it is anticipated that removal of resulting form distortion will require sizing and straightening. However, the thickness control and precision form provided by spinning should eliminate difficulties in achieving near standard tolerances in the heat treated and sized-straightened product.

Three-roller CNC spinning of full-size tubes was proposed for the second phase effort subject to MICOM approval. This method was proposed because it is most cost effective based on the cost estimates, and the trial machine was the only known three-roller CNC machine with the required bed length.

BENEFITS

This project establishes the optimum process for the manufacture of rocket motor bodies from ERW steel tubing, and paves the way for the phase II concept demonstration, testing and preparation of detailed manufacturing procedures.

IMPLEMENTATION

Project results are incorporated in the FY81 follow-on effort.

MORE INFORMATION

Additional information may be obtained by contacting Mr. William Crownover of the US Army Missile Command at AV 746-5821 or Commercial (205) 886-5821.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 580 4037 titled "Process Improvements for Plastic Bonded Explosives" was completed by the US Army Armament Research and Development Command in March 1983 at a cost of \$255,800.

BACKGROUND

The present methods for the production of PBX (plastic bonded explosives) Compositions and Composition C-4 made use of facilities which were required for the manufacture of Composition B during mobilization. Due to this conflict, a limitation in the total production capacity for both Composition B and the PBX Compositions was apparent. In addition, the present batch processing of PBX Compositions are production limited due to low capacity in formulating, filtering and drying. Earlier efforts, under MMT projects 57T 4252 and 577 4252, emphasized coating and formulating of Composition C-4.

This project generated data for manufacturing processes of PBX Compositions in support of production requirements. This included the investigation of present processing methods as well as applying new technology to coating, drying, and finishing PBX Compositions.

SUMMARY

The objectives of this project were to develop and evaluate improved methods for formulating, dewatering, and drying explosive products containing RDX and various binding or coating agents. Emphasis was placed on four PBX's: PBX C-117 precoat, PBX W 109 precoat, PBX 0280, and LX-14-0. The precoat were not regularly produced at Holston AAP; whereas, the PBX 0280 and LX-14-0 are regular production items. The approach was to develop methods for producing C-117 and W 109 precoat and improve the methods for producing PBX 0280 and LX-14-0.

PBX C-117, PBX W109

PBX C-117 and W109 are plastic bonded explosives used by the Navy for the Explosives Advanced Development program. The C-117 contains dioctyl maleate (DOM) and RDX (Type II, Classes 3,5) and W-109 contains dioctyl adipate (DOA) and RDX (Type III, Classes 1,5). Laboratory studies were conducted on coating the RDX with wet and dry coating techniques. The wet coating techniques involved coating an RDX/water slurry with DOA or DOM for 15 minutes with agitation at ambient temperature. This coating process was done either before or after blending the two RDX classes. Since both the DOA and DOM were insoluble in water, the RDX was readily coated in the water slurry. The water slurry technique was successful in producing PBX's meeting specification requirements.

A number of dry coating techniques were evaluated for the PBX's. These were the rotary coating pan, twin-coned blender, incorporation kettle, fluidized bed, Gemco formulator/dryer, jet-o-drier, Wurster air-suspension, and coating drums. All of the techniques evaluated suffered from major problems such as inability to obtain a homogeneous blend, electrostatic charge buildup, dusting, small material throughput, and excessive capital cost. Therefore, the dry coating techniques were eliminated from further consideration.

PBX 0280, LX-14-0

PBX 0280 contains 5% estane and 95% RDX (Type II, Classes 5,7). The current process consisted of adding an estane/methyl ethyl ketone (MEK) lacquer to an RDX/water slurry. This causes the RDX and estane to agglomerate and form granules. The MEK is removed by distillation and the PBX is then filtered and dried. LX-14-0 was produced by a process similar to PBX 0280 with minor variations. The objective was to develop another process to increase the capacity and reduce the overall cost of the product without reducing quality.

A new process, called the direct coating process, was developed for producing PBX 0280 and LX-14-0. This process eliminated the lacquer preparation in the current process by adding ground estane to an RDX or HMX, water and MEK slurry. The ground estane was dissolved in a short time in the slurry. No significant differences were found in the specification properties and performance of PBX 0280 and LX-14-0 made by the direct coating process in the laboratory with production made material. A photograph in Figure 1 is a comparison of PBX 0280 and LX-14-0 made by the direct coating process. The pictures reveal no differences in the products made by the direct and current coating process.

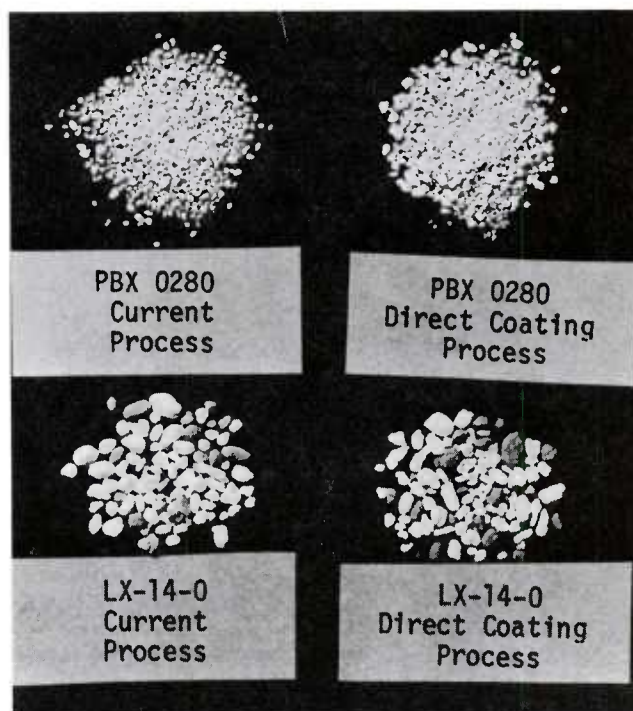


Figure 1 - Comparison of PBX's Made by Current and Direct Coating Process

Filtering (dewatering) and drying studies were conducted to determine the best methods for use on the PBXs. Three filter media candidates exhibited satisfactory filtration characteristics in the laboratory for filtering C-117 precoat, W 109 precoat, PBX 0280 and LX-14-0. These candidates included Tetko's polyester PE7-1050K-50 and PE7-110K-31 and Eimco's polypropylene POPR-853F. These materials were suitable for use on the Eimco traveling belt filter.

Moisture left after filtration of C-117 precoat, W 109 precoat, PBX 0280 and LX-14-0 was essentially all surface moisture. Based on drying studies of similar materials having surface moisture, it was determined that these products were suitable for drying in dryers similar to the Wyssmont Turbo Dryer. This type turbo dryer is currently being procured under MMT project 580 4508. The filtering and drying of the PBXs will be evaluated under MMT 580 4508.

BENEFITS

Water slurry techniques were developed for the successful formulation of PBX C-117 and PBX W 109 precoat. The development and use of the direct coating process for PBX 0280 could result in reduction in production costs. A reduction in overall costs was attained by increasing the batch size of PBX 0280 and LX 14-0 to 2,000-4,000 pounds.

IMPLEMENTATION

The batch size for PBX 0280 and LX-14-0 have been increased to 2,000 and 4,000 pounds, respectively, at Holston AAP.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. J. Dowden, ARRADCOM, AV 880-4122 or Commercial (201) 328-4122.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 579 4059 titled "Optimization of Nitroguanidine in M30 Propellant" was completed by the US Army Armament Research and Development Command in September 1982 at a cost of \$271,000.

BACKGROUND

The particle size of nitroguanidine (NQ) is an important parameter in controlling the ballistic performance of triple-base propellants. The current method for determining particle size, Fisher Sub-Sieve Sizer (FSSS), employs the air-permeability method for measuring the average particle size of a powder. It is based upon the fact that a stream of air flows more readily through a coarse powder bed than through a fine powder bed. Due to the criticality of the particle size requirement, the need for an in-process monitor at the crystallization stage was recognized.

SUMMARY

The objective of this project was to select, procure, install, and evaluate a nitroguanidine particle size monitor for the crystallizer and final product in the Sunflower AAP NQ Facility. In order to accomplish this objective, two Microtrac Particle Size Monitors, one for dry powder and one for slurry, were procured from Leeds and Northrup Company. These monitors operate on the principle that particulate material suspended in a liquid or air media scatters light at angles which are inversely proportional to their diameters and with an intensity directly proportional to the square of the diameter.

Both monitors were modified in accordance with a hazards analysis which was performed and installed as a part of the continuous NQ process at the Nitroguanidine Support Equipment (NSE) Facility. The powder monitor (Figure 1) was installed adjacent to the NQ Dryer along with an automatic sampler and conveying system for delivery of a continuous sample of dry NQ to the monitor. Initial efforts using the automatic sampler revealed that the NQ exiting the dryer was too lumpy to feed naturally. Efforts to break up the agglomerates by impingement were unsuccessful, as were other techniques. Therefore, work on the powder monitor was suspended in favor of working with the slurry monitor.

The slurry monitor (Figure 2) was installed in close proximity to the Swenson vacuum crystallizer. The remote sampler was installed in the crystallizer recirculation line. A pure filtrate handling system was designed and installed to provide conditioned water to the monitor. The NQ saturated water was used to dilute the slurry sample to the desired solids concentration and to assist in controlling the temperature of the sample entering the monitor.

water was used to dilute the slurry sample to the desired solids concentration and to assist in controlling the temperature of the sample entering the monitor.

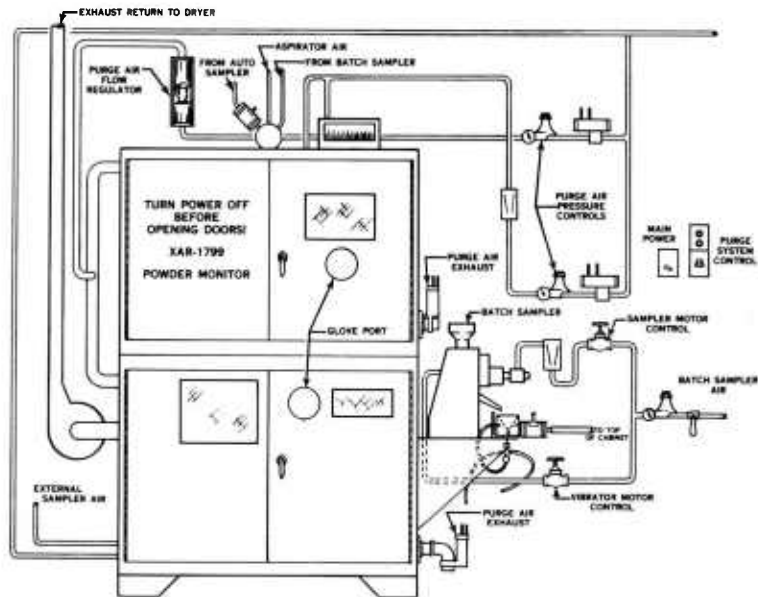


Figure 1 - Dry Monitor

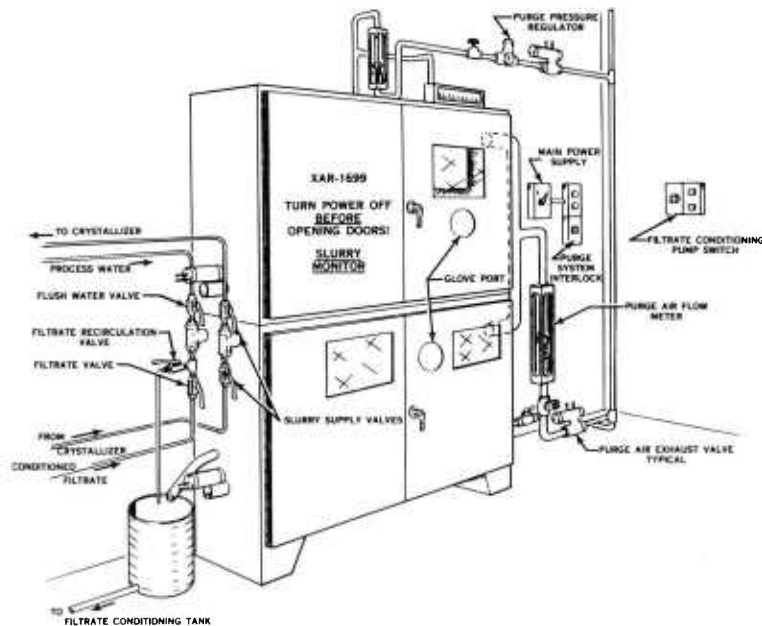


Figure 2 - Slurry Monitor

Comparative measurements were taken by microscope, FSSS, and the slurry monitor on lots of NQ stored at Ravenna AAP. Statistical analysis of the data showed no correlation between the Microtrac average particle diameter values and the microscopic or FSSS measurements. However, the particle size measured by FSSS did correlate with the microscopic measurements. Additional tests demonstrated that doubling the analysis time from 25 to 50 seconds slightly improved the precision of the measurements. Longer analysis times lowered the average particle size values.

During proveout of the main NQ plant crystallizer, paired samples of pure slurry and dry NQ product were tested for particle size on both the slurry monitor and FSSS. Again, there was no correlation between the slurry monitor values and those obtained by FSSS for the pure slurry. However, testing with the dry NQ product exhibited a good correlation between the two methods. This analysis showed that the correlation coefficient was 0.377, significant at the 99.9 percent confidence level, with a standard error of estimate of 0.58.

BENEFITS

The slurry monitor investigated in this work has the capability of being used as a process control instrument in the NQ crystallizing operation. However, additional work to refine the automatic sampling system during sustained runs of the crystallizer operation needs to be conducted. In addition, further work is required to satisfactorily feed NQ to the powder monitor. This additional work is being conducted under Project 581 4059.

IMPLEMENTATION

The results of this project will not be implemented until Project 581 4059 has been completed.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. A. Litty, AV 880-3637 or Commercial (201) 724-3637.

Summary Report prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 5 79 4064 titled "Automated Load Assemble and Pack Operations for 105mm Tank Cartridges" was completed by the US Army Armament Research and Development Command in December 1982 at a cost of \$1,320,000.

BACKGROUND

Load, assembly and pack (LAP) operations for the family of loose-loaded 105mm tank cartridge ammunition is largely done on manual production lines. Characteristics of these lines include: a low level of product quality and control, a high manual labor content with concurrent high unit-item costs, and variable and uncertain production lead times due to a high product mix. This project was undertaken to determine the design criteria and equipment design requirements for an automated LAP line for the family of 105mm tank cartridges. There were no prior efforts to mechanize or automate the assembly of this type of ammunition.

SUMMARY

The objectives of this project were to improve item quality, achieve labor savings, shorten lead times, lower end item cost, and achieve higher production rates. The approach was to design, build, and install an automated line to load and assemble a family of 105mm tank cartridges.

A production system for these LAP operations was designed. The general concept for the load and assembly line system consists of modules of automatically operating workstations connected by a nonsynchronous pallet conveyor system.

The work flow and sequence of operations for the system are illustrated in Figure 1. The remote data management and control center consists of two microprocessors. One microprocessor directly controls individual workstation operation, pallet flow, component and end item identification and disposition. The companion microprocessor collects, processes, and displays production and equipment status data. It also initiates, directs, and records equipment diagnostic and maintenance procedures. A manual jogging mode can be used at each workstation for set-up adjustment or repair conditions.

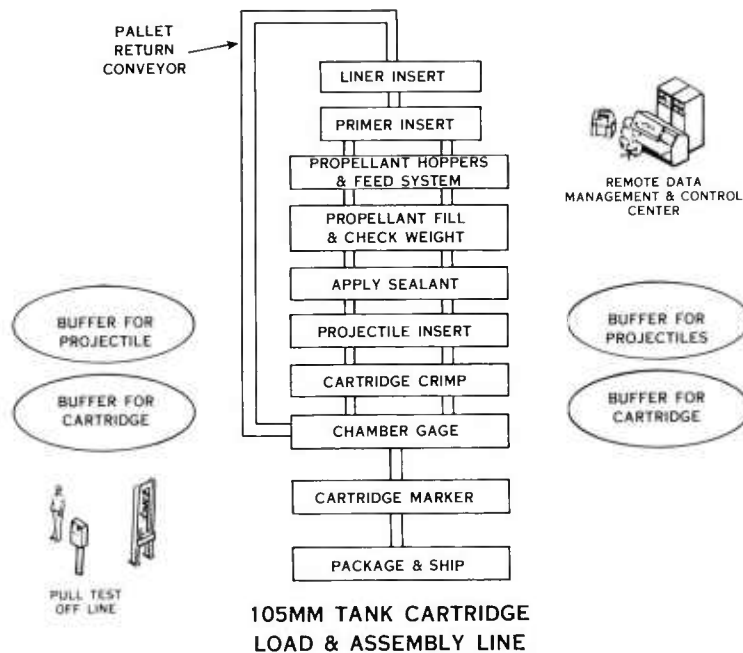


Figure 1 - Work Flow and Sequence of Operations for Production Line

The liner-to-case assembly subsystem and the projectile insertion mechanisms were experimentally modeled, including mock-up demonstrations. A detailed technical data package on the liner-to-case assembly was completed. A preliminary hazard analysis and a reliability, availability, and maintainability analysis of the complete system were completed.

BENEFITS

The designed system is expected to produce any of the six types of 105mm tank rounds at a rate of 10 rounds per minute. A change-over capability from one lot of ammunition to the following lot within the six types of rounds, is planned. A compliment of 10 attendants will be able to achieve a zero change-over time. Duplication of equipment is only required at two workstations, the propellant loading station and the projectile insertion station.

An estimated annual savings of \$4.5 million can be achieved through the total system under peacetime production requirements.

IMPLEMENTATION

The design package for the load and assembly line needs to be translated into prototype production hardware. An incremental plan has been established. The additive liner-to-cartridge case assembly section will be built as a prototype under MMT Project 5 84 4510 and installed at Milan Army Ammunition Plant.

MORE INFORMATION

Additional information can be obtained from the project officer, Mr. Ed Lischick, ARRADCOM, DRDAR-LCM-M, Dover, NJ, AUTOVON 880-4162 or Commercial (201) 724-4162.

Summary report was prepared by Steve McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 576 4237, 577 4237, and 578 4237 titled "Continuous TNT Process Engineering" were completed by the US Army Armament Research and Development Command in July 1980 at costs of \$940,600, \$265,000 and \$130,000, respectively.

BACKGROUND

The high use of TNT for military applications necessitates the need for a continuous means of production. Four GOCO facilities have been equipped with relatively new, continuous TNT lines to meet mobilization requirements. However, it is still necessary to further improve the continuous TNT process. Previous work developed a new low temperature TNT process and the design for a 22.7 kg/hr (50 lb/hr) TNT pilot plant. It is upon this previous work that these projects are based.

SUMMARY

This project was intended to provide and operate a 45.4 kg/hr (100 lb/hr) TNT pilot plant under varying conditions to verify that improved safety, pollution abatement, higher yields and cost savings would be obtained. More specifically, dynamic separators, (Figure 1) incorporated to reduce the in-process quantity of explosive hold-up, were to be evaluated; acid consumption optimized; mononitration temperatures lowered to suppress unsymmetrical TNT isomer formation; and white compound (2,2'-dicarboxy-3,3', 5,5'-tetranitroazoxybenzene) formation minimized.

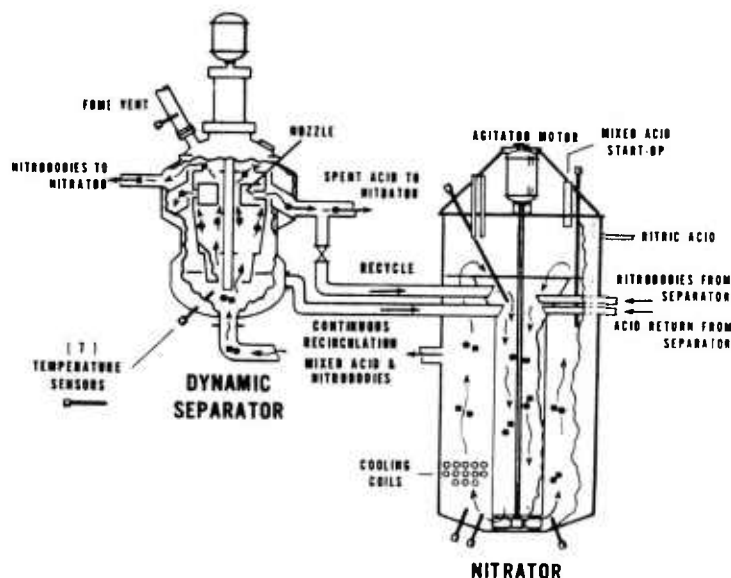


Figure 1 -

TNT Nitrator With
Dynamic Separator

In order to accomplish these goals, the construction of a pilot facility located in building 1031 at ARRADCOM was begun under prior funding. The original work effort was directed toward a pilot plant for a low temperature process. However, capital expenditures became prohibitive. Therefore, the pilot plant design was re-oriented for process engineering of the existing TNT process.

The equipment and piping for the TNT pilot plant were installed in conjunction with the installation of a smaller scale RDX/HMX pilot plant being constructed in the same building under project 57X 4252 by the same contractor. Installation of a sprinkler and deluge system, acid-resistant flooring, a forced air ventilation system, and other auxillary equipment was accomplished. Modifications were made to adapt the control room's digital computer, (building 1029) analog controls and programmable controller to the specific operational tasks for the TNT pilot plant. Prototype dynamic separators were also incorporated based on a hazards analysis obtained from Radford AAP which has installed them in their restored TNT lines.

Limited mechanical and water testing of the installed equipment revealed some minor problems but these were easily corrected. Subsequent start up of the TNT pilot facility with live materials did not occur, however, due to a reduction in funding. These funds were reprogrammed for project 578 4447 concerning process control for the new nitroguanidine plant being constructed at Sunflower AAP.

An investigation into methods to inhibit oxidation during the nitration of dinitrotoluene to TNT was conducted by Stanford Research Institute (SRI). SRI conducted nitrations in both strong sulfuric acid and oleum while examining ways to suppress ring oxidation. Some of the methods considered were nitrogen purging, electrochemical conversion, and the addition of picric acid. None of these methods were successful in suppressing ring oxidation although significant effects were noted in the case of side-chain oxidation.

BENEFITS

A 45.4 kg/hr TNT pilot plant has been designed and installed at ARRADCOM. Technology derived from the limited testing of this facility will benefit other facilities with continuous TNT lines. Further benefits were not obtained because the pilot facility was not activated due to the reduction in funds.

IMPLEMENTATION

The results of this effort were not implemented due to the curtailment of funding.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Robert Wolff, AV 880-4122 or Commercial (201) 724-4122.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 577 4281 and 578 4281 Subtask A08 titled "Cavitation Removal of Explosives" were completed by the US Army Armament Research and Development Command in July 1981 at costs of \$298,000 and \$296,800, respectively.

BACKGROUND

Currently employed methods for removing explosive from rejected projectiles at Army Ammunition Plants or projectiles to be demilitarized at Depots include such techniques as steamout, hot water washout, direct melt and rinse, and high pressure washout. Depending on quantity and quality, the reclaimed explosive is either burned or sold to commercial users. Growing prohibition of open burning and other environmentally unacceptable methods for disposing of rejected explosive has necessitated the use of special furnaces. The explosive removal methods using steam require copious amounts of energy. This has motivated a search for an improved alternate technique which is economical, effective, and energy efficient.

SUMMARY

The objective of this project was to determine the feasibility of using cavitating water jet technology as a means of removing explosive filler from various munitions. This method, which uses cavitation erosion to augment the cutting action of a fluid jet, is capable of removing missile propellants at pressures well below those currently used by a high pressure washout system. The CAVIJET cavitating fluid jet process was selected as the method to be examined based on prior demonstrations of its ability to remove the propellant and liner from TARTAR missile motors at reduced pressures, increased removal rates, and lower energy requirements.

The basic concept of the cavitating fluid jet consists of stimulating the growth of vapor-filled cavities within a relatively low velocity liquid jet by appropriate nozzle design. With proper adjustment of the distance between the nozzle and the surface to be fragmented, these cavities are permitted to grow from the point of formation then collapse on that surface in the high pressure stagnation region where the jet impacts the solid material. Because the collapsed energy is concentrated over many small areas, extremely high, localized stresses are produced. This local amplification of pressure provides the cavitating fluid jet with an advantage over a steady non-cavitating jet operating at the same pump pressure and flow rate.

An experimental facility was designed and built at HYDRONAUTICS, Incorporated, for studying and developing practical devices which use the CAVIJET cavitating fluid jet principles. The primary components of the

facility include a pump, reservoirs to recover and store the water, filters, controls, pressure and temperature gauges and flow measuring devices for accurately measuring all system parameters, and a large test chamber which contains the means for translation of the CAVIJET nozzle relative to test specimens at precisely controlled rates of motion and at any desired angle of attack. Within this test chamber, tests may be conducted on specimens either in air or submerged. A schematic of the test facility is shown in Figure 1.

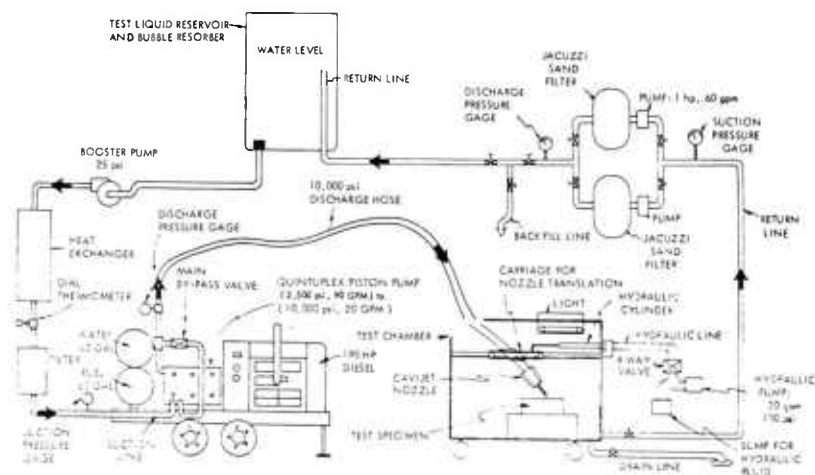


Figure 1 - Schematic of CAVIJET Cavitating Fluid Jet Test Facility

Tests were conducted to examine the effects of various system and operating parameters on the ability of the CAVIJET process to remove explosives from 105mm projectiles. Those parameters examined were the translation and rotation rates, pressure and nozzle size and type. From these tests, preliminary operational specifications for a pilot facility were defined.

A total of 230 hazards analysis tests was performed with test blocks of TNT and Composition B along with 11 tests of 105mm projectiles containing Composition B. Conclusions drawn from these tests were: 1) Composition B had a 97.4% probability of safety and 2) TNT had a 95.2% probability of safety, at 20.7 MPa (3000 psi). Although these tests yielded probabilities of safety which were below the 98.5% probability at a 95% confidence level recommended, it was decided that because no reactions occurred, sufficient safety evaluations had been conducted.

A pilot plant facility plan was then developed for Iowa AAP to modify its present high pressure water washout facility. This plan included: (a) development of cavitating jet cutting heads for both the 155mm M549 and 8-inch

XM650 projectiles; (b) evaluation of a filtering system to allow recirculation of the process water; (c) evaluation of a means of controlling the foaming problem which occurs with the present system; and (d) installation of a dryer to reduce the moisture content of the reclaimed explosive to enable it to be salable. This work is presently being conducted.

BENEFITS

The CAVIJET system as presently conceived appears to offer a 27% potential cost savings over the high pressure washout method and has a greater degree of versatility for the removal of various explosives. The full benefits will not be realized until completion of 581 4281-A08 which includes the evaluation of the pilot facility.

IMPLEMENTATION

Implementation of this project will be through the modification of the high pressure washout facility at Iowa AAP under the on-going project 581 4281-A08.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Edward Krajkowski, AV 880-3258 or Commercial (201) 724-3258.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 580 4288 titled "Explosive Safe Separation and Sensitivity Criteria" was completed by the US Army Armament Research and Development Command in March 1982 at a cost of \$767,000.

BACKGROUND

This project is a continuation of a multi-year effort to develop safety criteria that can be used as a basis for the design of all future explosive production facilities. At the present time, an Army-wide modernization program is underway to either upgrade existing or develop new explosive manufacturing and load-assembly-pack (LAP) facilities. This effort will enable the US Army to achieve increased production cost effectiveness along with improved safety as well as to provide manufacturing facilities for new weaponry with existing facilities. The prior year's effort consisted of studies to determine safe separation of explosive end items such as 155mm M795 HE projectiles, 155mm M549 HERA projectiles, cyclotol, and BLU bomblets.

The effort described here will emphasize studies in safe separation distances and sensitivity for 8-inch M509 HE projectiles, 105mm HEAT-T cartridges M456, M55 stab detonators, and small arms propellants.

SUMMARY

The objectives of this project were to establish the safe separation of explosive end items, in-process materials, and establish the sensitivity of explosives at various stages of the manufacturing process to primary and secondary fragment impact. Project accomplishments were numerous, and the following paragraphs provide examples of work accomplished on specific items and explosives.

8-Inch M509 HE Projectiles

This test program was implemented in order to determine the safe spacing of 8-inch M509 HE projectiles under simulated loading plant conditions and to determine the necessary shielding required between projectiles.

The projectiles were tested in a vertical, baseup configuration on a prototype cross transfer system pallet. The actual tests involved three projectiles, aligned in a straight line and elevated to simulate the conveyor system. The center projectile served as the donor (initiated projectile) while the two end projectiles were the acceptors. All projectiles were mounted on the transfer pallets using v-shaped steel shields.

It was concluded from the tests that 8-inch M509 HE projectiles contained within prototype pallets with v-shielding could be positioned with a 1.5-meter (5.0-foot) center-to-center distance between them without a significant chance of propagation of an explosive incident. Also, the rigidity of the prototype pallet was sufficient to prevent major grenade spills and the resultant hazard of secondary sub-projectile detonations.

105mm HEAT-T Cartridges M456

The purpose of this effort was to provide safety criteria to support facility modernization at Milan AAP where a family of 105mm tank cartridges will be assembled on a single line. The safe separation distances were determined experimentally for five different stages of assembly encountered on the conveying systems. The five stages of assembly were M83 primers, M148 cartridge cases, M456 projectiles, and M456 cartridges vertically and horizontally oriented. The test results were as follows:

1. M83 primers will not rupture their containing M148 cartridge case in the current machine configuration.

2. Use of the complete cartridge vertical safe separation distance for both the loaded M148 cartridge case and the M456 projectile conveyor spacing is a valid substitution since this distance is a "worst case" condition.

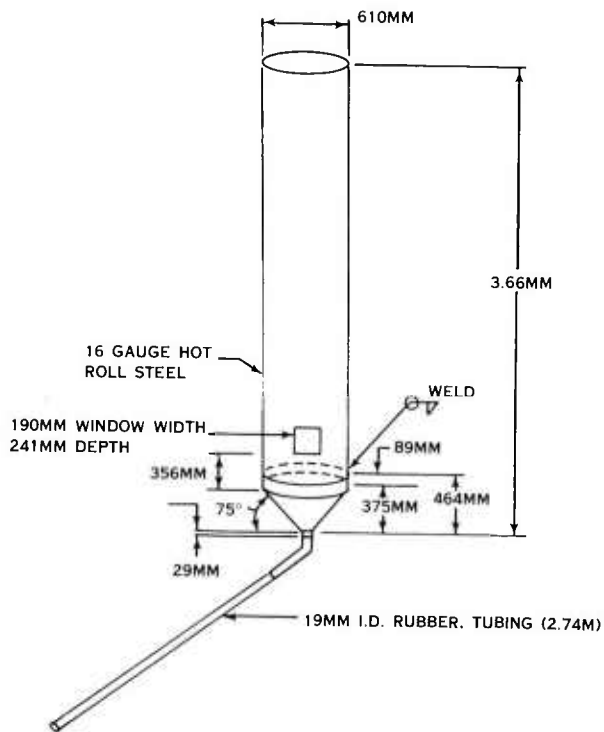
3. The safe nonpropagation distance for fully loaded M456 cartridges is 58.4 centimeters (23.0 inches) in a vertical orientation and 38.1 centimeters (15.0 inches) in a horizontal orientation, provided 7.6 centimeter (3.0 inch) diameter aluminum bars (6061-T6) are used as shields between cartridges in both cases. (These are not minimum distances, but are tailored to fit a given loading line situation.)

Small Arms Propellants

Propellant is loaded continuously into hoppers during a typical loading operation of small arms ammunition.

The objective of this task was to determine if any of the propellant types (IMR-5010, WC-872 and HPC-13) would change from burning into explosion or detonation reactions when initiated at weights, hopper configurations, and feed tube configurations which are representative of in-process conditions. The propellants were evaluated for the critical height at different bed depths for various loading hoppers. (conventional, scamp). A conventional loading hopper is shown in Figure 1.

Previous tests with 91 kg of WC-844 in a Scamp hopper resulted in an explosion. A potential mechanism for eliminating explosions in hoppers was to place a 254-mm vent pipe in the center of the stack. A total of 45.4 kg



each of IMR-5010 and WC-872 produced no explosion or detonation reactions when bottom-ignited in the conventional hoppers, and 27.5 kg of HPC-13 produced no deflagration-to-detonation reactions. Only the rubber feed tube for HPC-13 propellant produced an explosion reaction; however, this propellant is not a fragment hazard.

Figure 1 - Conventional Loading Hopper

BENEFITS

This project developed new safety criteria which was integrated into safety regulatory documents (DARCOM-385-100) to permit construction of both functional and safe munitions manufacturing facilities. The data generated is derived from realistic testing rather than engineering judgment.

IMPLEMENTATION

The safe separation distance data developed from this project was applied to the designs of LAP lines at Milan and Mississippi AAP.

MORE INFORMATION

Additional information on this project is available from Mr. R. Rindner, ARRADCOM, AV 880-3828 or Commercial (201) 328-3828.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 576 4303 and 577 4303 titled "Acceptance of Continuously Produced Black Powder for Artillery, Mortar, Rocket Systems" was completed by the US Army Armament Research and Development Command in November 1980 at a combined cost of \$423,000.

BACKGROUND

Historically, technical data packages addressing propellants and ignition items, such as black powder and its source materials, are generally prepared independently without regard to the demands of the end items which use black powder. Project PIF 574 2084, Continuous Manufacturing of Black Powder, which specified a quality assurance system that defines and assures reliable performance of black powder in end item use, was implemented at IAAP.

Employing the technique of system analysis and placing heavy emphasis on computer modeling, it was the intent of this project to assure reliable performance of black powder produced by the continuous process.

SUMMARY

The purpose of these projects was threefold as listed below:

- a. To establish product, process, and source material requirements and develop test methods compatible with a continuous process.
- b. To identify key process steps which must be controlled to assure end product acceptability and homogeneity.
- c. To develop a functional test for black powder process.

The completion of the major tasks was accomplished by the combined efforts of Indiana Army Ammunition Plant (IAAP), Ballistic Research Laboratories (BRL), and Princeton Combustion Research Laboratories. These contributions are briefly summarized in the report.

Indiana Army Ammunition Plant (IAAP)

IAAP manufactured eleven special black powder lots. A detailed analysis and results of closed bomb testing of the special lots were prepared.

Ballistic Research Laboratories (BRL)

BRL characterized the special lots. BRL fabricated static test fixtures designed to simulate; 1) M28B2 bayonet primer (105mm Howitzer); 2) center

core igniter (155mm M203 propelling charge); and, 3) base pad igniter (8 inch M2 propelling charge). Earlier tests indicated that these test fixtures would function as intended for black powder.

Princeton Combustion Research Laboratories (PCRL)

PCRL designed and fabricated an apparatus to investigate the feasibility of measuring flame spreading rate through a loosely packed bed of black powder. The fiber optic system used to detect the apparatus was not initially designed to allow venting of the combustion gases. After modification to provide uniform venting of the vessel, reproducible results were obtained.

Relying on the data obtained from the testing at PCRL, a prototype flame spread testing apparatus was designed, fabricated, and modified for end-of-line use. After the completed system had been demonstrated to ARRADCOM, the necessary spare parts were prepared for shipment to Indiana AAP. The actual installation of the flame spread tester was performed by an INAAP contractor.

BENEFITS

Utilization of the flamespreader tester to reduce analytical testing of black powder is estimated to provide a savings of \$264,000 per year at mobilization. In addition, the device should prove useful as a diagnostic tool during proveout of the modernized black facility and may prove useful as a development aid for black powder initiated propulsion systems.

IMPLEMENTATION

The flamespread tester has been installed at INAAP, and laboratory personnel there have been trained in its use. The tester will be used during proveout of the modernized black powder facility as a first step in determining acceptance criteria for black powder.

MORE INFORMATION

Additional information is available from Mr. Dane Hanson, ARRADCOM, AUTOVON 880-2856 or Commercial (201) 724-2856.

Summary report was prepared by T. Locke, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 579 4312 and 580 4312 titled "Injection Molding for Production Explosive Loading" was completed in December 1982 by the US Army Armament Research and Development Command at costs of \$261,000 and \$279,000, respectively.

BACKGROUND

Melt-pour loading of small munition items, particularly the BLU-63 and BLU-61, characteristically results in large amounts of explosive riser scrap in relation to the amount of explosive loaded. During the late 1960's, an improvement in melt-loading of BLU items utilized special pouring trays which eliminated the machining requirement (fuze cavity). Although this simultaneous pouring of 16 items resulted in increased production, it also increased the amount of riser scrap remaining in the trays, at times averaging 200% to 400% greater than the explosive loaded in the items. This resulted in material handling problems during recycling of the riser scrap and increased safety problems since personnel had greater exposure to explosives during the handling and recycling processes.

The use of injection loading to load bomblets was originally studied by ARRADCOM in 1970. Two prototype devices were developed. One used a diaphragm and the other a piston to inject the explosive. The feasibility of these devices was demonstrated. However, modifications and further evaluation was necessary. Since injection molding provided a positive and controlled volume displacement of explosive into munitions, a project was initiated to eliminate the large quantities of riser scrap generated by the current method of melt-loading these munitions.

SUMMARY

The objective of this project was to determine if the technique of injection molding could be successfully adapted to provide an improved method for automated loading of automated explosives. Three models of prototype injection molding equipment were tested by loading molten composition B, cyclotol and 75/25 octol explosives.

Model 1 was originally a prototype single injection cell device using low pressure air to expel a fixed quantity of molten explosive. The original prototype cell was evaluated with inert material such as wax and soap in loading BLU 26 hemispheres. A number of modifications to the prototype cell had to be made after the initial testing effort. Testing the modified unit with 70/30 cyclotol explosive resulted in solidification of explosive in the bottom of the reservoir in the area just above the reservoir diaphragm. This problem was resolved with a new heat control valve installed in the heat exchanger.

After the modifications were made, four tests were conducted which revealed that three were of acceptable quality and one had a small cavity at the injection spur hole. Testing with the Model 1 design indicated that a more positive and variable volume displacement, a more positive temperature control, elimination of rubber diaphragms and heat jacketing of all parts were needed.

It was decided that the Model 1 design was not satisfactory for production loading. The four injection tests did demonstrate that it was possible to injection load BLU 63 bomblets. Work was immediately initiated on a Model 2 design.

The Model 2 design involved injection loading by a syringe action with a one plunger stroke displacement of explosive in a cylinder. A diagram of the injection unit with the injection spool closed is shown in Figure 1. The operation was initiated by closing the injection spool with air pressure. Then molten explosive was drawn into the injection chamber by activating the pneumatic cylinder attached to the explosive plunger. The injection nest and tooling were raised by pressurizing thereby opening the injection spool. The molten explosive plunger was then pressurized to inject the molten explosive into the mold.

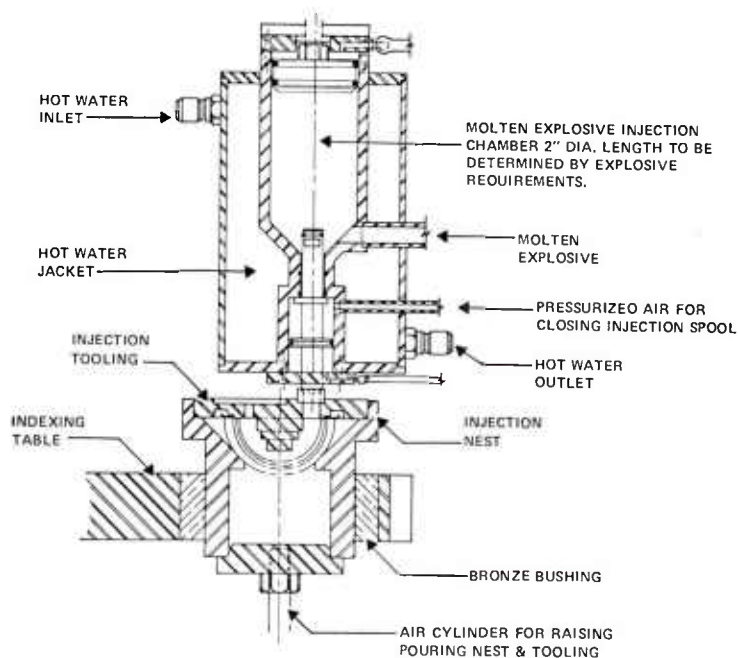


Figure 1 - Injection Unit With Nest And Tooling

Initially, inert testing of the Model 2 design was conducted with wax and with stearic acid. During inert testing work, the injection unit functioned satisfactorily with no material being forced by the "O" ring or past the plunger seals. Due to the low viscosity of the inert material used in the inert testing, the volume could not be accurately controlled. It was established that the molten wax and the stearic acid was draining from the diaphragm valve into the injection unit. A decision was made that because of the great difference in viscosity between the inert materials and molten explosive, drainage should not occur if explosive was tested. A total of 112 BLU 63 bomblets were loaded with cyclotol 70/30 with no evident defects. After successful completion of cyclotol loading, the injection unit was prepared for composition B loading. This required a lowering of the steam pressure of the melt kettle and reducing the temperature of the hot water heating media of the injection system. A total of 104 BLU 63 bomblets were successfully loaded with Composition B with no defects.

The attempt to injection load anti-armor cluster munitions (ACM) with 75/25 Octol was unsuccessful. The problems were due to the accumulation of HMX, a component of octol explosive, plugging the rectangular openings of the injection spool. The Model 2 design was then redesigned so that the explosive was horizontally dispensed instead of vertically. The new design for the ACM was first tested with inert material followed by loading with 75/25 Octol. A total of 100 ACM's were loaded and resulted in high quality casts which were acceptable.

BENEFITS

Prototype injection loading equipment and procedures were developed to successfully load bomblets and ACM submunitions with 70/30 Cyclotol, Composition B, and 75/25 Octol type explosives. This resulted in reducing riser scrap to 10% of the ACM charge weight and reduced personnel exposure to hazardous materials.

IMPLEMENTATION

A late start MMT FY82 follow-on project was programmed to fabricate and evaluate a production prototype injection molding unit. The equipment will be installed as production equipment under facility project 582 0048 at Kansas AAP.

ADDITIONAL INFORMATION

To obtain additional information, contact the Project Officer, Mr. T. Calderelli, AV 880-4205 or Commercial (201) 328-4205.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 577 4462, 578 4462, and 579 4462 titled "Modernized Forced Air Dryer (FAD) For Multi-Base Propellants" were completed by the US Army Armament Research and Development Command in July 1981 at costs of \$163,000, \$592,000 and \$542,000, respectively.

BACKGROUND

Work on the Continuous Automated Multi-Base Line (CAMBL) at Radford AAP has resulted in the need for a forced air dry system which incorporates energy savings and pollution abatement features. The present method for drying solvent type multi-base cannon propellant is to force heated air through a room or bay containing tray-racks loaded with fresh-cut propellant granules. The air heats the room and contents to a temperature of 60°C (140°F) causing vaporization of volatile solvents and moisture. However, the air is exhausted to the atmosphere after one pass through the propellant and applied thermal energy is lost. Furthermore, hydrocarbon emissions (ethyl alcohol and acetone) are in excess of the amounts allowed under the Commonwealth of Virginia pollution regulations. Consequently, efforts were initiated to modernize the existing dry house facilities and adapt them to support both the automated and batch production processes.

SUMMARY

The objective of this effort was to establish a prototype facility and design criteria to modernize the present FAD houses. To achieve this objective, a review of data generated and collected during previous work on the removal of solvent from multi-base propellants was conducted. This review indicated a better method of cleaning the exhaust air from a FAD would be to pass the exhaust air through a dilute aqueous caustic solution for removal and decomposition of nitroglycerin (NG) vapor, and to use either additional water scrubbing or a sodium bisulfite solution to absorb the acetone and ethanol solvent from the exhaust air stream. Using caustic water to decompose the NG vapor has the advantage that there would be no NG accumulation, which could require barricades around the NG container and would reduce the load limits on the dry houses.

Bench scale evaluation of the proposed scrubbing system indicated that the decomposition time of the NG could be shortened by increasing the temperature or the concentration of the caustic solution. The use of a plain water scrubber to absorb the acetone and ethanol solvent was found to be ineffective on the acetone. To improve acetone retention, a sodium bisulfite solution was used in the scrubber. However, it was necessary to also use a fresh water

scrubber downstream of the bisulfite scrubber for alcohol removal. Since it was uneconomical to use two scrubbers for solvent removal, the bisulfite approach was abandoned in favor of the one column water scrubber exclusively.

One bay of an FAD house was modified with the installation of new lead floors, hot water panel coil heaters, new air ducts and air distributors. Propellant drying tests were conducted in this bay using both M30 and M31A1 propellant and compared to drying in a conventional bay. It was concluded that the modernized bay was capable of acceptably drying multi-base propellant in larger quantities, 4580 vs. 3920 kg (10,080 vs. 8,640 lbs), and at a lower air flow rate, 708 vs. 2595 l/sec (1500 vs. 5500 cfm), than a conventional bay. Cold weather testing also showed that it was easier to maintain the floor temperature of 49°C (120°F) in the modernized bay. Additional cold weather testing with M30 propellant was conducted in the modernized bay at 708 l/sec air flow rate with an outside temperature range of -2 to 9°C (28 to 48°F) with no NG condensation occurring.

Site preparation for, and installation of, an NG scrubber and associated equipment for the modernized bay were accomplished also. The complete process flow diagram is shown in Figure 1. Debugging and evaluation of the modified FAD bay and pollution abatement equipment will be accomplished under 580 4462.

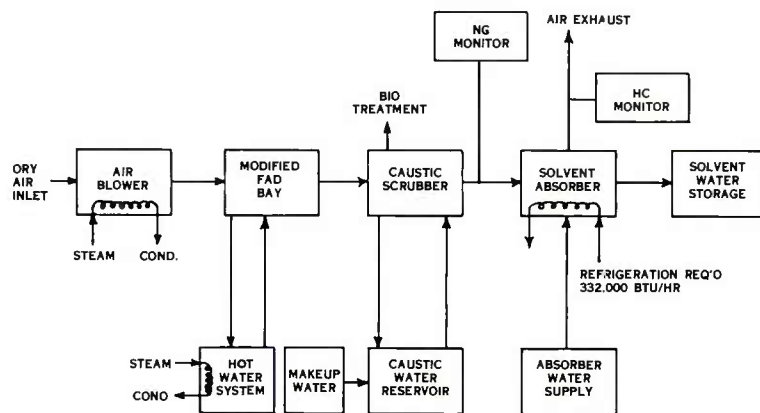


Figure 1 - Modernized FAD Process

BENEFITS

Federal and state regulations for organic vapor emissions will be met which will significantly improve the environmental quality by reduction in hydrocarbon and NG emissions. Also, the design criteria for similar facilities at both Radford and Sunflower AAP have been developed.

IMPLEMENTATION

Implementation of the benefits derived from this project are deferred until completion of the follow-on project 580 4462.

MORE INFORMATION

For additional information, contact the Project Officer, Mr. Arthur Graff, AV 880-5572 or Commercial (201) 724-5572.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 580 4462 titled "Modernized FAD For Multi-Base Propellants" was completed by the US Army Armament Research and Development Command in September 1982 at a cost of \$908,600.

BACKGROUND

Drying multi-base propellants requires large amounts of energy and discharges large quantities of waste heat because of the single pass heating system. Pollutants discharged into the atmosphere include nitroglycerin (NG), acetone and alcohol. From the previous engineering work and bench scale studies conducted under 57X 4462, a concept for a modified bay with pollution abatement equipment was developed. It is upon this earlier work that this project is based.

SUMMARY

The objective of this project was to install, debug and evaluate the modernized FAD bay and the associated pollution abatement and solvent recovery systems.

The FAD was modified by an improved air distribution system and panel coils which kept the bay floors warmer and contributed to a more uniformly dried propellant. This system also permitted the use of 28 cabinets containing 4580 kg (10,080 lbs dry weight) of propellant instead of 24 cabinets containing 3920 kg (8460 lbs dry weight). The improved air distribution system successfully reduced the amount of air required to dry propellant to 708 l/sec (1500 cfm) which reduced the amount of steam required to dry M30 propellant by 59%.

A total of 16 propellant drying runs were conducted successfully in the modified FAD with the following propellants:

- M31A1 for 8-inch projectiles
- M30A1 for 155mm projectiles
- M30 for 105mm M456
- M30 for 195mm M735
- M30 for 105mm M490

Comparisons with propellants dried in a conventional bay demonstrated there were no significant chemical or physical differences between the two. Ballistic test results likewise showed no significant differences.

Evaluation of the caustic scrubber for NG vapor removal revealed a 99% removal efficiency when using caustic solutions of up to 13%. Approximately 0.88 kg of caustic was required to destroy one kilogram of NG. However, caustic solution strengths above 9% are not recommended because of possible solids accumulation. This system also effectively removed the carbon dioxide from the exhaust air.

Pilot plant evaluation of the solvent absorber showed a removal efficiency of 95% at the 708 l/sec flow rate. However, the water flow rate for concentrating the solvents was too high for their economical recovery by distillation as the average solvents concentration was only about 0.1%. Computer analysis of the solvent absorber showed that even with a recycle system, the concentration of solvents would not be above 0.9% while decreasing solvent removal efficiency to 85%.

Based on the pilot plant evaluation, it was recommended that the modified bay be operated without the aid of heat panel coils to determine if the low air flow has the capability of drying propellant to specifications within the same drying times. It was further recommended that installation of the pollution abatement system be postponed but studies involving this system should be continued.

BENEFITS

This project has demonstrated the propellant drying capabilities of the modified FAD bay operating at reduced flow rate and increased load. In addition, it has demonstrated the capability of the associated pollution abatement to meet federal and state regulations.

IMPLEMENTATION

The process criteria established will provide the technology for the design of a 20 FAD complex at Radford AAP and facilitation at Sunflower and Badger AAP.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Arthur Graff, AV 880-5572 or Commercial (201) 724-5572.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 578 4466 and 579 4466 titled "Evaluation of TNT, Cyclotol, Octol With ARRADCOM Melt-Pour Facility" were completed by the US Army Armament Research and Development Command in September 1982 at costs of \$182,700 and \$698,800, respectively.

BACKGROUND

The continuous melt-pour pilot plant facility at ARRADCOM, developed under 57X 4162 and 57X 4263, was designed specifically for the processing of Composition B explosives. This was because Composition B is the Army's preferred fill for high explosive loaded artillery ammunition. Since the approved alternate fill for artillery projectiles is TNT, it is in the best interest of the Government to insure that the newly developed melt-pour technology is compatible with other explosives.

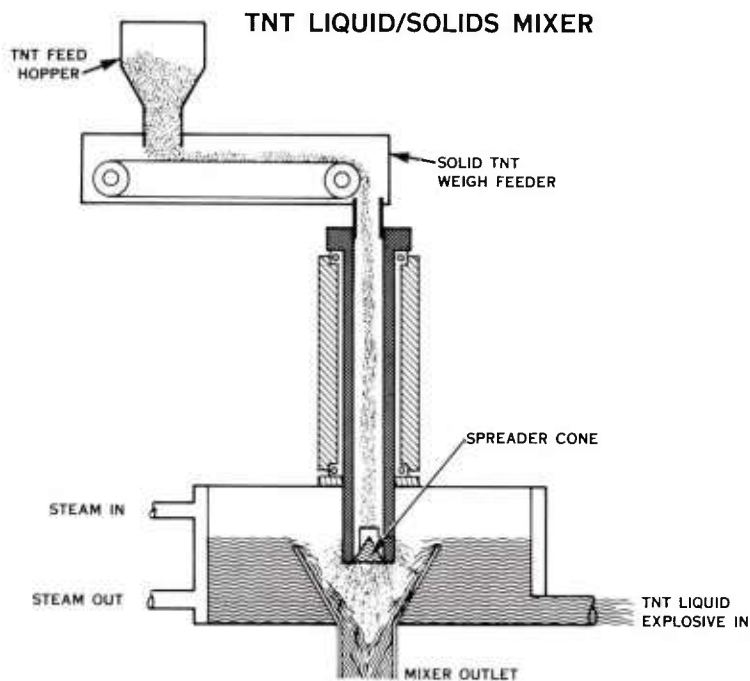
SUMMARY

The objectives of this effort were to evaluate the ARRADCOM continuous melt-pour line for loading of TNT slurries and development of an automated feed/mixing system for molten/flake TNT. In order to accomplish these objectives, a survey of previous tests using TNT in the melt system was conducted to find a means of determining the amount of solids added to liquid TNT during the melting process. Analysis of the data showed that the pressure generated by the hydraulic drive to the agitator increased as solids were added to the melter and, likewise, decreased upon melting. Efforts to correlate the viscosity of the TNT solids mixture to the hydraulic pressure, however, were unsuccessful.

Other alternative techniques for determining the optimum solid-to-liquid TNT ratio were also explored. An electronic torque meter was examined based upon the Navy's experience indicating that torque changes closely followed viscosity changes in molten explosive mixes. Unfortunately, the equipment was found to be intrinsically unsafe due to the possibility of sparking. Capacitance probes and ultrasonic sensors were also examined and found unsuitable because the range of TNT liquid-solid densities were not far enough apart to allow adequate detection. From these examinations, it was determined that control of the solid-to-liquid ratio in the melt kettle was not possible by control of the viscosity.

An automated feed/mixing system for molten/flake TNT explosive was fabricated and installed in an existing ARRADCOM melt-pour building. The mixer system blends flake TNT with liquid TNT in preselected proportions to

yield the desired solid-to-liquid ratio. Flake feed rate can be controlled from 0.1 lbs/hr to 1000 lbs/hr through the use of a computerized weigh feeder unit incorporated into the system. The flake TNT feeds down a rotating (40 rpm) funnel onto a spreader plate which radially accelerates the material into the liquid TNT cascading over a cone-shaped reservoir. The resultant mixture then enters the pour machine (See Figure 1).



Tests were conducted with 155mm, M549 projectiles which were preheated to 160°F. During the pour operation, the slurry was poured to a height of one inch below the funnel rim. During the cooling process, the water was constantly recirculated to maintain a temperature of 128°F, the shells were not probed and no TNT top-off was performed.

As a result of the test program, the maximum solids-to-liquid ratio TNT slurry that could be effectively processed was established to be 30%. Pour times averaged 50 seconds using 0.5-inch I.D. pouring nozzles and a pouring temperature of 174°F. The casts were free of piping and other defects. The slurry appeared to be uniform in terms of the solids dispersion and there was no evidence of partially melted flake settling out. Also, as long as the slurry was properly agitated, no freeze-up or solids agglomeration was evident. The major problem encountered was the entrapment of air that resulted in a significant amount of porosity in the explosive cast. However, steps to correct this problem have been identified, but project funding was inadequate to implement the recommended corrective actions.

BENEFITS

The establishment of the TNT mixer system has eliminated the need for cast probing and has reduced the slurry preparation time. This system is capable of a solids-to-liquid ratio TNT slurry of 30% and is compatible with the continuous melt-pour system.

IMPLEMENTATION

The detailed drawing packages, process descriptions and equipment specifications that have been developed for the TNT mixer system will be used to support modernization and expansion projects related to TNT loading and melt systems.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Frank Daly, AV 880-5839 or Commercial (201) 724-5839.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 579 4474 titled "Dehumidified Air For Drying Single-Base Propellant" was completed by the US Army Armament Research and Development Command in December 1981 at a cost of \$175,000.

BACKGROUND

The present method of drying solvent-type single-base propellants at Radford AAP is to force heated air through a bed of propellant granules to remove excess moisture. The air is exhausted to the atmosphere after one pass through the propellant. This procedure is both wasteful and costly with respect to energy consumption. A laboratory study, conducted at Radford AAP in 1976, indicated that unheated, dry air could be used to dry M1MP propellant but excessive drying time was required. An engineering review of the problem suggested that using heated, dehumidified air with partial recycle of the exhaust air would be more cost effective than the present method.

SUMMARY

The objective of this project was to determine the most cost effective method of drying single-base propellants. These studies included (1) a thorough review of previous and current technology for removing moisture from solids, with emphasis on reduction of the present expenditure of thermal energy during single-base propellant drying by using dehumidified, heated air as the drying medium, (2) bench-scale studies, and (3) a hazards analysis of the use of a dehumidified air propellant drying system.

The results of the literature search revealed that except for the preliminary laboratory tests conducted at Radford AAP in 1976, no information was available on the drying of single-base propellants using this process. However, reports from Indiana Ordnance Works and Radford AAP regarding the continuous manufacture and drying of single-base propellants did contain useful information on the drying theory and characteristic drying curves of single-base propellants.

Originally, bench-scale studies were to be conducted using a modified version of the existing pilot-scale drying unit previously used in the development of design criteria for the Continuous Automated Single-Base Line Propellant Manufacturing Facility. However, it was found that excessive repairs would be required. Therefore, the bench-scale dryer used for development of design criteria for the Continuous Automated Multi-Base Line Propellant Manufacturing Facility was selected. Although this unit could be modified for studies involving various levels of humidity and temperature, the equipment size and design precluded the inclusion of a small regenerative air dehumidifier, waste heat recovery unit, and partial recycle of the drying

air. Nevertheless, it was decided that enough data could be generated from this unit to determine the overall effect of humidity and temperature of the drying air on the M6MP propellant drying cycle. A sketch of the modified system is shown in Figure 1.

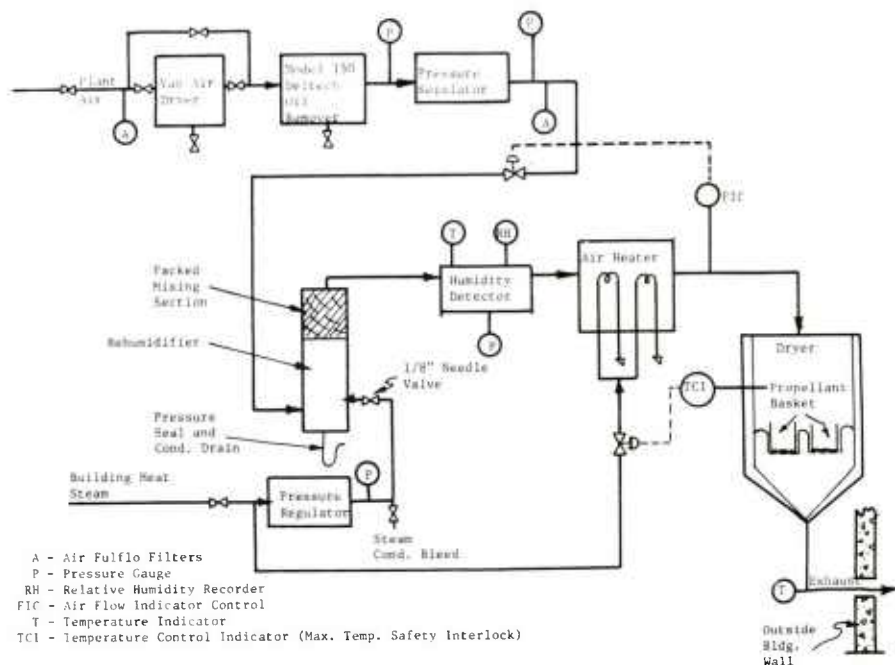


Figure 1 - Single-base Propellant Bench-scale Dryer Process Flow Sheet

A total of nine test runs was made in the bench-scale dryer with an air flow of 2.36-2.83 L/Sec (5-6 CFM) or 4.72-5.66 L/Sec (10-12 CFM), a temperature range of 38-63°C (100-145°F), and the relative humidity between 25-100%. Prior to use, the drying unit was allowed to warm up to the desired drying temperature (usually overnight). The M6MP single-base propellant for each test was obtained from the production line at the wet-screen house, just prior to drying by standard methods, and weighed between 13.5 and 22.9 kg (6.1-10.4 lbs). The test charge was divided equally into two aluminum baskets and sampled periodically throughout each drying cycle for moisture, ethyl alcohol, and diethyl ether content.

The results of these tests confirmed that the drying of single-base propellant was not just a function of removing surface moisture, but was more a function of driving the internal moisture out of the propellant granules. This drying phase requires an elevated air temperature to provide sufficient driving force to diffuse the moisture through the propellant to the surface where it can be removed. The use of lower temperatures (<63°C) can be used also if the drying time is extended. While the use of dehumidified air would reduce the drying time, the cost of additional energy for regeneration of the dehumidifying agent in an adsorptive type air dryer or to compress and refrigerate the air for dehumidification would offset any savings obtained from a reduced heating cycle.

A survey of available types of sizes of air-to-air heat recovery equipment, with emphasis on the heat pipe and plate-type modes of recovery, was conducted. This survey revealed that the installation of an air-to-air heat exchanger between the open tank air dry exhaust and intake air would result in a savings in both steam and cost. It was recommended, therefore, that such a system be procured and evaluated.

BENEFITS

Results of the engineering studies demonstrated that the use of dehumidified air for drying single-base propellant was neither cost nor energy efficient. However, installation of a plate type air-to-air heat exchanger between the exhaust and intake air streams would effect an annual energy savings in the amount of steam consumed.

IMPLEMENTATION

The results of this project were not implemented because there would be no cost savings in the use of dehumidified air for drying propellants. Installation of the heat exchanger has been deferred until further design studies can be performed. However, a technical report describing the work conducted under this project is available at the US Army Armament Research and Development Command.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Sam Moy, AV 880-3258 or Commercial (201) 724-3258.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 579 4508 titled "Process Improvements for Pressable RDX Compositions" was completed by the US Army Armament Research and Development Command in October 1982 at a cost of \$266,100.

BACKGROUND

Mobilization planning has emphasized the importance of the pressable RDX compositions (A-3, A-4, A-5 and A-7) for manufacture at Holston AAP (HAAP). A review of the standard processes for these products at HAAP indicated that their capabilities were severely limited by out-dated technology and that operation was occurring under safety waivers. This review included the coating, filtration, and drying facilities.

During the initial startup and proveout operations of Line 1 at HAAP in 1976, it became evident that A-7 dusting in the drying operations was too severe; hence, drying evaluations were halted.

An FY78 MMT project emphasized the evaluation and development of improved coating and filtering processes for the A compositions. This project was initiated to improve the present drying process and produce a safer operation.

SUMMARY

The purpose of this effort was to correct the severe dusting problems encountered with the Wolverine Jet-Zone Dryers. These dryers were located on line 1 at Holston AAP and were part of the continuous Composition B production line. These dryers were used to filter and dry composition A-7 (RDX coated with wax).

Based on operating experience and the recommendations of consultants who visited Holston AAP, a multi-step plan for improvement and re-evaluation of the prototype continuous drying process was developed by Holston Defense Corporation. Project 579 4508 was funded to accomplish the first four steps of the improvement plan. In Step 1, preliminary building modifications were completed. These included the enclosure of the discharge area from the dryer, sealing the photocell ports with optically clear covers, and the installation of a make-up air system for the scrubbers. Step 2 required the installation of a system to recycle the dried product to furnish a continuous supply of feed material to the system. In Step 3, piping and equipment which permitted the evaluation of using clean filtered water in the scrubbers were installed. In Step 4, a series of experimental runs and a 120-hour final evaluation run were completed. The experimental runs were designed to evaluate each of three modes of operation. The three modes were:

1. Operation using plant filtered water in the scrubbers and with hydrocyclones to remove explosive solids from the resultant waste water stream being pumped to the filtrate distribution tank for subsequent disposal.
2. Operation using filtered water in the scrubbers but without hydrocyclones. Clean-up of the waste water stream depends upon completeness of settling in the filtrate distribution tank.
3. Operation using water from the filtrate distribution tank in the scrubbers and hydrocyclones as described in 1 above. This procedure was expected to result in increased filter-dryer operational efficiency and less loss of explosives in the waste water streams as compared to Mode 1 operation.

A diagram showing the Mode 3 operation with typical water balance values is provided in Figure 1.

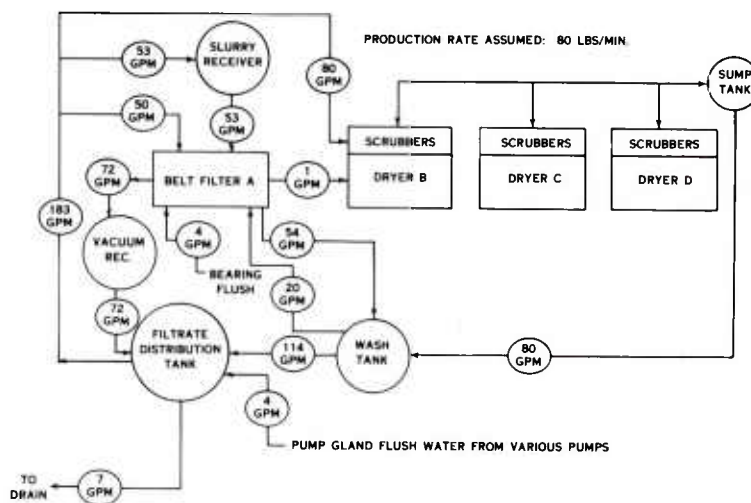


Figure 1 - Flow Diagram of Mode 3 Operation

Start-up of the modified Building I-1 process occurred by employing Mode 1 operation in the initial runs. The dusting problem was successfully controlled throughout the Mode 1 operation. Mode 1 operation was satisfactory except for problems with the motor for the scrubber exhaust fan and wearing and adjustment problems with the filter cloth.

Mode 1 operations were completed with a total operating time of 64 hours and 23 minutes. Mode 2 operation was not evaluated since it was felt that Mode 1 was superior. The hydrocyclones effectively reduced the water load on the filter to a significant degree.

After completion of the initial two-day run, Mode 3 operation was selected for the final evaluation run. Mode 3 was selected because Mode 1 and Mode 3 were essentially equal with regard to control of the dusting problem; and Mode 3 generated less overflow of water to the drain because it uses water from the filtrate distribution tank in the scrubbers. Mode 3 operations resulted in increased filter-dryer efficiency and reduced the amount of explosives lost to the waste water streams.

BENEFITS

The Building I-1 dusting problem was resolved by the modifications to the Wolverine Dryers. Holston AAP now has the capability of drying Composition A-7 explosive to 2% moisture at the Wolverine Dryer design rate of 140lb/min.

IMPLEMENTATION

The Wolverine Dryer is now an integral part of Line 1 at Holston AAP.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. J. Dowden, ARRADCOM, AV 880-3637 or Commercial (201) 328-3627.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 5 76 6200 titled, "Small Caliber Ammo Process Improvement Program," was completed by the US Army Armament Research and Development Command in July 1981 at a cost of \$1,297,000.

BACKGROUND

This project was one of a series of projects in support of the development of new and improved methods for producing ammunition in the 5.56mm to .30 caliber range. This equipment will operate in a continuous production mode at rates up to 900 acceptable parts per minute.

SUMMARY

This project supported the installation and acceptance of follow-on equipment in Building 1 (LCAAP). In addition, engineering and product assurance assistance and management of process and equipment investigations were provided.

Extensive testing was performed on the first and second case submodules. Design changes and process corrections were made and tested to reduce scrap rates. Acceptance testing of the bullet submodule has been performed. An extensive effort was performed to improve the functioning of the part detectors. Several changes were recommended to the control circuits which were subsequently incorporated. Performance was greatly improved but the problem was not completely eliminated.

The Process Quality Control Computer System (PQCS) was installed and debugged. Some problems surfaced in the interface between the PQCS and the automated material handling system during the ten-day integration test. These problems were corrected.

One load and assemble submodule was accepted conditionally and turned over to Remington Arms Company for integration into the SCAMP production system. Two units were considered for provisional acceptance and testing was partially completed on the remaining two submodules.

Debugging of the module A1 prototype equipment at Twin Cities AAP and a ten million piece confirmatory test was completed. Equipment modifications deemed necessary for the initiation of the system integration run were completed.

BENEFITS

A portion of the checkout and installation of SCAMP module A1 was completed with this project funding. Integration runs were performed and a ten million piece confirmatory test was completed. System enhancements were defined and the specifications for a bearing monitoring system were established.

IMPLEMENTATION

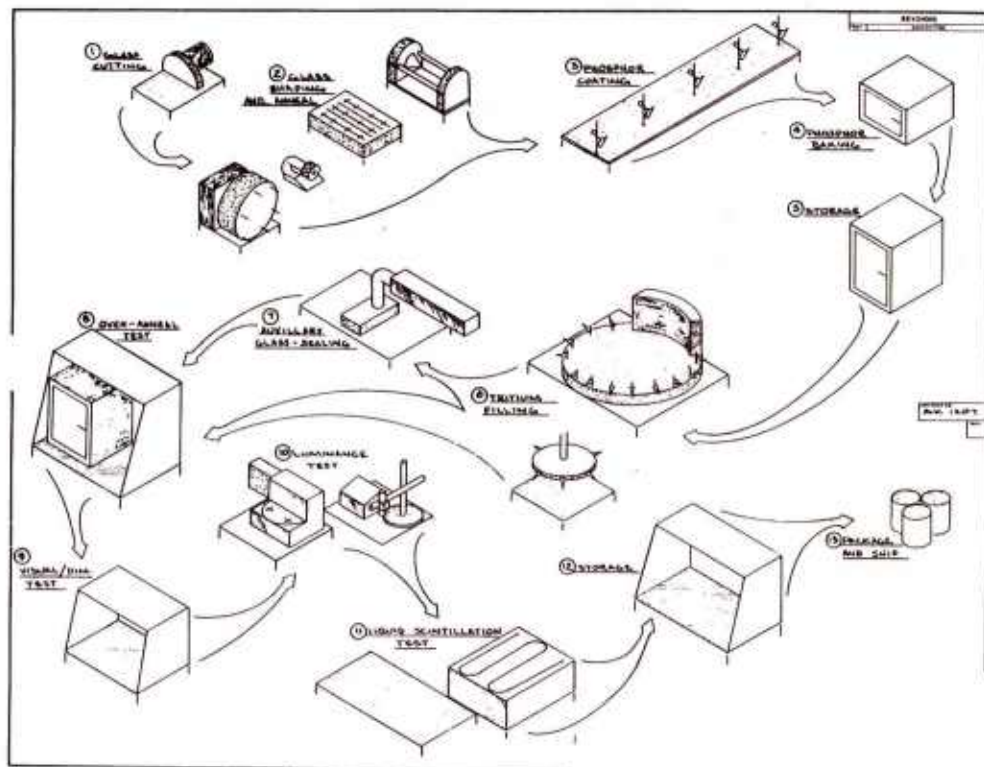
Information developed under this project has formed the basis for much of the production line updating planned for SCAMP Lines 1 and 2 under ECP funding, Line 3 under Facilities Project 5 83 2201, and Lines 4 & 5 under Facilities Project 5 83 2202. Portions of this work are being completed under MMT Project 5 80 4411.

MORE INFORMATION

Additional information may be obtained by contacting Mr. E. Rempfer, ARRADCOM, AUTOVON 880-3737 or Commercial (201) 328-3906.

Summary report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

NON-METALS



SELF-LUMINOUS LIGHT SOURCE PROCESS

ABSTRACTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
381 1108	Radio Frequency and Laser Hardening of Missile Domes	N-13

This project was to investigate materials and processes for coating the inside of small polycarbonate or polysulfone missile domes for protection against radio frequency and laser energy. A coating system for applying Indium Tin Oxide (ITD) and electrical coatings to the dome in uniform thickness was designed and fabricated. Of the hundreds of coatings evaluated, the reactive magnetron sputtering approach appears promising and will be further developed in a follow-on project.

376 3135	Process Development for Carborane	N-19
37T 3135	Manufacture	
377 3135		

The objective was to scale-up a bench scale process for the manufacture of m-hexyl carborane to a production sized facility. A description of the process that was developed is described. Because of the increased scale of production, the cost of producing the carborane was reduced by \$1000 per pound.

R77 3188	Imaging Infrared Seekers for Thermal	N-22
R78 3188	Homing Missiles	

The IRIS, an imaging infrared seeker compatible with the Hellfire missile, was subjected to rigorous design-to-cost studies and producibility analysis. Make-or-buy decisions were made on each component and a 40 percent carbon-fibre reinforced plastic replaced many of the metal parts. Ten IRIS seeker heads were fabricated and cost vs. quantity information generated. A modified IRIS is currently being used by the Air Force.

R79 3219	Automatic Polymer Attachment Production	N-25
R80 3219	Methods	

Human fatigue due to repetitive inspection was a cause of missing and misoriented components on hybrid bonding areas. Electronics, hardware and software, and a final integrated system for an automated hybrid die bonder were designed. A video subsystem has the capacity to store and manipulate up to 50 different chip types, each having as many as four views. Bonding yield increase is estimated at 25% and a prototype machine will be developed in an on-going effort.

5-4281-A01

Process Energy Inventory

N-38

An energy inventory of manufacturing and loading operations at selected Army Ammunition Plants was conducted. The inventory was to identify where immediate energy reduction measures could be implemented and where needed follow-on engineering projects were required to accomplish energy conservation. Inventories were prepared for Radford, Volunteer, Holston, and Kansas AAPs.

579 4281-A02

Optimized Insulation

N-41

The purpose of this project was to select, install, and evaluate a thermal insulation system for the stainless steel boiling tubs at Radford AAP and other Army ammunition plants. Insulation of 30 boiling tubs at Radford AAP has been scheduled. An annual savings of \$57,000 is anticipated.

580 4291

Blast Effect in the Munition Plant
Environment

N-44

This project was to evaluate the usefulness of strengthened steel buildings as protective structures and to provide recommended design procedures whereby the full-blast capacity of the structure could be achieved. A building was erected and instrumented to detect blast effects of explosives being detonated nearby. The information developed was integrated into existing safety regulations.

678 7808

Leak Detection Technique for Small Sealed
Fire Control Assemblies

N-47

This project was to identify both leak detection and leak rate test procedures which are more accurate, less costly and less time consuming than those currently in use; and make recommendations to amend military specifications to include these methods. To accomplish this, a survey of leak detection techniques was conducted. The alternative techniques examined were the mass spectrometer probe test, mass spectrometer vacuum test, and acoustic leak detection systems.

678 8017
679 8017

Pollution Abatement Program

N-49

The plating facility at Rock Island Arsenal utilized cyanide based derusting solutions and copper or cadmium plating solutions making the rinse water a source of cyanide pollution. Non-cyanide based solutions were tested, and test panels coated using Kadized cadmium and cupure copper showed good adhesion and corrosion resistance. Both processes were implemented with no change in previous tank or rack design other than plasticol coating of the rack.

678 8049

Manufacturing Process Energy Conservation
Program

N-52

This project developed an energy recovery system for Watervliet Arsenal in order to reduce energy consumption during the peak winter months. The heat treat line was further insulated and the air infiltration and exhaust ducts reworked to retain and recycle heat. Implementation is currently underway and a 50 percent reduction in fuel consumption is expected upon completion.

680 8209

Pilot Production of Gradient Index Optics

N-54

This project investigated gradient index lenses as an alternative to current lens configurations in DOD purchased sights and viewing systems. The developed eyepiece limits distortion and transverse aberrations with fewer lenses than were required in homogenous eyepieces. Although gradient lenses are slightly more expensive than conventional lenses, substantial savings are expected due to fewer lenses per system and reduced alignment and testing.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 171 6050 titled "Automated Tape Layup System (ATLAS)" was completed by the US Army Aviation Research and Development Command in June 1979 at a cost of \$2,278,000.

BACKGROUND

Metal helicopter main rotor blades have long been recognized as having many inherent disadvantages. These include spar and aluminum honeycomb corrosion, sensitivity to small defects, rapid failure propagation, and low adaptability to advanced geometry blade designs. Glass composite blades, which were developed in the early 1960's, solved these problems and provided many additional benefits such as freedom from erosion, crash survivability, visual failure detection, and soft, slow failure modes.

Initially, fiberglass blades were being hand layed up and used in several helicopters models including the CH-47; however, the increased demand for these blades during the Vietnam conflict necessitated faster, more efficient methods of production.

The effort to develop an automated manufacturing process for composite blades began under an earlier project (169 6007) in which a three-axes tape laying machine was fabricated and tested. This machine served as a baseline for the design of a six-axis machine to be used for the production of advanced geometry blades. The final design, named the Automated Tape Layup System (ATLAS), was completed in March 1971.

This effort was initiated to provide for the complete fabrication of the ATLAS. The ATLAS was intended to drastically reduce fabrication time for composite helicopter blades and to develop technology for follow-on efforts.

SUMMARY

The scope of this project consisted of the fabrication, installation and qualification of the ATLAS, and the pilot production of two full length advanced geometry composite rotor blade spars.

Goldsworthy Engineering undertook a contract for the original production of the ATLAS. The capabilities of the 6-axis machine were to include longitudinal carriage drive, transverse carriage drive, vertical carriage drive, end Support Rotation, and a horizontal rotary table, Figure 1.

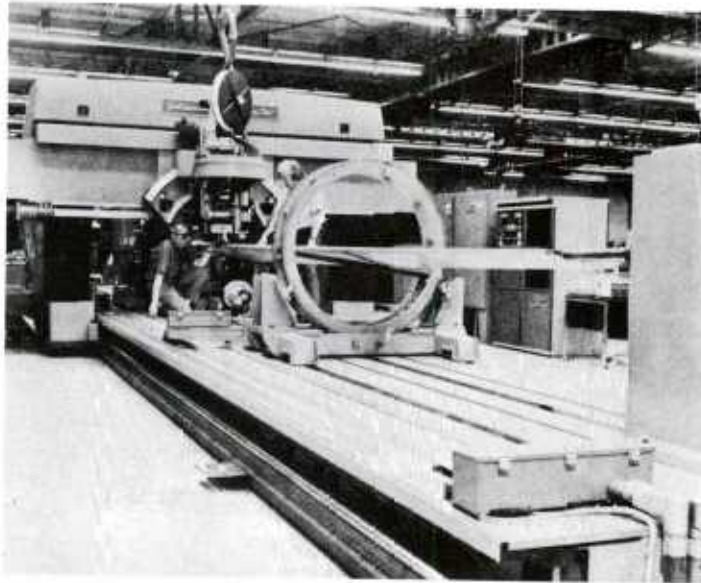


Figure 1 - ATLAS and Control Console Laying-up a CH47 Main Rotor Blade

The ATLAS design consists of several axes, Figure 2, and subassemblies integrated to operate simultaneously. The assemblies include a base and ways, a composite gantry, a tape placement head assembly, and a numerically controlled command system.

<u>AXIS</u>	<u>TRAVEL</u>	<u>RATE</u>
X LONGITUDINAL	432 INCHES	720 IN/MIN
Y TRAVERSE	96 INCHES	720 IN/MIN
Z VERTICAL	36 INCHES	150 IN/MIN
C ROTATION OF HEAD	410 DEGREES	1-10 REV/MIN
D ROTATION OF HEAD & TAIL STOCKS	360 DEGREES (CONTINUOUS)	1-10 REV/MIN
A TAPE HEAD TILTING	±45 DEGREES	

Figure 2 - ATLAS General Specifications

A cast iron base was chosen because of its lower cost and high weight.

Due to reduced force experienced when compared with conventional metal-working, Goldsworthy was able to construct the gantry from composites, composed of a polyester resin skin over a foam core. The weight reduction made possible rapid acceleration/deceleration of the tape placement head.

The tape placement head is designed to lay tape on compound curved surfaces. The tape supply reel can hold up to 3,000 feet of 3-inch wide preimpregnated composite tape and backing. A magnetic particle brake maintains constant tension. The tape guidance mechanism maintains the correct tape alignment. The tape slitting/looping mechanism divides the tape into narrow ribbons for application to compound curved surfaces, maintains the correct tension, and assures an adequate supply of tape for each ribbon. The tape shear assembly is designed to cut composite materials at an angle of up to 45° without adhesion to the tape or cutting of the backing paper. The tape heater contains an infrared emitter which raises the resin temperature and ensures tape tackdown. The compacting device is a belted tire type roller with steel plates for sidewalls. Due to difficulties with this roller, an interchangeable teflon bar compactor was also constructed. The backing paper/scrap material take-up mechanism collects and stores paper removed from the applied tape.

The numerical control system is an Allen Bradley 7300 with added digitizing capabilities. The machine can be programmed either programmer by processing or by running the optical digitizing head along the surface to be programmed. The optical digitizer senses a black center line on the tape of previously laid up prototypes and programs the computer accordingly. All tape control data is generated to position the tape along the centerline of the area to be laid. Manual controls located on the main, pneumatic and auxiliary control panels allow manual regulation of frequently used processes. These include a manual emergency stop button.

When the machine was completed, a battery of tests was run. These included successful attempts at machine motion checks, flat pattern layups, a root end mockup, and a series of repeatability and alignment tests.

The ATLAS was moved to Boeing-Vertol where the final control system was installed. Several prototype helicopter parts were successfully fabricated, including HLH spar filler packs, UTTAS spar straps, and CH-47 fairing skins and spar straps. Labor time was reduced from 12 to 2 hours on the HLH spar and from 24 to 4 hours for the CH-47 spar. Further, the compared hand layups exhibited wrinkles, non-uniform compaction and significant geometry variations not evident in automated layups.

An industry wide demonstration was held to demonstrate the ATLAS capabilities and versatility.

BENEFITS

While the ATLAS produced no direct, quantifiable benefits, it was technically successful and served as a valuable technical base for the development of automated layup machines. Boeing currently uses a 3-axis tape laying machine (PATLAM 1) which is based on the ATLAS. The PATLAM has resulted in time savings of up to 120 to 1 over hand layup techniques for certain helicopter composite parts. ATLAS also demonstrated high laminate repeatability and quality previously unobtainable.

IMPLEMENTATION

The ATLAS is currently located at AMMRC and is intended for non-production use in the fabrication of prototypes.

Final technical reports have been distributed and both Boeing-Vertol and Goldsworthy Engineering are utilizing information gained from the ATLAS project. Boeing's PATLAM 1 uses paper backed tape of the type proved out on the ATLAS and employs similar cutting tools and techniques. The PATLAM's numerical control is the same as that for the ATLAS. Since the completion of this project, Goldsworthy has produced and sold several single axis layup machines based on the ATLAS.

MORE INFORMATION

Additional information may be obtained from Mr. Daniel Haugan at AVRADCOM, Autovon 693-1625 or Commercial (314) 263-1625.

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 177 7112 titled "Composite Improved Main Rotor Blades" was completed by the US Army Aviation Research and Development Command in June 1979 at a cost of \$3,919,000.

BACKGROUND

Army experience with the Bell AH-1 Cobra helicopter led to new mission requirements necessitating increased lifting capacity. Studies indicated that the least expensive solution was to replace the existing metallic main rotor blade with one of increased aerodynamic efficiency that would be directly interchangeable. In addition to improved efficiency, the blade was to have improved ballistic tolerance, increased fatigue life (2400 hours minimum versus 1100 hours for the metal blade), and improved reliability and maintainability including field repair techniques. The blade that was designed to meet these goals, named the K747 Blade, consisted of a multi-tubular spar design with all-composite construction using filament wound S glass/epoxy and Kevlar 49/epoxy materials (Figure 1). The design approach was to match the dynamic characteristics and mass of the metal blade, and to apply the design-to-unit production cost contracting approach. The work was performed under contract by Kaman Aerospace Corporation.

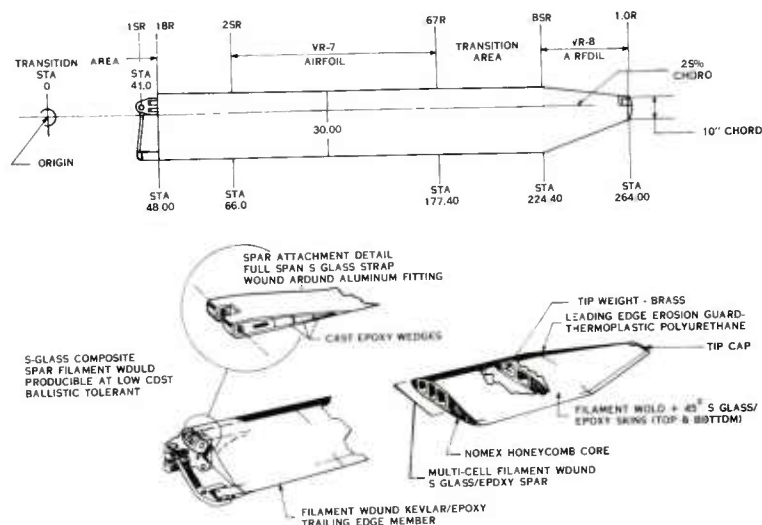


Figure 1 - K-747 Blade Configuration

SUMMARY

The manufacturing approach used in this project was to fabricate the components by filament winding, both dry and wet, and to cure them using hard tooling heated either integrally or by an oven. Wet filament winding was ultimately chosen as the primary fabrication method because of the immediate practical availability of automated assembly equipment and techniques, and because it uses the epoxy resin and fiber directly without costly intermediate processing steps. Hard production tooling in the form of closed metal molds was used for curing the spar and edge spline, and for the final assembly bond in order to produce accurate airfoil contours, achieve precise weight control, and preclude costly autoclave curing. The molds were machined from ductile iron castings having cast-in "egg crate" stiffening.

The spar manufacturing sequence is shown schematically in Figure 2. A unique feature of this process is the hard, extractable spar mandrels. This approach provides precise control of weight and internal geometry, particularly web straightness. The mandrels were machined from an aluminum alloy and coated with a teflon impregnated hard anodize to ensure good release properties. An aluminum alloy was selected for its high coefficient of thermal expansion. This produces pressure during cure and contraction during cooldown which facilitates easy mandrel extraction. After preforming, the spar assembly is cured in an oven heated mold.

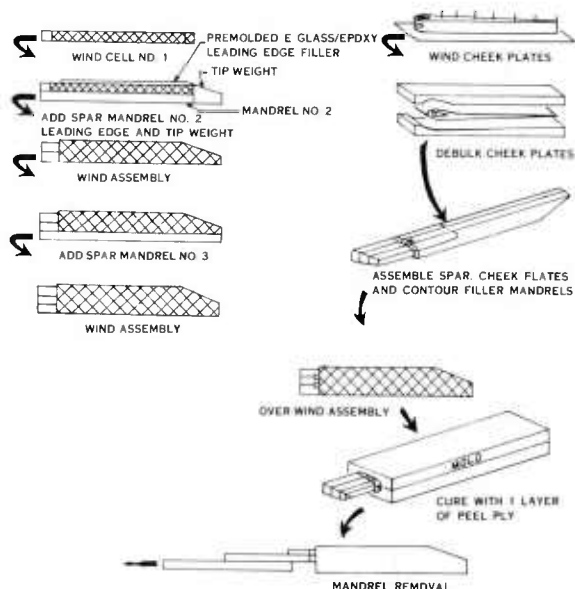


Figure 2 - Spar Fabrication Sequence

The trailing edge spline was unidirectionally wet filament wound and cured in an oven heated mold. The brass tip weight was enclosed in a neoprene jacket which was vulcanized in place in a closed mold. The skins were dry filament wound on a large drum using a band width of approximately one inch and applied in a two space "star" pattern. Resin impregnation was performed after winding with a staged and solvated resin system.

Final assembly bonding is accomplished by assembling the precured spar assembly, the precured spline, and the uncured skin and nomex core in the bottom half of the bond fixture, installing the fixture top, and curing at 250°F. Film adhesive is used only at solid adherent joints. Machined core height tolerances are controlled to assure positive contact with the skins, and are formed to final contour during the cure cycle. Core splices are made with conventional expanding adhesive during final assembly bond.

A total of twenty-six blades and twenty-nine spars were produced and subjected to a full range of structural and performance tests to qualify the design, fabrication practices and controls. This program included static, fatigue, environmental, ballistic, lightening, radar, whirl stand, and instrumental flight load and performance tests, as well as process control and NDI testing. The NDI testing consisted of automated, through transmission, c-scan, ultrasonic inspection for the spar section, ultrasonic pulse echo methods for the composite-to-metal joints, resonance techniques for delaminations in the area near the surface, and visual inspection of the final assembly bond which was permitted by the transparency of the skin. The tests indicated that the manufacturing process developed was successful and that the blade demonstrated improved lifting capacity (6.5 to 7.8%), maneuverability and cruising speed.

BENEFITS

A life cycle cost comparison of the composite blade with the metal blade resulted in a cost savings of \$226,415,000. This cost comparison is for a peacetime scenario for 1000 aircraft operating 40 hours per month per aircraft for a 15-year period (14.4 million blade hours). The cost factors considered were initial blade procurement, field repairs, depot repairs, blade scrappage, and blade retirement. The cost saving is attributable to the longer service life and greatly improved reliability of the composite blade.

IMPLEMENTATION

Production of 2,151 blades will be completed in the summer of 1983. They are being implemented on the AHIS helicopter on an attrition basis in place of the current metal blade.

MORE INFORMATION

Additional information can be obtained from Mr. Sy Wiesenberg, AVRADCOM, St. Louis, MO, AV 693-1625 or Commercial (314) 263-1625.

Summary Report was prepared by Ferrel E. Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 1 80 7412 and 1 81 7412 titled, "Infrared Detector for Laser Warning Receiver," were completed by the US Army Aviation Research and Development Command in June 1982 at cost of \$100,000 and \$650,000, respectively.

BACKGROUND

When this project was conceived, there was no domestic source for indium arsenide (In-As) wafers and no volume source for In-As detectors for use in airborne laser infrared (IR) detector systems. A Laser Warning Receiver picks up laser energy beamed toward a helicopter or airplane by an enemy illuminator and warns the pilot of an impending threat. This gives him time to take evasive/defensive action. Special processing techniques including diffusion, photolithography, etching and assembly were needed to make the detector and had to be scaled up for volume production.

There was also a problem with availability of In-As wafers from which to make the detectors. An east coast firm imported the wafers from a manufacturer in England, but the supply was not assured, particularly in an emergency. Thus, a domestic source of wafers was also sought.

SUMMARY

A contract at Perkin Elmer Corporation, Electro-Optical Division, Danburg, CT, resulted in the development of manufacturing methods for fabricating, assembling and testing interdigitated infrared detectors for the AN/AVR-2 Laser Warning Receiver. Process controls and procedures for high volume production were established, and semi-automated testing methods are being developed and will be completed with the third year of funding.

Areas covered on this contract include:

- a. Production engineering of high volume methods.
- b. Qualification of material vendors.
- c. Establishment of new production processes.
- d. Development of tooling and techniques.
- e. Establishment of semi-automated test procedures.
- f. Fabrication of sample detectors.
- g. Pilot run of detectors.

BENEFITS

Methods for diffusing the detector junction, for passivating the surface, and for bonding the interdigitated etalon to the interdigitated detector were automated. Also, alternate sources of In-As material were developed. Further, the contractor invested approximately one million dollars of its own funds for facilities to build detectors and receivers.

In addition to the capability now available at Perkin Elmer Corporation, there is privately funded capability for making indium arsenide detector arrays at Barnes Engineering Company, Stanford, CT, and at Judson Infrared, Inc., Montgomeryville, PA.

Project H 84 5194 for "Etalons for Laser Detectors" is expected to be funded and contracted to develop production methods for making stepped etalons (disc-shaped filters) for the detector.

IMPLEMENTATION

Project 1 82 7412 for "Infrared Detector for Laser Warning Receiver" will continue the work of the present project. Perkin Elmer Corporation, Electro-Optical Division, will become a source for infrared detectors for use in the AN/AVR-2 Laser Warning Receiver.

MORE INFORMATION

Additional information on this effort is available from Mr. Richard Brady, ERADCOM, AUTOVON 995-3108 or Commercial (201) 544-3108, or from the Project Manager - Aircraft Safety Equipment (PM-ASE), AUTOVON 693-1480 or Commercial (314) 263-1477, Mr. Richard Poletski.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 3 81 1108 titled "Radio Frequency and Laser Hardening of Missile Domes," was completed by the US Army Missile Command in July 1982 at a cost of \$440,000.

BACKGROUND

There was need to develop production processes, equipment and specifications for coating the inside of small polycarbonate or polysulfone missile domes for protection against radio frequency (RF) and laser energy. Two types of coatings were needed: a transparent, conductive coating for the entire dome and a metallic, conductive coating for the threaded area. See Figure 1 for coating details.

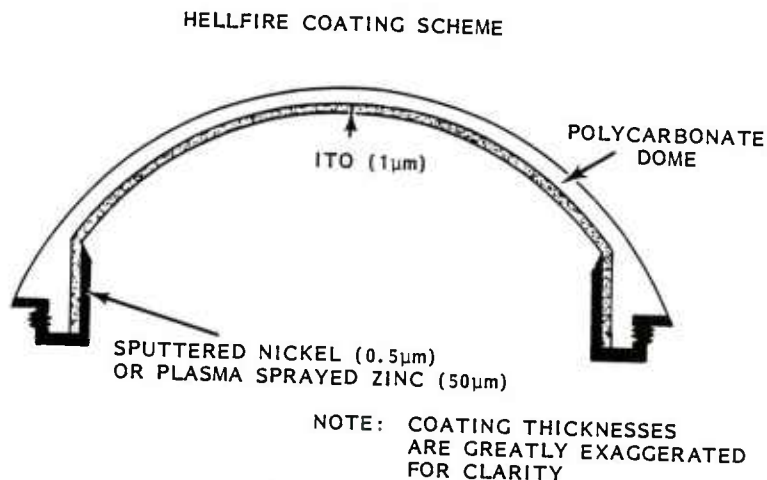


Figure 1 - Coating Requirements

SUMMARY

Battelle Northwest, Richland, WA, contracted with the US Department of Energy to perform the technical investigation for MICOM. The primary objective of the first year's work was to demonstrate RF hardening of Hellfire and Copperhead 1.06-micron missile domes by use of transparent conductive Indium Tin Oxide (ITO) coatings. The project involved adaptation of a conductive material and coating process developed for flat glass components used in fusion lasers to hemispherical or conical heat-sensitive plastic domes used on laser-guided missiles. Specific coating property goals were an electrical sheet resistance of 10 ohms/square, good adhesion, and a coated-dome transmission of 80% or more at 1.06 micron wavelength compared to 90% for a bare dome. The sheet resistance goal of 10 ohms/square was expected to result in an RF attenuation of 30 dB at the frequencies of importance.

Coating of the missile domes involved design, part fabrication, assembly and testing of a coating system for applying ITO in uniform thickness to temperature-sensitive parts with complex shapes. See Figure 2. Achievement of coating property goals required systematic optimization of deposition parameters. Metal electrode materials for contacting the ITO to the metal missile body were selected, evaluated, and optimized. Electrical and optical properties of hundreds of ITO and electrode coatings were evaluated. Thickness uniformity over the dome surface and adhesion to the plastic were measured on selected coatings. Procedures were developed for cleaning the plastic before coating, and for fabrication of source materials used in the coating process. Finally, a number of domes were coated and sent to MICOM for RF shielding tests and evaluation.

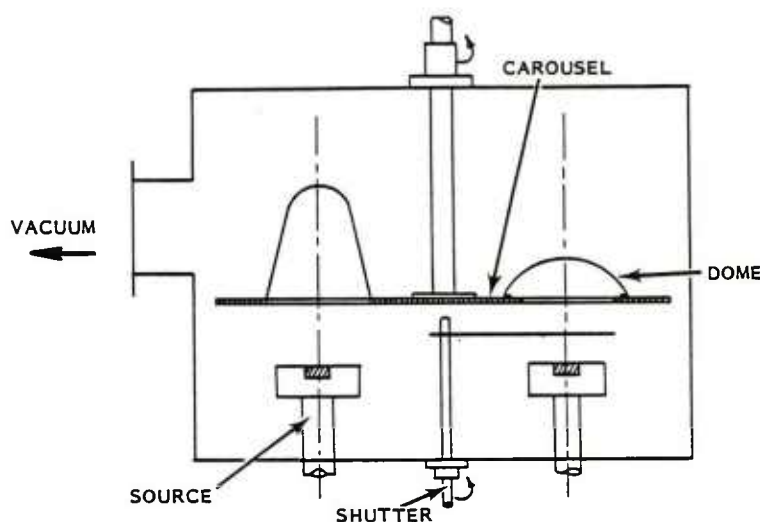


Figure 2 - Dome Coating System

Future work is planned to include: 1) coating of more domes for additional RF tests as well as optical, environmental and field testing, 2) multilayer coatings for laser hardening, 3) production coating cost estimates, and 4) assesement of and improvement in production readiness leading to ultimate production implementation.

BENEFITS

The reactive magnetron sputtering approach appears promising for mass production coating of missile domes at a reasonable cost, although very precise control of deposition parameters is required. Procedures were developed for cleaning plastics before coating and for fabricating In/Sn sputtering sources. Some of the coating process concepts and procedures needed for mass production were determined. Tensile pull tests for ITO on polycarbonate Hellfire and polysulfone Copperhead plastics indicated adhesion of several thousand psi.

IMPLEMENTATION

The results of this contract will be worked into the option for a follow-on contract for project 3 82 1108.

MORE INFORMATION

Additional information may be obtained from the project engineer, Mr. David Jones at the US Army Missile Command, DRSMI-RST, Redstone Arsenal, AL 35898, AUTOVON 746-8331 or Commercial (205) 876-8331.

The final technical report prepared by Battelle Northwest entitled, "Improved Manufacturing Techniques for RF and Laser Hardening of Missile Domes," number PNL-4335, UC-38, describes sputtering parameters and equipment control settings. The report should be consulted for details of coating operations.

Summary report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 375 3135 titled "Process Development for Carborane Manufacture" was completed by the US Army Missile Command in June 1977 at a cost of \$500,000.

BACKGROUND

Shoulder fired, tube-launched rockets must consume the motor's propellant before the rocket leaves the tube. Specially formulated propellant compositions are developed to meet this critical requirement. One such composition uses an ingredient called n-hexylcarborane (carborane) as a burning rate additive. However, carborane is only available in small quantities which are produced in a bench-scale operation. The cost of carborane at this level of operation is quite prohibitive, approximately \$1450 per pound. It was imperative that the cost of this material be reduced. A cost reduction was expected to result from the scaling up of the bench-scale operations to a production sized facility.

SUMMARY

The objective of this effort was the development of a low cost process for the manufacture of carborane. The manufacture of carborane is a three-step process. The first intermediate that is produced is diborane. There are many routes by which this intermediate can be reached, so no problem was posed by this step. However, diborane is a relatively unstable gas at normal temperatures and pressures for its conversion to decaborane as the second intermediate was going to require some investigation and development. The third and final step is converting the decaborane to carborane but a reliable and satisfactory process for this conversion already exists. So the only obstacle that had to be overcome was the conversion of diborane to decaborane.

A proposal submitted by the Callery Chemical Company to define process parameters (temperature, pressure, flow rate, etc) and a reactor design which would result in optimum conversion of diborane to decaborane was selected for development. The Callery concept was to pyrolyze diborane gas in a tubular, closed loop reactor, see Figure 1. Convective flow in the reactor is caused by hot-cold gas density differences resulting from heating one vertical leg of the loop and cooling the opposing vertical leg.

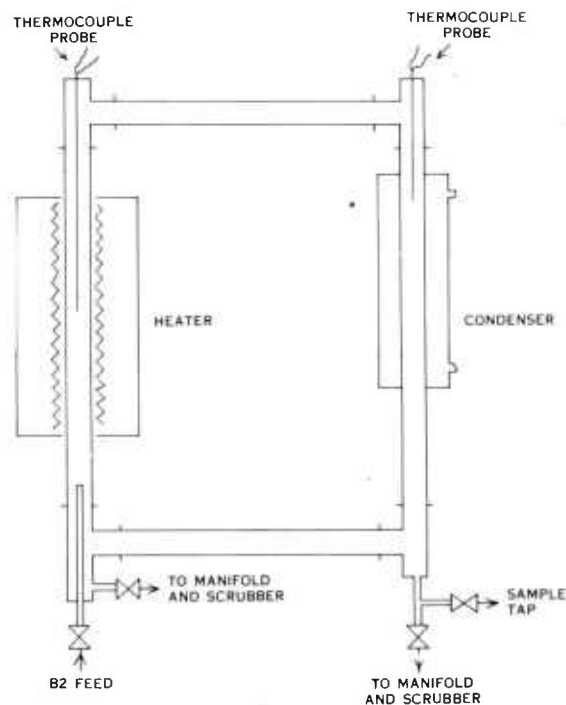


Figure 1 - Schematic of Closed Loop Tube Reactor

Diborane is fed into the heated leg and the decaborane that is formed is condensed and removed from the opposite vertical leg. The overall reactor flow is controlled by back pressure regulation of the off gas at 3-5 psig. Electrical resistance heating of the outer surface of the heated leg allowed control of the hot surface temperature while bulk gas temperatures were monitored by a thermocouple located axially in the hot gas stream. Various modifications to the cold, condenser leg of the loop, resulted in the optimum configuration which employed a modified commercial gas mixing device, (Ross "Motionless Mixer") as a means of improving condensation and removing condensed product.

Preliminary investigations were conducted in a 1" Pyrex pipe loop reactor. The reactor concept was verified with the achievement of pyrolysis yields of decaborane equivalent to those obtained in prior laboratory pyrolysis studies. Correlation of the 1" ID reactor data, aided by computer modeling studies with a simple convection flow model, indicated feasibility

of scale-up and also indicated the possibility of multiple stage operation (individual loops connected in series) to increase diborane conversion and decaborane yield.

Preliminary confirmation of scale-up and staged operation was then obtained by construction of a 2" ID Pyrex pipe reactor and operation as both a single 2" ID stage and as a two stage system in combination with the original 1" ID loop. Yield data from both 1" and 2" single stage operation were found to be consistently correlated at similar hot gas temperatures. Staged operation was found to be similarly correlated by application of a correction factor for the actual diborane content of the second stage.

Optimization studies included investigation of the effect of temperature and feed rate variation as well as modifications to the reactor geometry and condenser internals. In the bulk gas temperature range of 200°C to 260°C and at diborane feed rates from 0.04 to 0.14 g/min (residence times from 47 to 13 minutes), the decaborane yield was found to increase with increasing temperature and residence time. Increasing the temperature had only a moderate effect on decaborane yield but resulted in marked increases in undesirable side product polymer formation, particularly at gas temperatures above 240°C.

In the preferred pyrolysis temperature range of about 205° to 235°C, single stage decaborane yield based on diborane feed was found to vary from about 30 percent at the highest feed rate, corresponding to a nominal reactor residence time of about 12 minutes, to near 60% at the lowest feed rate, corresponding to residence times of 45 to 50 minutes.

Future plans are to scale up the 2-inch reactor to a 4-inch reactor and define and optimize the operating parameters.

BENEFITS

The technical results obtained have indicated that the yield of product can be increased significantly over previous methods. This yield increase, 25% to 79%, will result in a cost reduction that exceeds 60%.

IMPLEMENTATION

Data and correlations from the 1" and 2" loop reactor studies will be used to develop preliminary process designs for large scale production plants.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. N. C. White, AV 746-2612 or Commercial (205) 876-2612.

Summary Report was prepared by Andrew Kource, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 376 3135, 37T 3135, and 377 3135 titled "Process Development for Carborane Manufacture" were completed by the US Army Missile Command in December 1980 at a total cost of \$4,800,000.

BACKGROUND

A low cost process was needed by the Army for the manufacture of n-hexyl carborane (NHC). NHC can be manufactured in a three-step process where the first intermediate product is diborane (B2), the second intermediate product is decaborane (B10), and the final product is NHC (also known as carborane). In a previous project, 375 3135, Callery Chemical Company had been awarded a contract to develop a scalable process for the conversion of B2 to B10. This additional series of projects was to advance the technology previously developed into a fully operational production facility.

SUMMARY

In the FY75 project, Callery developed a vapor phase pyrolysis method for converting B2 to B10 in a unique convective circulation reactor. The final process step, conversion of B10 to NHC, was developed by in-house Callery laboratory and engineering studies from a laboratory method provided by the Army. These process improvement studies resulted in a commercial scale process with B10 to NHC yields in the order of 50 percent of theoretical, compared with only 30-35 percent yield obtainable from the original laboratory procedure.

The following is a brief description of the process that was developed, see Figure 1. B2 is converted to B10 by continuous vapor phase pyrolysis in parallel unit reactors. Each unit reactor consists of three 4-inch ID pipe loops staged in series to provide efficient B2 conversion and B10 yield.

The design of the reactor loop provides for rapidly heating a small portion of the gaseous reaction media, moving the reacted gases by convection quickly to the scrapped condenser to remove the decaborane from the gaseous media and continue to recycle the unreacted gases back through the heated reaction zone. On each pass, a small amount of diborane is converted to the desired decaborane. Repeated passes result in decaborane yields of 75-80%.

The decaborane is scraped from the condenser as it is formed and collected in product hoppers prior to being transferred to a dissolver where B10 is dissolved in reaction solvents, filtered, and pumped to the NHC Area. In the NHC Area, B10 is converted by sequential batch solution processing to give crude NHC. Key parameters in achieving high conversion yields are reactant and solvent ratios, addition rates, and time-temperature conditions.

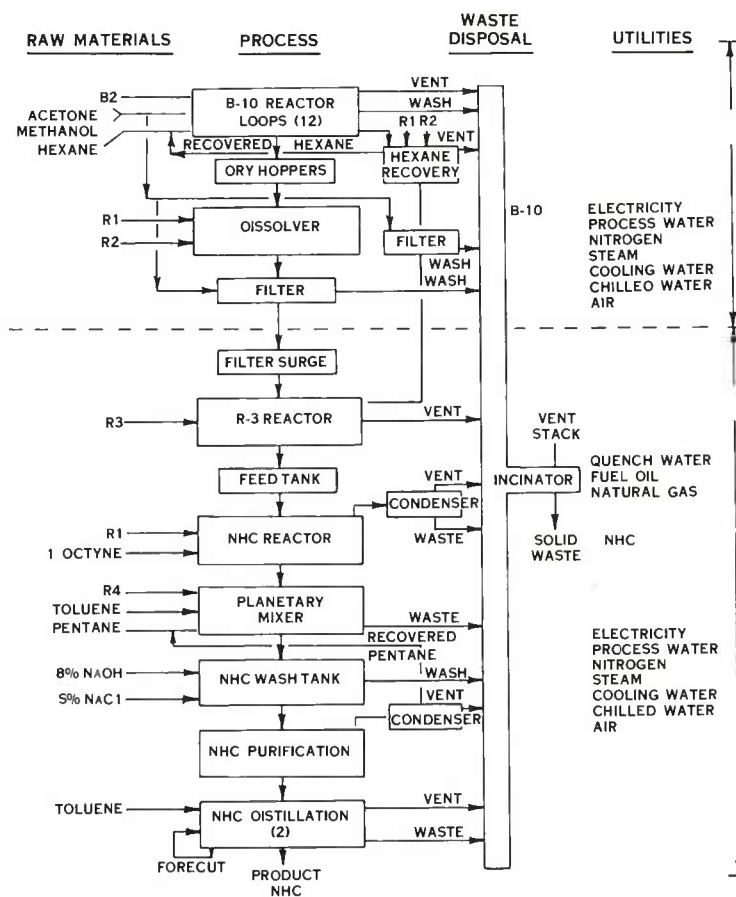


Figure 1 - NHC Facility Block Diagram

Subsequent processing involves the extraction of NHC from its waste co-products with pentane, purification by aqueous salt solution washing, solvent stripping and high vacuum distillation.

The reactor loop becomes more effective as a unit when two reactor loops are placed in series so that a portion of the reaction gaseous media is bled from the first stage reactor loop to the second stage loop for further cycling through the reactor and condenser system. Off gases from the second stage, consisting primarily of hydrogen and a very small amount of gaseous borane are sent to the waste disposal system for decomposition.

All process wastes, both vapor and liquid, are converted to relatively innocuous combustion products by direct flaring or incineration. Incineration combustion products are direct water quenched and bag filtered to remove and collect particulates. Collected particulate matter is packaged in drums for contract waste disposal. Sanitary wastes are piped to the existing waste treatment facility.

BENEFITS

A process for the manufacture of NHC was successfully developed. This project provided a method and source for an increased supply of NHC. The former annual supply was only 200 pounds. Now, up to 8000 pounds per year can be produced. An additional benefit is that the cost of NHC was reduced by \$1000 per pound.

IMPLEMENTATION

A facility was constructed and demonstrated at the Callery Chemical Company at Callery, PA. The facility can be expanded to produce up to 30,000 pounds of NHC annually.

MORE INFORMATION

Additional information may be obtained by contacting Dr. James G. Carver, MICOM, AV 746-1645 or Commercial (205) 876-1645. Most of the information presented here was extracted from the contractor's report: Callery Chemical Company, May 1979. Design of a Facility to Implement a Low Cost Process for Production of NHC. Division of MSA Company, Callery, PA 16024. 98p.

Summary Report was prepared by Andrew Kource, Jr., Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects R 77 3188 and R 78 3188 titled, "Imaging Infrared Seekers for Thermal Homing Missiles," were completed by the US Army Missile Command in February 1981 at costs of \$450,000 and \$500,000, respectively.

BACKGROUND

The ability to mass produce a moderate performance stabilized FLIR and its associated electronics for a cost commensurate with the low cost objectives of the Hellfire weapon system has long been in doubt. In 1972, Texas Instruments (TI) designed and developed an Imaging Infrared Seeker based on a parallel scan concept under contract to the Army. Captive flight testing indicated possible implementation in the Hellfire weapon system. Additional contracts were awarded to TI to update the performance. The objectives were to increase the optical collecting aperture to increase sensitivity; and incorporate the TOW night sight detector module. This would ultimately provide cost leverage through a large production base and associated life-cycle cost savings through logistics commonality. This seeker is referred to as MICOM II IRIS.

SUMMARY

The objectives of this effort were to identify high-risk, high-cost assemblies and components and to develop manufacturing methods to yield an affordable, producible implementation of IRIS shown in Figure 1. Concepts developed under earlier contracts were converted to a 7-inch outer diameter configuration compatible with the Hellfire missile. Comprehensive design and producibility studies were undertaken that identified the alternative design concepts and manufacturing processes available for production of each component or assembly. Rigorous design-to-cost (DTC) studies were initiated in parallel with the producibility analysis.

The alternatives resulting from the studies were compared to the system requirements in accordance with DTC concepts to obtain the optimum balance of performance and cost in a production configuration. Make/buy decisions were made on all the components, resulting in the purchase of many of the specialized components, such as the gyro, from multiple sources.

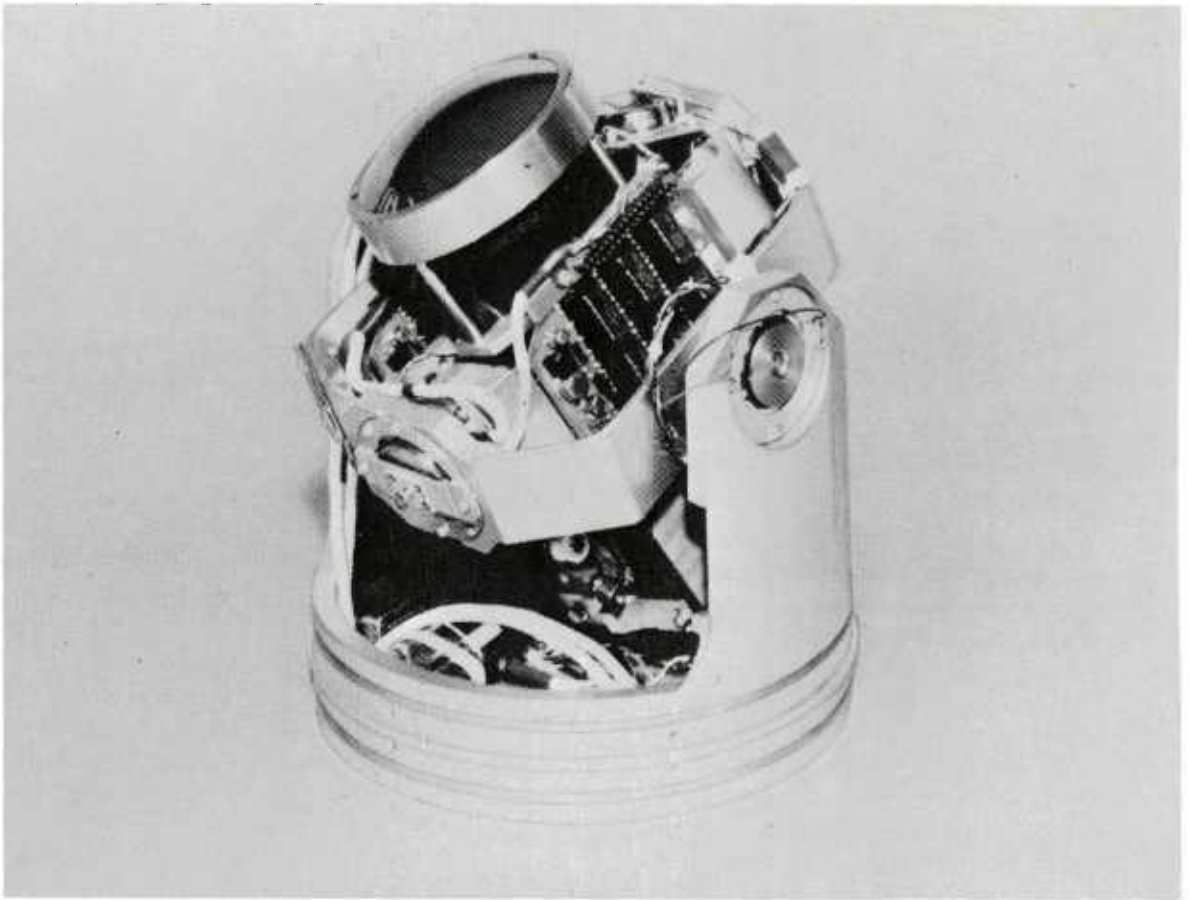


Figure 1 - MMT Infrared Imaging Seeker

As the trade studies were analyzed and the best approach was selected in each functional area, the optimum production configuration baseline for the IRIS seeker head was being defined. Data was tabulated to compare the Phase II configuration baseline with the production configuration baseline. Many subtle design changes were made to implement advanced manufacturing technology, and to reduce the cost while maintaining essential function.

An extensive nonmetallic material study was conducted to identify specific piece parts and classify them according to principal material property requirements. A 40 percent carbon-fiber reinforced plastic was tentatively selected as the material that best satisfied all the primary requirements. The decision was made to concentrate on low-risk parts, and to this end, the candidate parts were rank ordered. In most selected applications, the plastic performed as well or better than the metal it replaced. One exception to this was the plastic afocal housing. The first prototype housing was compression molded with very thick walls, contributing to a poor expansion coefficient that was not acceptable for a lens mounting material. A later housing was built with injection molding tooling and had the proper characteristics needed for the afocal, but the design was too late to impact Phase II.

Another consideration was the molding technique. Although injection molding is desirable in a production situation, compression molding is a viable, lower tooling cost alternative for small quantities.

BENEFITS

Ten IRIS MM&T seeker heads were fabricated from the Phase I baseline with a few improvements. A MIL-D-1000 Level 1 drawing package was generated and assembly procedures were written for all the major subassemblies and assemblies with references made to tooling.

Based on the design and manufacturing methods selected for the production baseline, Texas Instruments developed unit cost versus quantity information. For a production quantity of 40,000 seekers, the unit cost is \$5417, very near the DTC target of \$5160 set in Phase II.

IMPLEMENTATION

The Texas Instruments MM&T IRIS seeker was not used by the Army because the Hellfire seeker ED effort was not funded. The Air Force is currently using a modified MM&T IRIS in the Infrared High Value Target Acquisition Program for Low Level Glide Bombs involving the 500 lb and 2000 lb bombs.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Dave Lacy, MICOM, AUTOVON 746-7463 or Commercial (205) 867-7463. The contract number was DAAK40-77-C-0104.

Summary report was prepared by Dan Richardson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Projects R79 3219 and R80 3219 titled "Automatic Polymer Attachment Production Methods" were completed by the US Army Missile Command in June 1981 at a cost of \$200,000 and June 1982 at a cost of \$200,000, respectively.

BACKGROUND

Operator optical alignment of semiconductor chips on hybrid bonding areas was inefficient due to human fatigue introduced by repetitive inspection. Missing and misoriented components resulted in high cost rework and retesting. Existing computer controlled optical pattern recognition equipment had software limitations.

Remedies for these problems were to modify and advance optical pattern recognition equipment to recognize component and bond pad alignment for larger numbers of electronic devices per substrate. New software and the capability to read chip topology and identify chip circuit type by recognizing the number and location of bonding pads or other identifying criteria was needed.

SUMMARY

This effort's objective was to develop a semi-automatic chip recognition die bonding system. Work was divided into three phases. The Phase I (FY79) task was contracted to MEC AUBURN Alabama and the Phase II (FY80) work was awarded to Hughes Aircraft Co., Tucson, Arizona. Phase III to build the actual prototype system was awarded to Kulicke and Soffa (K&S) as follow-on project 3 82 1076.

MEC performed an in-depth study that evaluated present and future capabilities of major hybrid equipment manufacturers and hybrid assembly sites. Work scope included selecting a final machine type and preparing a prototype equipment fabrication schedule.

Hughes designed the electronics, hardware and software, and final overall integrated system for this automatic hybrid die bonder. The central mechanism of the hybrid bonder is the Kulicke and Soffa Small Parts Assembly Robot (SPAR). Figure 1 shows the SPAR based system mockup. This model was used to evaluate parts locations, human engineering interfaces and general equipment layout. Circuits having in excess of 200 components may be assembled. Chip rotation, pickup, orientation and placement are accomplished by using servomotors controlled by a Digital Equipment Corp. PDP 11/23 host computer.

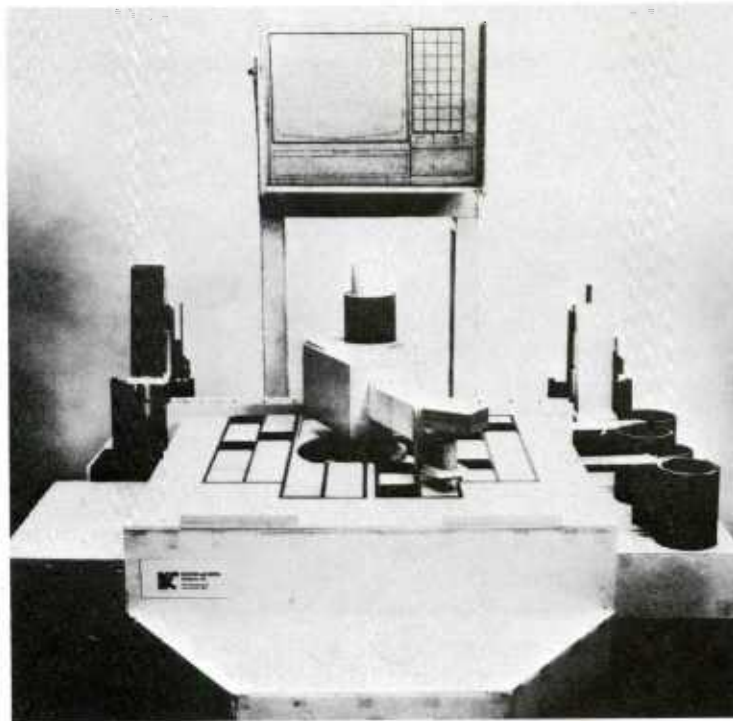


Figure 1 - SPAR Based System Mockup

The SPAR system includes 4 DC servo axis each with microprocessor control, RS 232 serial communications ports, binary I/O ports, floppy disk mass storage and control panel. A component pickup tool and CCTV camera mounted in the robot arm are capable of being positioned anywhere within a 12 inch maximum, 5 inch minimum reach. The rotating TV camera assembly is shown in figure 2.

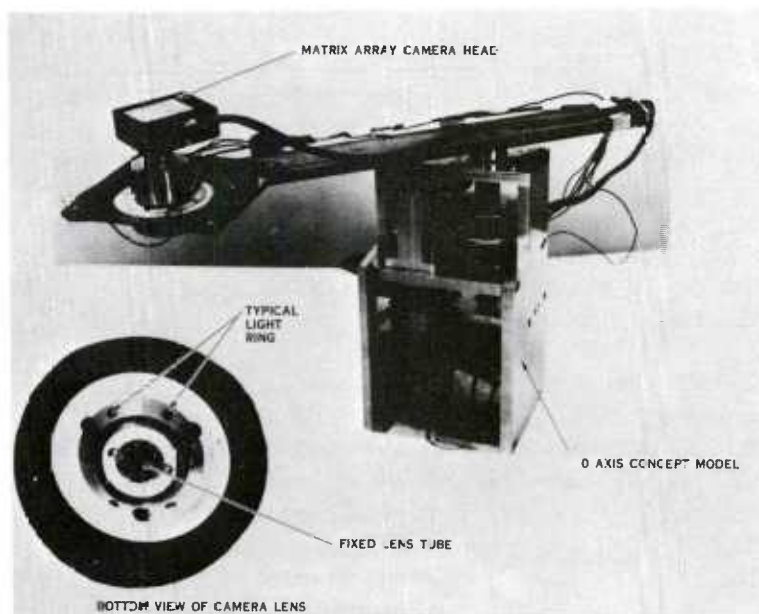


Figure 2 - Concept Model - T.V. Camera Assembly

The video system consists of a commercial vidicon camera, mixer, keyboard/terminal, monitor and a specially designed video augmentation subsystem (VAS). The VAS determines die location, orientation and substrate alignment. It is an external peripheral slaved to the main processor through a RS-232 serial interface. This subsystem has the capacity to store and manipulate up to 50 different chip types, with each chip having as many as 4 views.

Software design for the complete die bonding system is divided into two parts: robotics and hybrid die bonder. Robotics are controlled by the real-time multi-tasking disk operating system KSDOS. This program controls and manages the computer memory, processor, and input/output facilities. All diagnostics and run-time security and safety features are under control of the robot. The hybrid die bonder control executive is the manager of all bonder processes. This program performs management of all die bonder operational modes (manual, teach/edit, auto, single-step, and diagnostic/set-up) and was developed in PASCAL and Robot Control Language (RCL). RCL is a hierarchical high-level language with control and datum constructs specifically designed by K&S for the assembly environment.

BENEFITS

New attachment techniques and production methods demonstrated by Hughes will increase hybrid bonding yields 25 percent.

IMPLEMENTATION

Results of the MEC and Hughes effort, Phase I and Phase II respectively, have been documented in separate final reports. The Phase III final task is continuing with Kulicke & Soffa's construction of the prototype machine on follow-on project 3 82 1076 under contract DAAH01-82-C-0878.

MORE INFORMATION

Additional information may be obtained from Mr. Milton Sulkowski, US Army Missile Command, Redstone Arsenal, AL, AUTOVON 746-2147 or Commercial (205) 876-2147. The contracts were DAAH01-80-D-0002 for phase I and DAAH01-81-D-A002 for phase II.

Summary report was prepared by Steve Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project R 80 3396 titled, "Injection Molding of Low-Cost, One-Piece Nozzles", was completed by the US Army Missile Command (MICOM) in December 1982 at a cost of \$180,000.

BACKGROUND

Solid propellant motor nozzles are currently fabricated by three methods; machining of refractory alloys, machining of graphite, or compression molding from reinforced plastics. These methods involve substantial production time and cost.

Previous R&D projects have demonstrated the feasibility of injection molding advanced thermosetting or thermoplastic materials to a nozzle configuration. During the first year of this two-year MMT program, candidate thermosetting materials were evaluated and selected for an injection and compression molding comparison study on mechanical properties, flame erosion resistance and their processing parameters. The most dramatic comparison resulting from this study was that of the cost differences between compression and injection molding. In terms of man-hours required in molding, the injection molding process was approximately ten times more cost effective. Tooling for injection molding an eight-inch exit diameter nozzle was designed and fabricated. A quantity in excess of twenty nozzles was delivered for Government evaluation.

This project, the second and final year of the program to establish the production process, was conducted at MICOM and under contract with the Boeing Aerospace Company, Seattle, WA.

SUMMARY

The contract objectives were to utilize the material test data and processing specifications generated in the prior year to establish an improved process for nozzle injection molding. The improved process would then be applied to a production nozzle configuration.

The nozzle configuration selected by MICOM was the Vought/ARC design for the Multiple Launch Rocket System (MLRS) shown in Figure 1. The contractor, therefore, directed his efforts to the production of the MLRS nozzle. Rework of the eight-inch nozzle mold was initiated. Additional improvements such as hydraulic core pulls were added to insure safety and to facilitate loading of a steel mounting ring. In addition, a refinement to the 500 ton molding machine was made to alleviate excessive downtime resulting from extrudate blockages in its nozzle housing assembly.

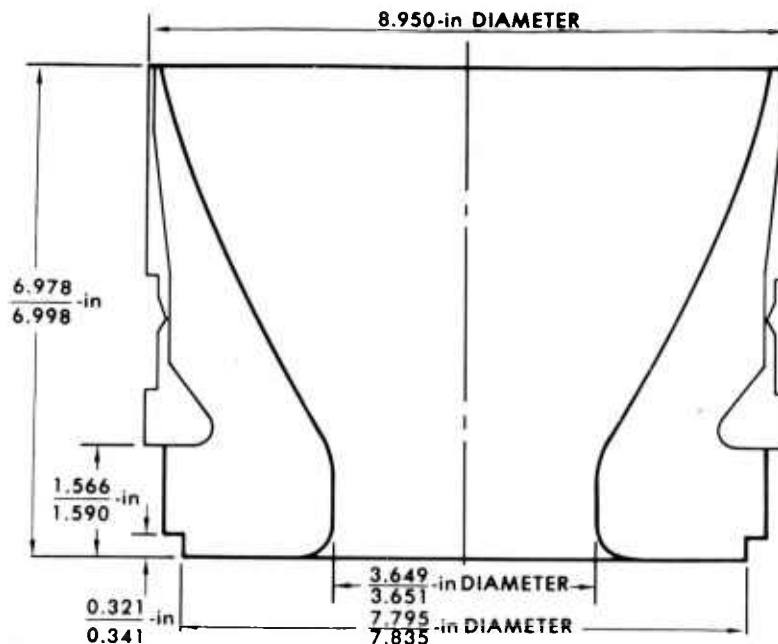


Figure 1 - MLRS Nozzle

A quantity of 40 nozzles were injection molded, twenty each of Durez 29053 (a glass and mineral filled phenolic) and twenty each of Rx 865 (a long glass filled phenolic). Forty additional nozzles were molded in four additional materials of ten each of Durez 23570 (glass and mineral filled), Durez 29237 (cellulose filled), RCI 25450 (cellulose and glass filled) and FM1132-P (cellulose filled).

Before the MLRS nozzle could be molded, various cleaning and priming operations had to be accomplished on the GFE nozzle mounting ring, a steel collar surrounding the nozzle wall. Ring preparation was the most time consuming of all molding functions but it was done to assure absolute adhesion of the phenolic molding compound.

After the mold and machine were preheated according to specifications, the primed mounting ring was hand loaded into the mold and hydraulically clamped. A semi-automatic injection cycle followed. The filled mold cavity was then allowed to cure. After the part was removed and cleaned to remove flash, it was post cured to assure complete curing of the thick sections.

Samples were drawn from each batch of nozzles that were molded from different materials. They were sectioned by an abrasive saw and examined to correlate surface conditions to internal conditions. The Durez 29237, 29053 and 23570 and the RCI 25450 molding compounds performed well. The parts were free from cracks, pits, voids, and knit lines on their surfaces or internally. Attempts to x-ray the parts were unsuccessful and ultrasonic inspection results were indeterminate.

BENEFITS

Each nozzle required about 50 minutes to process. By eliminating the ring preparation process and running the molding machine on a fully automatic cycle, the contractor expected that processing time could be reduced to six minutes per part.

IMPLEMENTATION

The implementation plan was based on the six minutes per part criterion. All tooling, equipment and facility cost estimates were based on actual machine supplier estimates or historical data.

In order to scale-up from the low rate capability made possible by this MMT effort, additional expenditures would be required. Production at 120 and 240 parts/day rates could be reached by investing \$135,000 and \$465,000, respectively.

MORE INFORMATION

Additional information on this project is available from Mr. William Crownover, MICOM, AUTOVON 746-5821 or Commercial (205) 876-5821. The final technical report from the contractor is TR-RK-CR-82-4, "Injection Molding of Low-Cost, One-Piece Nozzle."

Summary report was prepared by Gaylen Fischer, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 476 4563 titled "Rotational Molding of Large Capacity Fuel Tanks for Combat Vehicles" was completed by the US Army Tank-Automotive Command in February 1981 at a cost of \$325,000.

BACKGROUND

Fuel tanks for combat vehicles are made of metals such as aluminum and steel. In the design of a combat vehicle, the engine, transmission, and suspension take precedence over all other componentry as to their size and location. In order to satisfy the travel range requirements for the particular vehicle, much of the extra space is utilized for fuel storage. The resulting fuel tanks are not symmetrical in shape and exceedingly difficult to manufacture. Further, combat vehicles operate in adverse climatic and terrain conditions wherein water, dirt, and contaminated fuel are introduced into the metal tank. These factors generate stress concentrations that lead to cracking, corrosion, fuel leakage, and safety hazards.

An earlier project (473 4311) produced a simple geometry nylon-6 rotationally cast fuel tank for the 1/4 ton (M151) and 1 1/4 ton (M715) trucks. These tanks were relatively small (under 30 gals) and their shapes regular and symmetrical. Adapting this same process to fuel tanks of the larger unsymmetrical shapes of a combat vehicle could resolve the problems mentioned above.

SUMMARY

The objective of this project was to establish the manufacturing techniques for rotational molding of large capacity one-piece plastic fuel tanks for combat vehicles. The M88 and M551 vehicles were chosen for this project. The M88 has three main tanks which were felt could be molded separately. The M551 Armored Reconnaissance Airborne Assault Vehicle (ARAAV) has only one very long tank but it was decided to mold it in two sections and bolt them together in the middle.

The approach taken was to design and fabricate steel molds of the existing tanks for use in rotational molding. Then the non-metallic fuel tanks will be completely interchangeable with the existing metal tanks. No modification to the vehicle would be required. To allow for plastic shrinkage, all dimensions were increased by 0.025 in.

In rotational molding, the molding material is placed inside the mold. The mold is rotated simultaneously about two axes. The molding material coats the surfaces on the inside of the mold as the mold is being rotated. Thickness of fuel tank walls can be controlled by varying the amount of molding material. One of the best features of this production technique is that there are no seams.

The fuel tanks for the M551 are installed by a strap arrangement. Those for the M-88 are installed by heavy duty metal brackets supported from the floor. The problem of installing metal inserts onto a plastic fuel tank is to be able to duplicate the exact configuration of the steel tank. Rather than mold in a similar bracket, it was elected to mold in inserts and mount brackets similar to the originals. With the exception of the bolt inserts used in the connection of the tank sections, all the other inserts were installed under compression. This means that a separate ring was placed inside the tank prior to molding. This was accomplished by supporting a rod halfway into the tank mold and connecting the ring inserts to the rod. The inserts were then wrapped with aluminum foil, the mold was charged and after the tank was completed, a hole was cut out to get access to the inserts inside the mold. This was done on all of the fuel cells molded. The ring that was inside the tank was then used to receive the bolts to hold down the insert after the hole was drilled and the insert was installed.

Nylon-6 was used first for fabricating tanks for the M88 vehicle. However, they failed the drop test (tank filled 3/4's full of water dropped 20 feet on concrete) even after returning to the contractor for correction. Scheduled testing of these tanks was not conducted.

Rotational molding with cross linked high density polyethylene was then used successfully. The tanks passed the drop test but the first ones made could not accept design capacity due to an air pocket. Modifications of the tanks by the contractor permitted tanks to accept design fuel capacity. They also passed the dart test (empty; 6 lb darts with 1/4" diameter head dropped 10 ft.) and leak/pressure test (empty, hold 4 psi for 3 min.), both conducted after the drop test.

It was discovered that the tanks swelled about 2% when filled with fuel. Hence, it was fortunate the insert approach taken was used. It will be longer lasting and better than an insert molded into the unit. The swelling tightens the insert so that no leaks can occur. If the insert were molded in, the swelling could cause a leak around the insert.

As a result of this project, the conceptual idea of being able to mold a plastic tank 97" x 36" x 36" is a basic reality. One of the plastic replacement tanks built for the M551 is compared with the original metal tank in Figures 1 and 2.

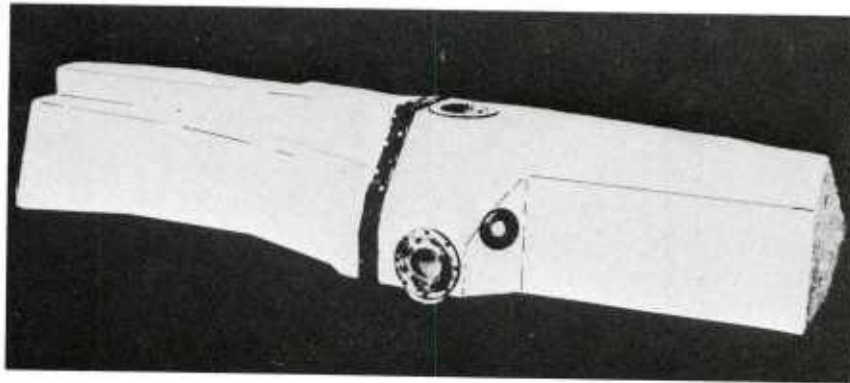


Figure 1 - Plastic Fuel Tank Assembly, Right Side,
For M551 ARAAV

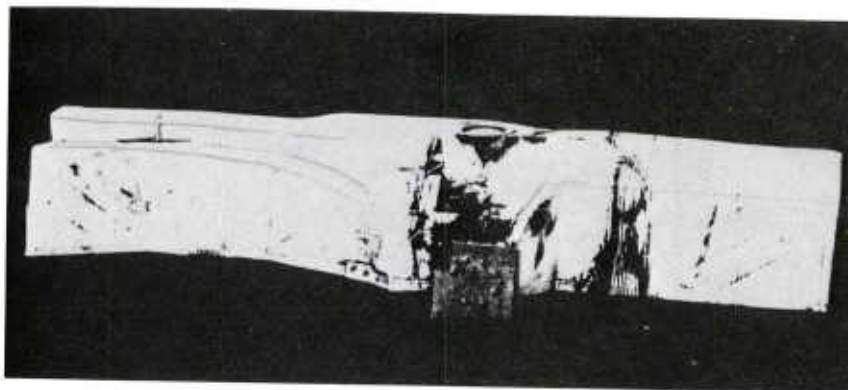


Figure 2 - Steel Fuel Tank, Right Side, Original,
From M551 ARAAV, USA REG. NO. 13C563

BENEFITS

There are a number of benefits to the fuel tanks made by rotational molding. Plastic offers weight reduction, better fuel economy, corrosion and impact resistance, as well as design flexibility. Odd configurations in rotational molded polyethylene allow the designer to maximize vehicle space available for the tank. Similar shapes would be very costly with fabricated metals. Finally, repairs and replacements should be easier with plastic than metal.

IMPLEMENTATION

Plastic fuel tanks from rotational molding are being made for both the M1 tank and FVS vehicle. Another candidate for future use is the M60 vehicle. If the M88 and M551 families are expected to remain in service, then they too should be considered for converting to plastic tanks.

MORE INFORMATION

Additional information can be obtained by contacting Dorothy V. McClendon at AV 786-6491 or Commercial (313) 574-6491. Also, technical report No. 12529 titled, "Rotational Molding of Large Capacity Fuel Tanks for Combat Vehicles" was prepared by TARADCOM in July 1980.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 579 1355 and 580 1355 titled "Manufacturing Plants Toxic Effluents/Emissions Pretreatment Evaluations" was completed by the US Army Armament Materiel Readiness Command in April 1983 at a cost of \$104,000 and \$222,000, respectively.

BACKGROUND

The Federal and State regulations (i.e., the Clean Water Act of 1977 as amended) have been passed since the construction of Pine Bluff Arsenal's (PBA) Pollution Abatement Facility which emphasize standards more restrictive than those in effect at the time of design.

The major regulatory emphasis has been the control of toxic pollutants through the use of the "Best Available Technology" (BAT). New parameters and standards have been identified by the Environmental Protection Agency (EPA) in PBA's new National Pollutant Discharge Elimination System (NPDES) permit that require BAT. For example, recent toxicity studies on elemental phosphorus by the Surgeon General's Office have established a stream toxicity value that limits the concentration to 0.01 ppb by weight in the Arkansas River. This value represents approximately 4 ppb at the lagoon discharge outlet. In addition, the EPA published list of toxic substances contains constituents that are in-use or proposed for use at PBA (hexachlorethane, zinc, cadmium, cyanide, lead, mercury, selenium, benzene, and chlordane). These substances may require pre-treatment before release to the presently designed control waste treatment system. In order to comply with the new regulations, a project was initiated to obtain the information necessary to improve the quality of the industrial waste water discharged.

SUMMARY

The purpose of this project was to identify toxic effluents/emissions from PBA through bio-toxicity and chemical testing and the best available methods for pretreatment of these toxics. This information would then be used to design modifications to the current pollution abatement facility to allow PBA to meet the EPA's FY84 deadline for BAT.

Since PBA is classified as a user of chemical compounds, a complete survey of chemicals used or stored at PBA was conducted. The survey identified impregnite as the only chemical for which PBA was required to report as a user under the Toxic Substances Control Act (TSCA) to the EPA for inclusion in the inventory of chemicals. The survey also identified hexachlorethane, zinc, dyes, benzene and lead as process or stored chemicals which were on EPA's priority pollutants list. Hexachlorethane, dyes and zinc are consumed in large quantities in PBA's processes.

A chemical evaluation of PBA's waste streams was conducted to classify and identify any hazardous materials. PBA's industrial waste, before treatment, was known to contain a high concentration of hexachlorethane. Tests were conducted at the Central Waste Treatment Facility (CWTF) both before treatment (influent) and after treatment (before transfer to the settling lagoon). The results identified chemical contaminants and showed their fluctuations varied depending on what production operations were active at the time measurements were taken. The effluent at the lagoon indicated compliance with the current regulatory requirements.

A series of static aquatic bioassays was conducted on the CWTF influent and the lagoon effluents using the bluegill fish as the test specimen. The test results verified the chemical analyses showing a variation of toxics (from very toxic to non-toxic) entering the CWTF. The tests indicate that continuous sensors and controls on the influent stream would provide a more efficient treatment by treating the waste only when the toxic and/or chemical level required it. Monitoring the lagoon discharge water using the bioassay indicated an effective treatment of the industrial waste.

A continuous biomonitoring system using the "breathing" movements of fish gills was evaluated as a tool to provide early warning of the presence of toxic materials in PBA's industrial waste stream both before and after treatment. Based on the results, the system was recommended as a method to control the feed rate of treatment chemicals for the removal of toxic materials.

Powdered activated carbon is currently used at PBA on a batch basis to treat the wastewater to reduce or remove the total organic carbon (TOC) and toxic content. The use of an activated granular carbon column was evaluated as a replacement for the current powdered carbon batch process. The granular carbon column process was found to be more efficient, economical, reduced the carbon consumption and reduced the sludge volume. A flow diagram of the granular carbon column treatment concept is shown in Figure 1.

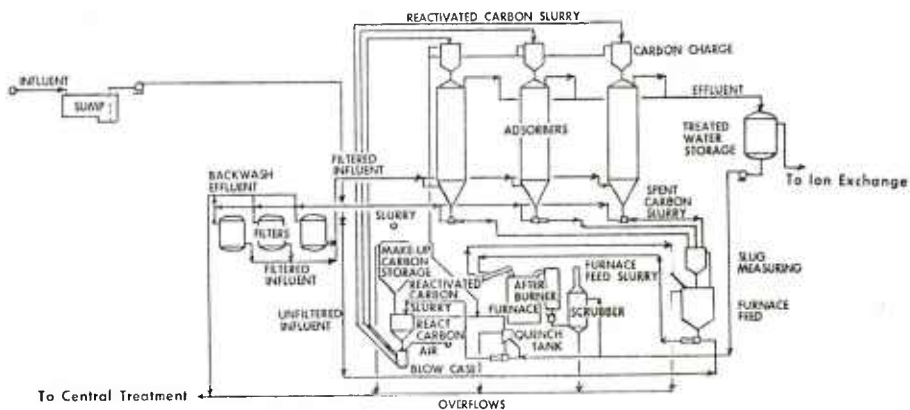


Figure 1 - Granular Carbon Column Treatment

The effluent from the carbon column would flow to an ion exchange treatment. This treatment was considered since it was known to be effective for removal of soluble heavy metals, hazardous anions, and cyanides. It provides the final treatment of the industrial waste. However, the EPA's final Resource Conservation and Recovery Act and toxic effluent rules did not require installation of the ion-exchange process.

As a result of this study, PBA recommended: (1) The implementation of the granular, carbon column treatment for its industrial waste water, and (2) On-line evaluation of continuous biomonitoring process to control treatment, feed and provide early warning of the presence of aquatic toxicants in the treated and untreated industrial waste water.

BENEFITS

A granular activated carbon column treatment was identified as a replacement for the current powdered carbon batch treatment process. Use of this new process will result in cost savings due to its higher efficiency, reduced carbon consumption, and reduced sludge volume.

IMPLEMENTATION

The granular carbon column process will be incorporated as a task in the FY86 MCA project T07600 for the CWTF at PBA.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. W. Fortner, PBA, AV 966-3578 or Commercial (501) 541-3578.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 576 4281, 577 4281 and 578 4281 Subtask A01 titled "Process Energy Inventory" was completed by the US Army Armament Research and Development Command in July 1981 at costs of \$375,500, \$351,800, and \$178,200, respectively.

BACKGROUND

Project 5XX 4281 "Conservation of Energy at Army Ammunition Plants" is an on-going effort to establish manufacturing methods and technology in the area of energy utilization and conservation during munitions manufacturing. Emphasis is on the adaptation of current technology to the peculiarities of manufacture of military unique materials. The measures developed under this project will be applicable during both peacetime and mobilization.

SUMMARY

The objective of this subtask was to conduct an energy inventory of the manufacturing and loading operations at selected Army Ammunition Plants in order to reduce the total consumption of energy. This effort was required to identify where immediate energy reduction measures could be implemented and where needed follow-on engineering projects were required to accomplish energy conservation. Also, a portion of this subtask was devoted to the use and application of infrared thermography as a means of determining and defining what unit operations/processes were losing heat and where the loss was occurring.

The process energy inventory conducted at Radford AAP centered on the activated carbon solvent recovery operation and the nitrocellulose (NC) boiling and poaching operations. In each area, the actual steam usage was monitored and the theoretical usage calculated. Where appropriate, electrical power measurements were taken also.

The activated carbon solvent recovery system is used to recover solvents that are inherently discharged into the atmosphere during routine propellant manufacturing operations. This is accomplished by collecting solvent laden air and forcing it through a bed of activated carbon which selectively adsorbs the solvent. After a fixed period of time, air flow is terminated and steam is forced through the bed to drive off the adsorbed solvent and regenerate the bed. Historically, adsorption cycles have been controlled by a simple timing mechanism which was unrelated to the degree of saturation and, thereby, inefficient. The efficiency of this system was improved by utilizing a lower

explosive limit (LEL) sensor at the effluent end to automatically control the adsorption cycle by the degree of saturation of the carbon bed. This has reduced the number of adsorption-regeneration cycles and, therefore, reduced the amount of steam consumed during this operation.

Steam usage monitoring of 14 tubs in the NC boiling area was conducted for one year. This study revealed that the actual usage was twice that theoretically required for reaching and maintaining boiling temperatures. Some of the excessive usage was attributed to (a) steam percolated into the tanks for agitation purposes, (b) steam leakage through valves, fittings, etc., and (c) poor regulation of the steam into the tanks. A variation of 22% was observed also among process cycles. To alleviate this variation and reduce steam usage, automated control valves, a temperature sensor and transmits the signal to the controller which governs the steam flow by incrementally opening and closing the control valve. The use of this instrumentation has resulted in a 30% decrease in the amount of steam used.

Process energy inventories were conducted also at Volunteer, Holston, and Kansas AAP. The inventory conducted at Holston AAP examined 18 major production processes and cited numerous opportunities for potential energy savings. The Kansas AAP inventory established the energy consumption baselines for all of the individual operations associated with the production of the M483 round.

The use of infrared thermography was investigated as a possible means for the identification and location of those areas exhibiting the greatest heat loss. Results of these tests demonstrated that infrared thermography could be used to provide quantitative information, but only after tedious and impractical data reduction. Classical engineering techniques such as direct temperature measurement and heat transfer would be the more reasonable approach to pursue. Therefore, the use of infrared thermography as a process energy inventory tool was considered too impractical to pursue further.

BENEFITS

These investigations have established the technological basis needed to define unit operation/process inefficiencies and the means which might be employed to correct them. Further benefits will result as more work is done in this area.

IMPLEMENTATION

The lower explosive limit sensor will be installed on the carbon solvent recovery system on C-line at Radford AAP. Annual savings of approximately \$54,000 in steam usage are expected.

The installation of automatic temperature controllers on 30 NC boiling tubs at Radford AAP is scheduled under PSR Project 583 5326. Automatic control will result in an annual savings of \$591,000 at the current production rate.

Implementation of other energy conservation measures identified by this effort are under consideration by the respective ammunition plants and pending further work in this area.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. D. J. Casey, AV 880-3998 or Commercial (201) 724-3998.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 579 4281 Subtask A02 titled "Optimized Insulation" was completed by the US Army Armament Research and Development Command in March 1982 at a cost of \$193,000.

BACKGROUND

Nitrocellulose (NC) purification boiling and poaching operations require a series of hot water boils ranging in duration from 1 hour to 84 hours during which the water/NC slurry is heated with steam either by percolation or by injecting the steam into the slurry. During the time that the tubs are brought to and maintained at the proper temperature, heat is lost through conduction and radiation from the sides of the stainless steel tubs. In view of the escalating cost of energy, it was apparent that a substantial energy savings could be effected if a safe insulating system could be designed.

SUMMARY

The purpose of this project was to select, install, and evaluate a thermal insulation system for the stainless steel boiling tubs at Radford Army Ammunition Plant and other Army Ammunition Plants. In order to accomplish this objective, a survey of insulating materials was conducted. For a material to be selected as a candidate, it had to meet the following criteria:

1. Zero permeability per ASTM C355
2. Low thermal compressive strength
3. High relative compressive strength
4. Lightweight
5. Impervious to nitric and sulfuric acids
6. Noncombustible per ASTM-E-136
7. Possess thermal insulating qualities

Foamglass, a resin impregnated fiberglass material manufactured by Pittsburgh-Corning, was the only material that met all of these requirements even though its insulating potential was less than other materials evaluated.

Particular attention was also given to material selection that would prevent tank surface corrosion and provide positive surface contact. Additionally, the material should not permit NC or moisture penetration if it becomes contaminated with the slurry. A final requirement was that the NC stability remain unaffected by the reduced energy of this purification process.

Preparatory work on the tank to receive the insulation consisted of welding two flanges around the periphery of the tank (Figure 1). The bottom

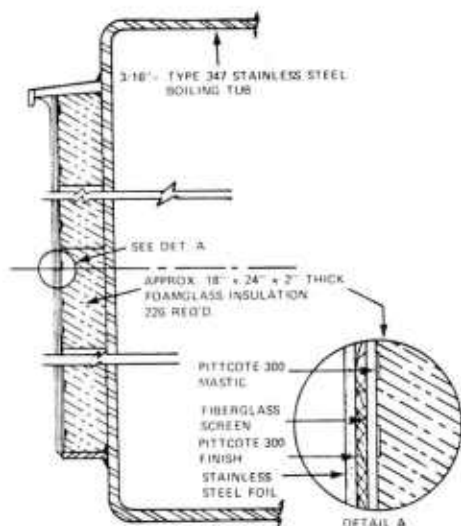


Figure 1 -

Boiling Tub Insulation Details

flange served as a support for the insulation, while the top flange served to protect the insulation from any water or slurry coming from the tank. A 2-inch thick Foamlglass insulation was applied to the tub surface, and a thin coat of Pittcote-300 mastic was applied to the Foamlglass. A fiberglass cloth was then laid over the entire surface as a reinforcing material, after which another coat of Pittcote-300 was applied. A 0.02-inch thick stainless steel sheeting envelopes the entire tub side to protect the insulation against damage.

Insulation was not applied to the boiling tub top or bottom. In the former case, insulation was not applied due to the many appurtenances which would present sealing problems. The energy conservation sacrifice due to this particular lack of insulation is 28.9% of the total potential savings or a maximum of 34,825 btu/hr per tub. The tub bottom was not insulated due to sealing problems and there was a minimum of heat lost through the bottom.

The amount of steam required to process various types of NC in a manually controlled, uninsulated tub varied from 3.49 kg of steam per kg of NC for P-7 pulp to 8.06 kg of steam per kg of NC for BL-7 cotton. The average steam usage was 857 kg/hr (1889 lb/hr) during three on-boil cycles for the four types of NC. For the insulated tub, the amount of steam required to maintain the on-boil temperature was reduced to 701 kg/hr (1545 lb/hr). This was a reduction of 155.8 kg/hr (344 lb/hr) from the average on-boil steam usage for the uninsulated tub.

Single and dual temperature sensor automatic control equipment was then installed on the insulated tub. Average steam usage with the single sensor for the on-boil cycle was 521 kg/hr (1148 lb/hr). This was a reduction of 126 kg/hr (277 lb/hr) over the uninsulated tub. Considerable adjustments were required with the dual sensors to obtain optimum operating parameters, but the 36.7 hours of on-boil operations showed a reduction in the steam usage to 309 kg/hr (681 lb/hr). This represented a steam reduction of 547.8 kg/hr (1208

lb/hr) from the uninsulated, manually controlled steam rates and 392 kg/hr (864 lb/hr) steam reduction from the manually controlled insulated tub. Further testing at the optimum setting was discontinued because C-line operations were shut down shortly after these tests.

A primary requirement of the study was that the stabilization of the NC be unaffected by a reduction in the amount of energy required to effect the purification process. Laboratory results from all NC processes through the insulated boiling tub showed no adverse stabilization effects.

BENEFITS

This project has demonstrated that it is technically feasible and economically desirable to insulate explosive/propellant processing vessels and is expected to promote the use of insulation in energetic materials operations.

IMPLEMENTATION

Insulation of the 30 boiling tubs at Radford AAP is scheduled to take place under PSR Project 583 5326. Annual savings of \$57,000 at the current production rate are anticipated.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Sam Moy, AV 880-3258 or Commercial (201) 328-3258.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project 580 4291 titled "Blast Effects in the Munition Plant Environment" was completed by the US Army Armament Research and Development Command in March 1982 at a cost of \$100,000.

BACKGROUND

This effort was the continuation of the development of safety design criteria for application in the design, layout and/or modernization of Army ammunition plants. The FY79 project under this effort emphasized the development of safety design criteria for the use of cold-formed steel panels to strengthen pre-engineered buildings. Because of the transient nature and the relatively high intensity of the blast loads, certain procedures and criteria have to be met in order to increase the capacity of the structure to resist these applied loads. Usually, the capacity of the frame members to resist blast loads greatly surpasses those of the supporting members. Thus, modifications have to be made in designing these support members. In order to determine where modifications are required and furnish reliable data for safety design procedures, a test program was initiated.

SUMMARY

The overall objectives of the project were to evaluate the usefulness of strengthened steel buildings as protective structures and to provide recommended design procedures whereby the full-blast capacity of the structures could be achieved.

To accomplish the objectives, explosive tests were conducted to evaluate the blast capacity of a strengthened steel building. A building was constructed at US Army Dugway Proving Ground (DPG) in Utah. The specially designed steel building was constructed with overall dimensions of 24.4m (80 ft) long by 6.1m (20 ft) wide by 3.7m (12 ft) high. The building was subdivided into four bays in the longitudinal direction, each of which was approximately 6.1m (20 ft) wide. The primary structural framework in the transverse direction consisted of three interior rigid frames and an exterior rigid frame at both ends. The column, girts, beams, girders and purlins had a minimum static yield stress of 248,200 kPa (36,000 psi). The walls and roof panels consisted of 18- and 20-gage cold-formed steel panels.

Instrumentation consisted of electronic deflection gages to record the movement of the structure, and pressure gages to measure the blast loads acting on the building as well as the free-field pressures. Photographic coverage, including both still photographs and motion pictures, was also used to document both pre-shot construction and post-shot test results. The cameras and explosive charges were located as shown in Figure 1.

BENEFITS

This project has developed safety criteria which can be used to design steel buildings for use at explosives manufacturing plants.

IMPLEMENTATION

The information developed from the project was integrated into existing safety regulatory documents (TM5-1300 and AMCR-385-100).

MORE INFORMATION

To obtain additional information, contact Mr. J. Caltagirone, ARRADCOM, AV 880-3662 or Commercial (201) 328-3662.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 678 7808 titled "Leak Detection Techniques for Small Sealed Fire Control Assemblies" was completed by the US Army Armament Research and Development Command in June 1982 at a cost of \$86,000.

BACKGROUND

Fire control equipment must be sealed from atmospheric contamination, especially condensation of water vapor on optical surfaces. The current testing techniques for detecting the presence and rate of atmospheric leak involve the measurement of gage pressure drop over a period of one to three hours. Disadvantages to this approach are that it is time consuming, the leak location is not determined and there is no accurate indication of leak size. In addition, this method is not precise and doesn't provide the desired confidence that the leak rate is no greater than 1×10^{-5} ml/sec at atmospheric differential. Consequently, the need for an alternative method exists.

SUMMARY

The objective of this project was to identify both leak detection and leak rate test procedures which are more accurate, less costly and less time consuming than those currently in use; and make recommendations to amend military specifications to include these methods. To accomplish this, a survey of leak detection techniques was conducted. Those alternative techniques examined were the mass spectrometer probe test, mass spectrometer vacuum test, and acoustic leak detection systems.

The mass spectrometer is probably the most sensitive instrument for detection of extremely small leaks through the presence of a tracer gas, commonly helium. In the mass spectrometer probe test, the assembly is pressurized with the tracer gas and a small sampling probe is run over its surface to detect minute leaks. Through the use of this probe, the leak location may be determined. However, sensitivity is less than that of helium vacuum testing since the probe draws in surrounding air which dilutes the tracer concentration. Therefore, it is an excellent method for leak detection and location but not for leak size.

In the mass spectrometer vacuum test, the fire control assembly is evacuated with the detector connected to the vacuum pumping system. The exterior of the assembly is sprayed with helium from a small nozzle and as the gas leaks into the instrument, it is detected. This technique is very accurate in determining leak location but the time necessary to run the test detracts from its efficiency.

The use of an acoustic detector to detect the high frequency emissions associated with leaks in vacuum and pressure systems was examined also. While these devices were capable of leak detection, they were incapable of determining leak size. Also, the wide variations in the commercially available equipment make the choice of a standard system difficult.

From these evaluations, it was evident that a combination of techniques must be employed to optimize the military specification sealing standards. This combination would (1) determine if a leak exists in a simple, accurate and time effective manner, (2) locate the leak site to facilitate repair and (3) determine the leak size in order to pass an acceptable standard. The final two operations would be performed only on leaky assemblies; whereas, the first operation would be done on all assemblies. Also, the examination for leak size could be performed in conjunction with another test, i.e., overpressuring the assembly with helium after the mass spectrometer probe test and then measuring the gage pressure drop calibrated to an appropriate standard leak. This comprehensive testing would then insure that a minimum standard is met in these assemblies and would enable them to be repaired.

BENEFITS

This project has evolved a combination of inspection techniques that will allow for increased sensitivity of leak detection measurement at a faster rate than is presently afforded by existing pressure drop methods. Also, alternative methods for leak location and size were established.

IMPLEMENTATION

It was recommended that an effort be made to ascertain what military standards covering sealed fire control assemblies should be modified in order to benefit from the conclusions of this project.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Thomas J. Gavanis, AV 880-2188 or Commercial (201) 724-2188.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 678 8017 and 679 8017 titled "Pollution Abatement Program" were completed by the US Army Armament Material Readiness Command in July 1980 at costs of \$82,000 and \$61,000, respectively.

BACKGROUND

The plating facility at Rock Island Arsenal is a potential source of excessive cyanide pollution. In this facility, parts are cleaned in a cyanide based derusting solution and plated in cyanide based cadmium or copper plating baths. During these operations, normal "dragout" occurs when work pieces from the derusting and plating baths are rinsed with water. This causes the wastewater to approach the cyanide limits established by the City of Rock Island, Illinois. Since an increase in production would result in even more dragout, a major effort was needed to reduce or eliminate all cyanide from Rock Island Arsenal's wastewater effluent.

SUMMARY

The objective of this project was to improve the quality of industrial wastewater effluent at Rock Island Arsenal by eliminating the use of cyanide based cadmium and copper plating and derusting baths. In order to accomplish this objective, two methods to produce cyanide-free wastewater effluent were considered. One method would be to construct separate sewers for collecting only cyanide wastes and divert them to holding tanks for chemical destruction when sufficient quantities were accumulated to warrant operation of the destruction process. The second method would be to replace the conventional cyanide based derusting and plating baths with appropriate non-cyanide solutions. This latter alternative was considered to be the most efficient and cost effective approach for resolution of the problem.

A literature search was conducted to find suitable, non-cyanide based chemicals to replace the cyanide based electroplating solutions presently in use. Only two cadmium and one copper cyanide-free plating solutions were found which appeared suitable for production use. Candidate solutions were acquired and used to plate test specimens. The resultant coatings were tested to confirm their conformance to required specifications. Those tested were:

- a. Cadvert cadmium: 3M Company
- b. Kadizid cadmium: Lea Ronal Incorporated
- c. Cupure copper: Lea Ronal Incorporated

Pure cadmium and phosphorized copper anodes were required for the respective baths. Additionally, acid and alkali resistant Dynel anode bags, zirconium anode baskets, and plastisol coated plating racks were required to prevent contamination of the baths.

Test panels measuring 1" x 2" x 0.125" and 2" x 3" x 0.125" were prepared from AISI 1009 steel for plating in a laboratory plater. These panels, after standard pretreatment, were cadmium plated at room temperature and copper plated at 150°F to prepare them for testing as specified by Federal Specification QQ-P-416C(1) and Military Specification Mil-C-14550A, respectively. Similar panels were plated in production baths for comparison.

Coating adhesion was evaluated by the knife test where the coating is cut through to the basis metal with a sharp knife and then examined under magnification for any evidence of non-adhesion. Both the cadmium and copper plated panels showed good adhesion. Further testing emphasized this point in that the deposits could not be scraped or peeled off with a knife or pulled off with adhesive tape.

Some of the cadmium coated panels were given supplementary chromate or phosphate treatments in accordance with Federal Specification QQ-P-416C. These panels were then exposed to a salt spray for 96 hours per ASTM Test Method B117. The panels from both types of cadmium baths showed no signs of corrosion during these tests. Extending exposure time to 192 hours, twice that of the specification requirement, failed to produce any evidence of corrosion.

The Kadizid cadmium process was chosen over the Cadvert system because it plated over a broader current density and produced a brighter deposit in the "as plated" condition. Kadizid coatings are also receptive to both chromate and phosphate supplementary treatments for added corrosion protection.

A summary of commercial non-cyanide derusting materials to replace the sodium hydroxide-sodium cyanide mixture presently in use was conducted also. The major requirement was that the material selected meet the requirements of Military Specification Mil-C-14460B, Type I. Several cleaning materials were chosen for evaluation of removal of soil, processing lubricants and other debris that are detrimental to the electroplating process. The most efficient derusting bath found was Oakite Super Rustripper.

BENEFITS

This project has demonstrated the use of non-cyanide based cadmium and copper plating and derusting baths in the electroplating of steel and brass. The use of such solutions will significantly reduce the amount of cyanide present in plating facility waste streams.

IMPLEMENTATION

Both the Kadizid cadmium and Cupure copper processes have been implemented into production plating at Rock Island Arsenal. These processes are being used in the same plating tanks that were used for cyanide plating. No change in the rack design, other than being plastisol coated, was required.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Frank Testroet, AV 793-5039 or Commercial (309) 794-5039.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 678 8049 titled "Manufacturing Processes Energy Conservation Program" was completed by the US Army Armament Material Readiness Command in January 1982 at a cost of \$104,000.

BACKGROUND

As the costs of energy continue to escalate, the cost of manufacturing weapon components correspondingly increases. The possibility of curtailing utilities during the winter months has been suggested in some northeastern states. Therefore, a thorough, analytical energy analysis of manufacturing facilities and processes at Watervliet Arsenal was necessary in order to provide a basis for a detailed energy conservation program in consonance with the Army's Energy Program.

SUMMARY

The intent of this project was to analyze Watervliet Arsenal's energy consumption and design an energy recovery system for manufacturing facilities and processes to include recommendations for alternate fuel usage, retrofit of energy recovery systems and renovation of facilities to gain maximum advantage of energy conservation techniques. To accomplish this objective, a two-fold approach was taken. The first involved data collection to indicate energy usage in the various processes, and the second was to develop a detailed plan for improved energy utilization.

Preliminary analysis of the rotary forge facilities to manufacture gun barrels resulted in the decision to focus further effort and evaluation on the forging and heat treat processes. The equipment used for cold sawing, straightening, and material handling represented too little energy consumed to warrant detailed investigation. Among the existing energy metering facilities, the most significant was the power-demand for the induction furnace, and integrating oil flow meters on the austenitizing and tempering furnaces. Additional monitoring equipment was installed as needed.

The rotary forge was designed to handle a variety of gun tubes ranging from the 105 M2A2 to the 8XM201. It consisted of the CFM rotary forge proper, the Cheston induction furnaces, induction furnace cooling tower, and the transfer mechanism between the furnace and the forge. Preliminary analyses indicated two major sources of potential energy recovery as (1) the heat generated in the induction coils, and (2) the heat given off as the tubes cool to room temperature. However, it was recommended that no immediate, specific action be taken to recover the heat energy given off, as the heat energy is at too low a temperature and/or is too difficult to capture to justify the expense.

The heat treat line was an integrated, continuous operation system composed of an austenitizing furnace with a charge table, a water quench, and a tempering furnace with charge and discharge tables, and post-temper continuous quench, designed and built by SELAS. This line was much more amenable to energy recovery because much of the "waste" heat was at a high temperature and was already contained. The source of this "waste" was the furnace flue products exhausted to the outside.

Analysis of the heat treat line revealed that added insulation, and rework of the existing air infiltration and exhaust dusts for recirculation would provide the best means for efficient energy utilization and recovery. Likewise, correct maintenance of the air-to-fuel ratio would insure good combustion. However, no effective means for the recovery of the energy in the roll cooling water was determined.

Two major alternative concepts were also considered as part of the evaluation process. These were the use of self-recuperative burners or a waste-heat boiler. The former alternative would have required major modifications to the furnaces, while the latter would need a main boiler in addition to the one proposed. Neither alternative would result in increased savings and both were dropped from consideration.

BENEFITS

The potential benefit of this project is a reduction of approximately 50% in fuel consumption in the SELAS heat treatment operation. Also, a thorough analysis of Watervliet Arsenal's operation was conducted for future reference needs.

IMPLEMENTATION

Implementation of the recommendations for the SELAS heat treatment operation is presently being conducted by the Manufacturing Engineering Branch at Watervliet Arsenal. It is anticipated that it will take one year to fully implement this recommendation.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Peter Thornton, AV 974-4201 or Commercial (518) 266-4201.

Summary Report was prepared by Mike Achord, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 6 80 8209 titled "Pilot Production of Gradient Index Optics" was completed by the US Army Armament Research and Development Command in March 1983 at a cost of \$213,000.

BACKGROUND

Prior to the proposal and execution of this project, research had been performed by the University of Rochester, Bausch & Lomb, Schott Optical and Kodak in the controlled insertion of an axial gradient index in various glasses. Much of the work involved the use of ion exchange to achieve a linear gradient to a depth of a few millimeters. Although the laboratory technology existed, the production technology had not been developed because of very small commercial demand.

The number of sights and viewing systems purchased by the DoD is significant. A reduction in the number of lenses in each system would result in tremendous benefits in cost and logistics. The use of gradient index lenses may enable the realization of this goal.

SUMMARY

Professor Duncan Moore, University of Rochester, was contracted to accomplish the first phase of a three phase effort, to develop manufacturing techniques for the production of gradient index optics and demonstrate their implementation in the M1 tank gunners primary sight or the M19 binoculars. The work in the first phase involved the redesign of the 6 homogenous lens eyepiece to a 3 gradient index lens design and the identification of manufacturing equipment such as furnaces to be purchased in the Phase II contract. Many Army lens systems were evaluated, but the eyepiece for the gunners primary sight was selected for implementation because of the high potential for cost savings.

The general performance of homogenous eyepieces of the Huygenian, Ramsden and Kellner configurations having two or three elements was examined. The requirements of the eyepiece were kept in mind during the examination. These are an eye relief of 12mm, constant image magnification, an f number of $f/3$, a focal length of 21.4mm, power of 10X, and a half field of view of 25° . The requirement for constant angular magnification results in a certain amount of barrel distortion. The limits of distortion used in the design were 3.5% for the fixed eyepiece and 6.5% when converted to the scanning design. Less than 4% is imperceptible to the human eye. During the design process, lens thickness and separation had the greatest effect on distortion. The eye lens tends to get thinner and the field lens tends to get thicker when reducing distortion. The curvature of the first surface of the field lens also effects distortion.

In order to achieve the 12mm eye relief, a flat sagittal field and a backward curving tangential field are desirable. This gives a relaxed accommodation on axis and maximum accommodation off axis. Field curvature is greatly affected by lens curvature.

The two element design was found not to have the appropriate degrees of freedom to correct lateral color. In order to achieve the color correction that was necessary, a doublet was introduced into the design, leading to the three element eyepiece. The classical Kellner configuration was optimized for an eye relief of 12mm and a half field of view of 25° , trading off distortion correction and field curvature correction. A maximum of -3.5% distortion was allowed because the fixed eyepiece design would be reoptimized to a scanning eyepiece design, relaxing the limit. A gradient was introduced on the back side of the eye lens to improve field curvature correction. This has little effect on distortion. A gradient was introduced on the front surface of the field lens to improve distortion correction. This has little effect on field curvature. The introduction of the gradients extends the eye relief, increases the field of view and helps correct monochromatic aberrations.

This fixed eyepiece design was reoptimized to produce a scanning system by slight variations in the parameters. Figure 1 shows the final eyepiece design. The distortion was maintained to -7.3% at 25° with the field curves well corrected. The transverse aberrations are well corrected with an axial spot of 42 microns and a spot radius of 160 microns at a fractional object height of 0.9.

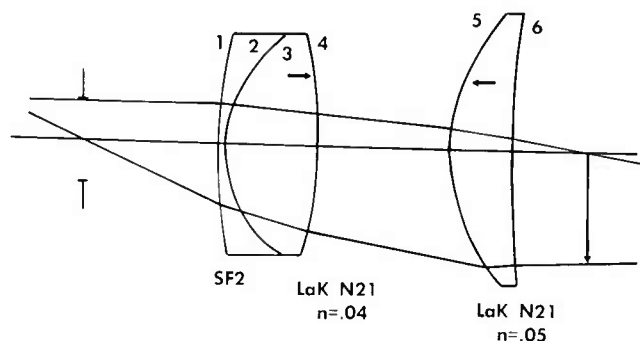


Figure 1 - Gradient Index Lens Eyepiece Design

Production and metrology equipment were selected which is the most likely to enable successful production of the optics. Lindburg furnaces were chosen because of the investigator's prior experience. These can operate around 1200 degrees C and can be controlled to 0.1 degrees C. The zone furnaces

allow better control of the central zone which may lead to a continuous processing system. A Cromenco System was chosen as the controller for the system. This allows flexibility in programming temperature profiles and controlling an electric field drive-in profile. It can be interfaced with a more powerful Eclipse S140 for more complicated computations if necessary. A small spectrometer will be purchased and an argon laser tube will be replaced in order to enable the measurement of the index profile.

BENEFITS

The use of gradient index lenses enables the use of lower cost conventional surfacing equipment instead of the higher cost aspheric lens surfacing equipment. The unit cost of a gradient index lens is expected to be only a fraction more expensive (10%) than a conventional lens because of the cost of simultaneously inserting the gradient in many lenses. The unit cost of the eyepiece is expected to drop significantly as a result of the use of fewer lenses in a system and reduced alignment and testing. Accompanying the use of fewer lenses are the added benefits of less weight, less volume, less lens spares, and ruggedization.

IMPLEMENTATION

Possible systems for implementation of gradient index fire control optics are M1 Tank, M60 Tank, M109A1 Howitzer, M113A1 Carrier, M198 Howitzer, and the M19 Binoculars. Because the M1 tank gunners primary sight is unavailable for testing, the M19 binoculars implementation is the most likely in this project. Phase II is presently continuing under MMT 6 81 8209.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Stan Kopacz, ARRADCOM, AUTOVON 880-6276 or Commercial (201) 724-6276. The contract number was DAAK10-81-C-0251.

Summary report was prepared by Dan Richardson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology Project E 79 3592 entitled "Improved Graphite Fiber Reinforcement, Phase II" was completed by the US Army Mobility Equipment Research and Development Command in October 1982 at a cost of \$307,000.

BACKGROUND

Aluminum components of military assault bridges are prone to excessive bending during vehicular crossings. To correct this problem, the materials for future bridging systems will be updated to improve rigidity and impact resistance. Existing aluminum structures will be replaced or augmented by graphite reinforced plastic or aluminum matrix composite structures. Currently available commercial grade graphite fiber could be used; however, an improved graphite fiber would further enhance operation and reliability. With improved fiber, the clear span of a bridge could be extended by 33 percent and service life would be lengthened.

Phase I of this Manufacturing Methods and Technology (MMT) effort was completed in December 1979 under Project Number E 77 3592. Phase I work efforts included the construction and operation of an arc-plasma fiber treatment facility which was capable of heating fiber bundles under tension in a controlled reaction atmosphere. A commercial high modulus fiber with 399,000 psi tensile strength and 53.9×10^6 psi modulus was passed through this furnace. Tensile strength was increased by thirteen percent and modulus was increased by two percent. The facility's capacity was limited to one-seventh pound of high modulus graphite fiber per hour.

Phase II was conducted to investigate another method which could attain the 750,000 psi tensile strength goal, the $60-65 \times 10^6$ psi modulus of elasticity goal, and the one pound per hour production goal. The Phase II project was conducted through in-house effort at MERADCOM and contractual effort at Fiber Materials, Inc., Biddeford, Maine.

SUMMARY

Fiber Materials, Inc. (FMI) constructed a pilot plant for the production of graphite fibers from a polyacrylonitrile (PAN) precursor. The attainment of the program goals depended greatly upon the characteristics of the precursor. Commercially available PAN fiber (Courtaulds SAF), with filaments drawn to the limit of standard technology (11 microns dia), was drawn an additional three to four times by means of a process developed on FMI's internal R&D funding. The filament size was reduced to approximately 6-8 microns.

Stretching the precursor fibers apparently led to improved alignment of the PAN polymer structure, which was in large part inherited by the resulting graphite fibers. Boron strengthened graphite fibers, containing 3-4 micron diameter filaments, were prepared from the drawn precursors using relatively conventional oxidation, carbonization and graphitization techniques. An average tensile strength of 550,000 psi at the 60×10^6 modulus level with a strain-to-failure value at 0.93 percent was achieved through a preliminary optimization of the plant processing conditions.

The pilot plant layout was separated into two lines: one line for two oxidation ovens and the other for the carbonizer and two graphitizers. The 1400°C pre-graphitization furnace and the 2400°C graphitization/boron treatment furnace are shown in Figure 1. The 1400° furnace appears on the right hand side of the figure.

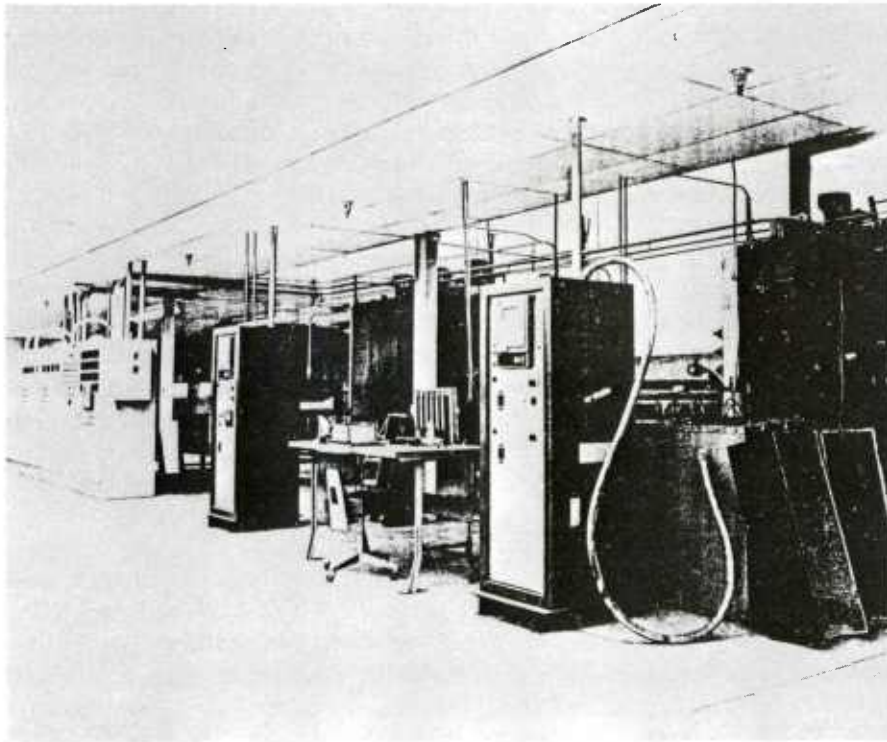


Figure 1 - Graphitization Pilot Line

The pilot plant was operated with a maximum of 24 tows. Shake-down trials of the plant revealed a multitude of processing problems. Most were corrected but improvements are needed before the production and physical properties goals can be reached. Temperature variations in the oxidation ovens, tarry deposits on the entrance and exit slots of the carbonization furnace, soot build-up and generally poor reliability of the graphitization furnaces, and a faulty drive and guiding system that could not apply adequate fiber tension during graphitization are the predominant areas requiring further optimization.

BENEFITS

The intended establishment of a manufacturing method for producing high strength/high modulus fibers at one pound per hour rates was not achieved by this phase of the effort. The contractor concluded that a 96 tow processing line should be built to meet the capacity requirements. Future work planned for the plant scale-up will complete the development and should lead to a further improvement in the tensile properties of high modulus graphite fibers.

IMPLEMENTATION

Implementation of this project depends upon the results of follow-on MMT Project E 82 3592.

MORE INFORMATION

Additional information on this project is available from Mr. Frank Harris, Material Tech Lab, MERADCOM, AUTOVON 354-5471 or Commercial (903) 664-5471. The final technical report from the contractor is FM-91178-2, "Improved Graphite Fiber," dated October 1982.

Summary report was prepared by Gaylen Fischer, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project E79 3708 titled "Coated Fabric Collapsible Fuel Tank Program - Circular Seamless Weaving" was completed by the US Army Mobility Equipment Research and Development Command in October 1982 at a cost of \$121,000.

BACKGROUND

Pillow tanks have been used by the military since the mid 50's for storing fuel in isolated locations or as an auxiliary to more permanent installations. These tanks are self-supporting, i.e., capable of supporting the fuel contents by the peripheral hoop stress of the coated fabric. No earth embankments are required to support the weight of the fuel. Panels of fabric are coated with an elastomeric compound, then seamed together to form a tank envelope.

Seams are the weakest element in collapsible tank construction, and seam separation is the most common catastrophic type of failure. In addition, making the seams requires considerable time and manpower. Much of the work is done by hand and the vulcanization at each seam requires from 1 to 3 hours to cure in the platens.

It has recently been demonstrated that it is feasible to weave the basic fabric into a circular sleeve type configuration, thus eliminating the weak longitudinal seams of current standard designs. Under these circumstances, it would be necessary to seam only two end closures to complete the tank envelope.

SUMMARY

The objective of this first year of a two-year effort was to perfect a weaving technique which will produce a seamless tube suitable for fuel tank construction. The second year project will produce a large circular sleeve for tank fabrication and testing.

Weaving of a tubular plain woven fabric is illustrated in Figure 1. This requires four heddles, one controlling yarns 2 and 6, one for 4 and 8, one for 3 and 7, and one for 1, 5, and 9. As shown, yarns 4 and 8 are raised first, then all except 3 and 7, then 2 and 6, then all except 1, 5, and 9, and then the cycle is repeated. In this way, two layers of plain woven fabric are formed, connected together at either edge by the filling yarns which pass consecutively from top layer to bottom layer and back to the top layer. The process is, in principle, no more complicated than weaving a single layer fabric. However, a special weaver's skill is required to adjust and control the loom operation so as to minimize or eliminate any discontinuity at the two edge turnaround points.

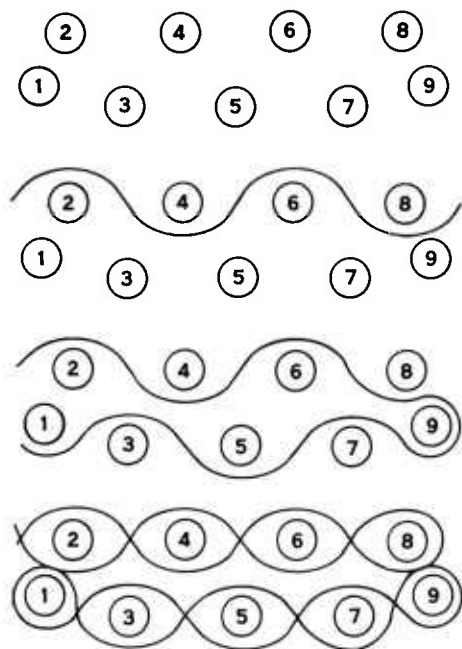


Figure 1 - Tubular Plain Woven Fabric

A contract was awarded to Albany International Research Company in April 1980 to advance the weaving technology for the production of large area tubular, seamless fabrics for the production of a 3,000 gallon collapsible fuel tank. Evaluations were made for yarn coating and sizing procedures. Also, an initial screening of water based coating compounds for use in trial coatings of the tubular fabric was made.

Scale model seamless fabrics were produced which were of such good quality that it was decided to amend the contract to require a larger size prototype tank. This 10,000 gallon tank would be more representative of the most commonly used collapsible tank.

Trial coatings were applied to small scale model seamless fabrics on a laboratory coater. However, problems were encountered in obtaining the desired coating properties using an aqueous based polymer solution. This resulted in a delay in the contract schedule and a small cost overrun.

Weaving of the full size seamless fabrics was successfully completed in January 1982. Fabric was woven in sufficient quantity to make two collapsible fuel tanks which will have dimensions (laid flat) of 23 by 17 feet. The fabric met the desired performance properties. Coating of these seamless fabrics and final tank fabrication will continue under project E803708.

BENEFITS

This effort has established the feasibility of producing a seamless fabric of a quality suitable for the production of collapsible fuel tanks. The coating of this seamless fabric with a compatible polymer has yet to be established under the present effort. Perfection of this technology will result in improved reliability and durability of collapsible tanks.

IMPLEMENTATION

Implementation of this seamless weaving technology for the production of coated fabric collapsible fuel tanks will be contingent upon the successful perfection of a coating material and application procedure. This manufacturing technology is continuing under Project E803708.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Charles Brown, MERADCOM, AV 354-5781 or Commercial (703) 664-5781.

Summary Report was prepared by Wayne R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

APPENDIX I

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HDL

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WVA

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