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MATERIEL DEVELOPMENT
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MANUFACTURING
METHODS &
TECHNOLOGY

**PROJECT SUMMARY
REPORTS**

(RCS DRCMT-302)

PREPARED BY

JUNE 1982

**USA INDUSTRIAL BASE ENGINEERING
ACTIVITY**

MANUFACTURING TECHNOLOGY DIVISION

ROCK ISLAND, ILLINOIS 61299

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

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1. In compliance with AR 700-90, dated 15 March 1982, the Industrial Base Engineering Activity (IBEA) has prepared the inclosed 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.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains summaries of 95 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.		

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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.

Contents

This report contains summaries of 95 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.

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 Mrs. Eileen Griffing and Mrs. Debra O'Connor with the typing and graphics arrangements.

ACHIEVEMENTS

This section contains abstracts of the key project achievements in this report. Attention is being focused on these projects because of significant benefits which are manifested through either technological advancements, cost reductions, or safety. This listing is not inclusive of all beneficial projects. Whether a project is beneficial or not depends upon one's needs. Therefore, even though the abstract of a project does not appear in this section, the reader should examine the body of this report for results that may suit his particular requirements.

TECHNOLOGICAL ADVANCEMENTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
R80 1021	Computerized Process Planning (CPP) for Cylindrical Parts	12

This project developed an operational computerized production process planning system for machined rotational parts. The resulting system, known as Computer Managed Process Planning is manufacture-independent and is generative in nature.

277 9812	Manufacturing Methods and Technology for Split Cycle Stirling Cooler	33
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This project describes the manufacturing procedures that were developed to produce qualified Stirling coolers. This lightweight, low power consumption cooler is currently in production at a unit price of approximately \$4000, which is \$400 less than the pre-MMT price.

277 9857	Automatic Separation, Carrier Mounting and Testing of Semiconductor Dice	36
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This project established a mechanized system for separating semiconductor wafers into chips, for attaching each chip to a metallized film carrier, for mounting film carriers into 35mm slide frames and for testing each framed chip. After testing, the chips can be incised from the film carrier and bonded to a substrate.

R78 3372	Manufacturing Methods for Magnetic Components	56
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The project identified several production techniques for improving the reliability of miniature inductors and transformers. The primary emphasis of the program was to determine those manufacturing processes and procedures that contribute to subsequent part unreliability and propose modifications to correct them.

R79 3410	Production Methods for Heat Pipes for Hybrid Microcircuits	60
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Low cost volume production techniques for fabricating heat pipe cooled microcircuit packages were established. Assembling, evacuating, filling, and sealing hybrid microcircuit heat pipe packages at a production rate of 15 per hour is possible. Heat pipe cooled packages lowered transistor chip junction temperature 50% compared to non-heat pipe cooled versions of the same package.

178 7123	In-Process Techniques for Continuous Balancing of Helicopter Shafting	83
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The purpose of this project was to build and demonstrate an automatic machine for the balancing of long hollow helicopter shafting. All required information is virtually obtained during a one cycle pass along the slowly rotating shaft. The ability to place the center of gravity at all stations along the shafts within 0.001-inch of the center of rotation was demonstrated.

R7T 3076, R77 3076	Mass Production Techniques for Composite Rocket Motor Components	113
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A three-phase effort was successfully completed to establish an economical production process for manufacturing small, high performance rocket motors. The process can be applied to motor case sizes up to six inches in diameter and seven feet in length. The motor cases were manufactured by the automated winding of resin impregnated fiberglass/epoxy rovings onto metallic mandrels.

575 4041, 576 4041, 578 4041	Automated Equipment for Assembly of Mortar Components	135
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A prototype line for loading and assembling of M204 (60mm) mortar propelling charges was designed, built and successfully tested. The prototype line is capable of assembling five increments per minute. The line is non-synchronous or a power and free production system and consists of six separate and different station designs and work areas. With some tooling changes, the line can be converted for the manufacture of the 81mm propelling charge.

579 4163	Controlled Production Loading System for 105MM HEAT-T M456AL	147
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The 105MM HEAT-T M456AL contains a shaped charge that is cast loaded with composition B explosive. Loaded projectiles were failing to meet inspection specifications with reject rates of 30 to 50 per cent. The project developed the technology and established a manufacturing method with an acceptance rate that exceeded 95 per cent. A production line based on this technology was constructed at Milan AAF.

579 4460	Continuous Mixer-Illuminant Composition Analysis and Control System	165
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The objective of this project was to design and evaluate a prototype analysis and control system to measure illuminant composition. Three techniques were investigated: nuclear activation, x-ray diffraction, and x-ray fluorescence. The latter approach was selected for prototyping. An x-ray fluorescence analysis system reduced the measuring time from the normal two hours to less than 15 minutes.

176 7164

Filament Winding Resin Impregnation System

183

This project successfully developed a roller resin impregnator capable of applying resin and hardener to fibers within two per cent by weight for a given fiber yield. This accuracy is attained by using metered pumps and pressure balance control.

H79 3504

Manufacturing Methods and Technology
Measure for Advanced Methods for
Fabricating Chalcogenide Glass Infrared
Lens Blanks

213

As a result of this effort, a production capability now exists for the compounding and casting of GeAsSe glass in 8 and 10-inch diameter plates. The number of lens blanks per plate was increased 180 per cent relative to the previous 6-inch diameter plate casting process. Additional cost savings resulted from processes developed for recasting glass scrap and for slumping glass blanks to curved form. Slumping lowered unit fabrication costs for curved lenses or domes.

COST REDUCTIONS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
274 9744	Fabrication of Universal Detector Modules	30
This project established a pilot production capability for producing Universal Detector Dewar Modules (UDDM) to a firm specification for Hg-Cd-Te photodetector arrays. The cost of producing detector dewar modules decreased by approximately 50%. Since the UDDM is applicable to a variety of 8-14 micron infrared viewing systems, this represents a large savings to the Army.		
R79 3146	Fine Line Hybrid Substrates	41
Manufacturing techniques were developed for thick film multi-layer conductor structures with dimensions as small as 2-mil lines and spaces. Production processes were established using commercially available materials and equipment. A cost comparison for a standard substrate using 10-mil lines and a fine line substrate was prepared. Material costs were halved and an area reduction of 2:1 was achieved. Substrate area used for the standard was 1-21 square inches and 0.64 square inches for the fineline.		
R77 3160, R79 3160	Establishment of Production Cleanliness Criteria and Processes for Printed Wiring Boards and Assemblies	44
This effort provided the ability to detect ionic and non-ionic PWP contaminants and measure their concentration in parts-per-billion or micrograms per square centimeter of board surface. Estimated savings averaged over a ten-year period amounted to \$966,000 per year.		
376 3227	Low Cost Production Methods for Handling Hybrid Chips Via Tape Carrier Lead Frames	50
This project established production methods and equipment for bumping semiconductor wafers, applying lead frames, testing the leaded devices, and attaching tested devices to hybrid substrates. Cost data developed showed that the number of components needed to justify the startup cost of lead-frame designs and tooling construction was lower than expected and begins with only several hundred to a thousand units.		
E(78-79)3606	Transcendent High-Power Rectifier	66
Specialized fixtures and procedures for rapid fabrication of heat pipes and for bonding the bases of two heat pipes to opposite		

sides of a silicon rectifier wafer were developed. High temperature brazing of the heat pipe body, sintering of porous copper wick, and ceramic-to-metal sealing were production engineered to permit volume manufacture. Cost of a typical high power rectifier was reduced from \$350 when built on a laboratory scale to \$80 when produced in volume.

175 7070

Cast Compressor Components

80

A cast stainless steel compressor impeller is normally manufactured by machining a 22-pound titanium alloy pancake forging to generate the 2.6-pound impeller at an approximated cost of \$2200. The method developed included hot isostatic pressing, heat treatment, and machining. The overall cost of the impeller is estimated to be about \$900 less than the hogged out forging for equivalent high volume production in lots of 50.

677 7644

Application of Integral Color Anodizing
for Aluminum

102

This project was to improve the anodizing process by modifying the acid bath to produce the desired dark gray or black color on the oxide coating. Commercially available integral color anodizing (ICA) processes were surveyed for application to aluminum alloy 7075-T6. The most feasible treatment was then applied to weapon receivers. The finishing costs on the M16A1 upper receiver show a savings of \$0.70 per item when the ICA process is used in lieu of the standard hardcoat process.

578 4143

Advanced Technology for Manufacturing
Canisters and Components (M259/XM264
Rocket Warhead)

144

The objective was to develop a method of manufacturing wick bodies that was more efficient and cost effective. All samples were produced using standard sheet metalworking equipment, including shear and pressbrake for the wick body and a simple punch and die set mounted in a punch press to blank out the end caps. The developed method could produce wicks at a cost of \$0.59 each resulting in cost savings of \$273,000 for each 300,000 unit production run.

178 7121

Integrally Heated and Pressurized Tooling
for UTTAS Rotor Blades

180

Significant costs are associated with autoclave curing and bonding of helicopter rotor blades. This project was to establish a

new, lower cost process by reducing tooling complexity and cure cycle time. The process selected was based on a mold system incorporating integral heating and pressurization. A projected minimum savings of \$257,000 is estimated for a production run of 1000 blades at five blades a day when compared to autoclave curing.

SAFETY

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
579 1403	Improved Process/Substitution of Nontoxic Dyes in Smoke Grenades	128

This project identified safer dyes and mixes which could be substituted into the yellow and green M18 grenades without changing the item configuration or performance. In addition to the improved safety, the new mixes are cheaper than the ones being replaced.

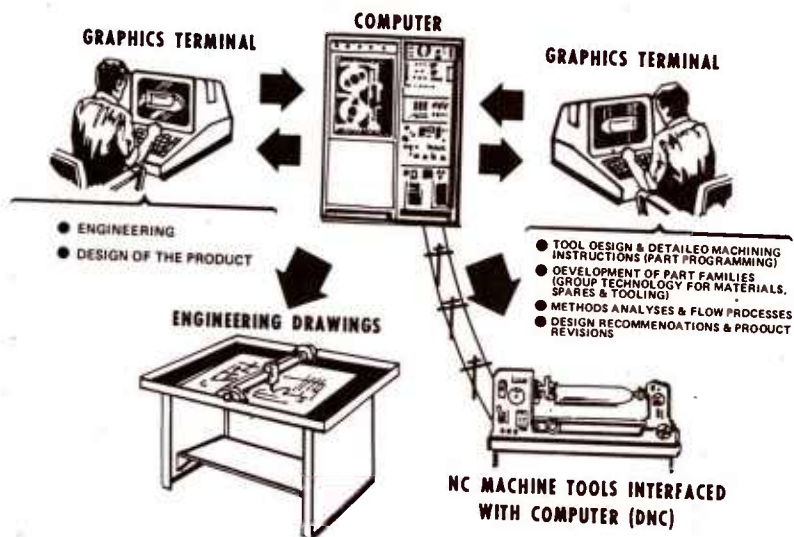
578 4267	Continuous Process for Granular Composi- tion B	159
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This work demonstrated that there was no impact hazard when dropping granular Comp B from a height of 35-feet in a prilling tower and that proper grounding should be incorporated to minimize the potential buildup of electrostatic charges.

576 6557	Continuous Propellant Drying, Salt Coating and Glazing	170
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This effort established a continuous drying process with significantly improved safety. Sufficient data was gathered and organized upon which the development of functional design criteria for a modernized drying plant can be used.

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



INFORMATIONAL FLOW IN A COMPUTER SYSTEM

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project R80 1021 titled, "Computerized Process Planning (CPP) for Cylindrical Parts", was completed by the US Army Missile Command in June 1981 at a cost of \$240,000.

BACKGROUND

Machined cylindrical metal components are significant cost drivers in missile systems. Currently, the process planning activities for these components are manually performed. The final set of operations detailing how to manufacture the components are subjectively determined and dependent upon the skill and expertise of the process planner. Traditional manual methods are slow, expensive, error-prone, and tend to produce unnecessary variety in the production processes specified.

Computerized production process planning (CPPP) offers an opportunity to overcome the shortfalls of manual procedures. Under a previous MMT program, the contractor, United Technologies Research Center, demonstrated the feasibility and benefits of CPPP technology through the development of a pilot system.

SUMMARY

The objective of this program is to develop an operational CPPP system for machined rotational parts and transfer the technology to industry. The program is divided into two phases, the Basic Effort (R80 1021) and Option I (R81 1021). The Basic Effort included development of specific system improvements. Option I provides for further improvements, demonstration, and delivery of software with extensive documentation. Process planning functions to be included are sequence and determination of operations; selection of dimensioning reference surfaces, dimension and tolerance analysis; and process documentation. Fabrication processes addressed include turning, grinding, lapping, honing, and plating.

The general approach adopted was to upgrade the pilot system to a production system. The resulting system, known as Computer Managed Process Planning (CMPP) was enhanced and will be delivered at the end of Option I. CMPP is capable of performing process planning for machined cylindrical parts. The system is manufacturer-independent and is generative in nature (i.e., it makes process planning decisions automatically). An overview is pictured at Figure 1.

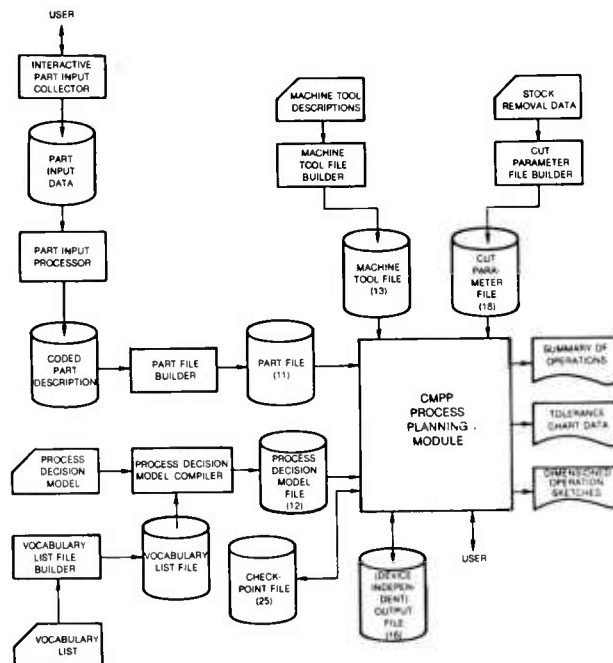


Figure 1 - CMPP System Configuration

CMPP is driven by an interactive part input system. The process planner enters a dimensional description of the part by responding to a series of questions. This information is stored in the part file and, along with the process decision model file and the machine tool file, is used to generate the process plan. CMPP has four modules that: (1) generates sequence of operations, (2) determines reference surfaces, (3) calculates machining dimensions and tolerances, and (4) produces the necessary process planning documents. The system does not eliminate the need for process planners, but is a tool that greatly reduces the time to produce process plans.

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 producing process plans.
- d. Improve the efficiency of process planners.

IMPLEMENTATION

The CMPP system has been partially implemented at three divisions within United Technologies Corporation; Pratt-Whitney, Sikorsky Aircraft, and Hamilton Standard. Numerous technical presentations have been made and an end of contract demonstration is planned upon completion of Option I.

MORE INFORMATION

Additional information can be obtained from Mr. Bobby Austin, US Army Missile Command, AV 746-2147 or Commercial (205) 876-2147. A copy of the Interim Report R81-945220-14, "Implementation of Computerized Production Process Planning" dated June 1981 is available.

Summary report was prepared by J. H. 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 579 6716 titled, "Development of Math Models of Forming Operations for Current/Future Artillery Metal Parts Designs (CAD/CAM)", was completed by the US Army Armament Materiel Readiness Command in June 1981 at a cost of \$306,000.

BACKGROUND

The manufacture of artillery shells typically involves a series of metalforming, machining, and heat treatment operations. Depending on the process, the metalforming is done at hot or warm working temperature ranges (conventional, hot forged method), at room temperature (cold extrusion method), or at both hot working and room temperatures (hot cup-cold draw method).

The flow of metal during these operations is complex and the slightest variation in processing conditions may result in misformed products. Metalworking equipment for these operations is often over-designed in most shell manufacturing plants requiring extensive experience and expensive trial-and-error techniques. In such situations, mathematical modeling of the process capable of predicting, for example, the metal flow and loads, appears to be very attractive. Thus, an objective and reliable procedure can be developed to select the optimum equipment, tooling, and operating conditions.

Under previous projects, mathematical models and computer programs were developed for the drawing and nosing operations.

SUMMARY

The objectives of this project were to verify the previously developed nosing model and develop and verify a computerized mathematical program for modeling the cabbaging, piercing and blocking operations.

Mathematic models for the optimization of the shell nosing process were expanded to include graphical display capabilities. To validate these mathematic models, confirmation tests of the cold and hot nosing of shells were conducted under production or near production conditions. For both cold and hot nosing operations, the computerized mathematic model predicted the load-displacement diagram accurately and reliably. It also predicted the metal flow accurately, except near the open end. For hot nosing, the preforms designed by the computer model produced shells of good quality.

In addition, mathematic models of the blocking, cabbaging, and piercing operations of shell manufacturing were developed and a general purpose finite-element method of analysis was adopted. The developed models are capable of predicting the metal flow and the load-displacement characteristics of the processes involved (see Figure 1). Finally, to validate these math models, cabbaging and piercing tests were conducted under production conditions. In all cases, the predictions were found to be in agreement with the measurements. All the important trends and features of the process were predicted accurately and the reproducibility of the results was excellent.

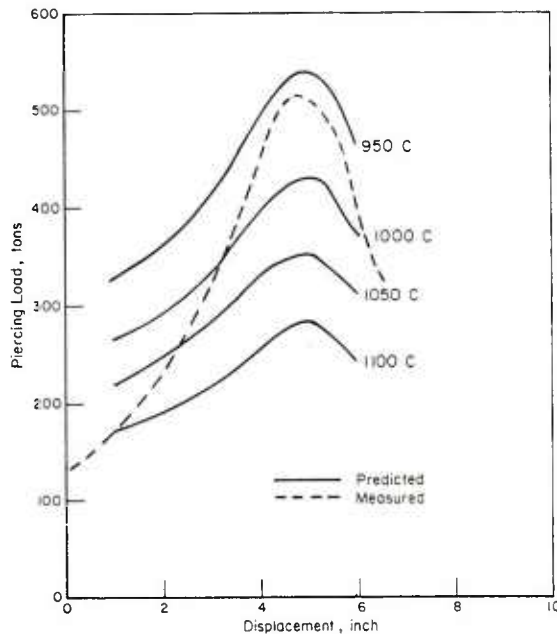


Figure 1 - Comparison of predicted and measured load-displacement curves for the hot piercing of 155mm M107 shell

BENEFITS

The time and expense involved in the design, coordination and optimization of the different operations in the production line will be reduced. Tooling life will increase, and mobilization times decrease. The results of the project are generally applicable to any shell production in which nosing, cabbaging and piercing are employed.

IMPLEMENTATION

Technical reports and related information has been widely distributed among the shell production industry. A follow-on project is underway to

integrate all the models (drawing, nosing, blocking, cabbaging, and piercing) into a single comprehensive computer system.

MORE INFORMATION

Contact Mr. F. M. Lee, ARRADCOM, AV 880-4726 or Commercial (201) 328-4726. The technical report titled, "Development and Confirmation of a Series of Mathematical Models for the Blocking, Cabbaging, Piercing, and Nosing Operations Involved in Shell Manufacturing", dated May 1981, is available from NTIS, reference AD Number E400681.

Summary report was prepared by Jim H. 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 675 7430 titled, "Fire Control Manufacturing Modernization Plan", was completed by the US Army Armament Research and Development Command in June 1979 at a cost of \$300,000.

BACKGROUND

Frankford Arsenal housed the Army's fire control manufacturing capability prior to its closure in 1977. Equipment and procedures were outdated and a modernization plan was needed. Since peace time requirements for fire control was significantly lower than mobilization rates, a flexible manufacturing capability was needed to economically accommodate changing requirements and technological advances.

SUMMARY

The original objective of this project was to provide Frankford Arsenal with a flexible rapid response capability for small lot production. A study was conducted to establish the basic requirements. During this phase, the concept of classification and coding/group technology (CC/GT) was identified. During project execution, Frankford Arsenal was closed and the fire control mission was transferred to the US Army Armament Research and Development Command (ARRADCOM). At this point in time, the emphasis of the program shifted to the purchase and installation of a computerized CC/GT system. It was felt this technology would provide the tool for restructuring and upgrading the small size manufacturing of fire control components.

Group technology is a manufacturing concept where parts are systematically classified and coded and grouped into families based on their manufacturing and design similarities (see Figure 1). Three commercial systems (Brisch, Code and MICLASS) were investigated and compared. The MICLASS system was purchased and installed on an in-house CDC 6500/6600 computer system. Approximately 1100 fire control part drawings were coded and along with manufacturing data were stored in a data base. Under a follow-on project, additional parts will be coded and analysis programs applied.

BENEFITS

This project established the feasibility of applying CC/GT systems in the Army's Production Base. This original effort has led to the application of CC/GT at Watervliet Arsenal and Rock Island Arsenal.

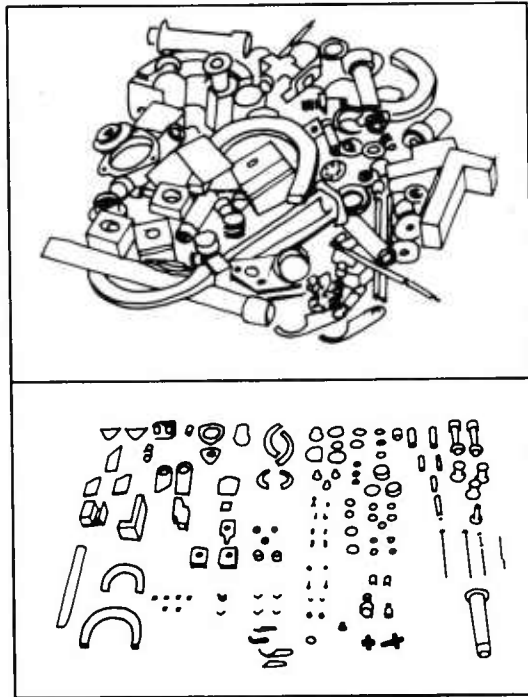


Figure 1 - Through Group Technology, Parts Can Be Classified Into Similiar Part Families.

IMPLEMENTATION

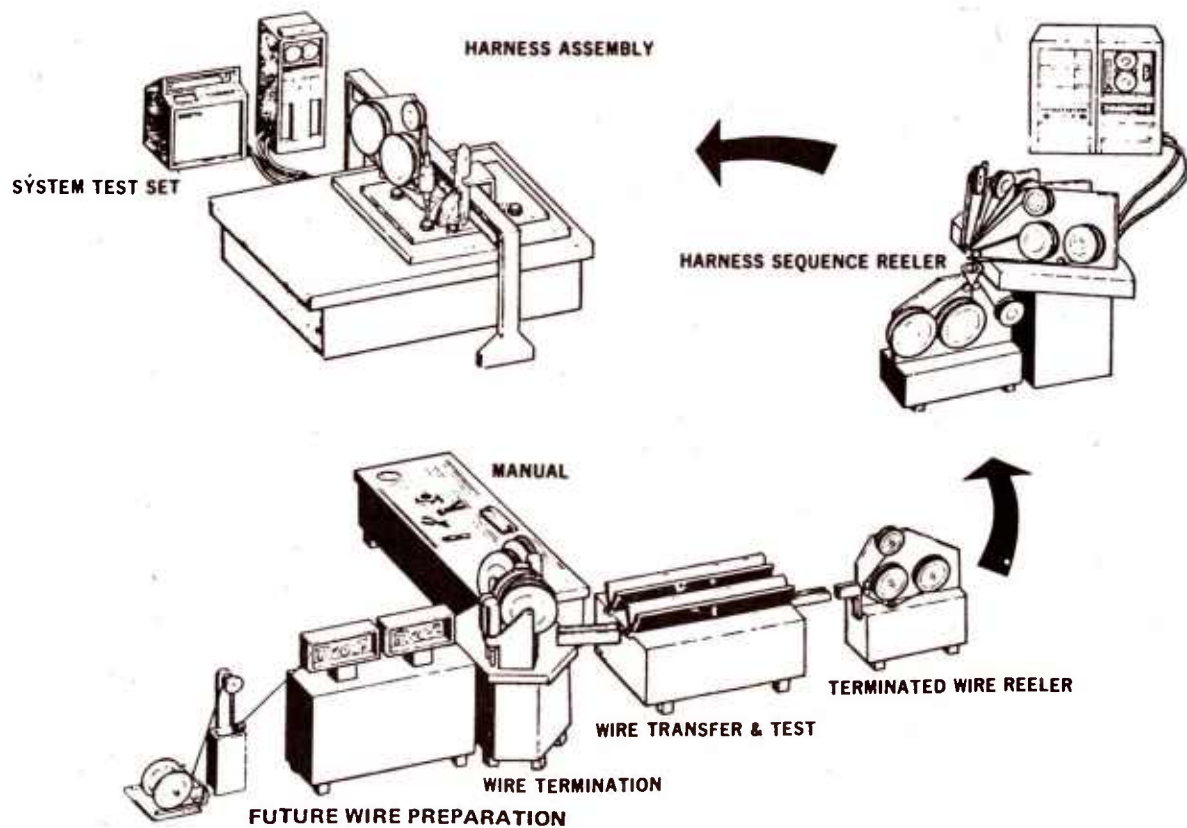
Results of this project are being used to drive MMT Project 679 7963, "Group Technology for Fire Control Parts and Assemblies". Project 679 7963 is expanding the prototype system at ARRADCOM to a production system.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Nathaniel Scott, Jr., ARRADCOM, AV 880-6213 or Commercial (201) 328-6430.

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

ELECTRONICS



CONCEPTUAL APPROACH TO FIXING
ELECTRICAL CONNECTORS TO CABLES

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

Manufacturing Methods and Technology Project 273 9638 titled, "Integrated Hybrid Transistor Switch for Solid State Converter", was completed in January 1976 by the US Army Electronics Command at a cost of \$410,000.

BACKGROUND

The Army did not have a production source for an Integrated Power Switch (IPS) which would be used to support all Turbo Alternator/Power Conditioners within a range of 5 to 40 KVA. In particular, an IPS was needed to support the 10 KW - Turbo Alternator Set (PM-401-A). This IPS would be a part of an AC to AC converter, changing 1600 Hz or 3200 Hz down to 50, 60 or 400 Hz. The new Turbo Alternator was scheduled to replace older low frequency Engine Generator Sets which are much larger, heavier and very difficult to service. The objective of this project was to establish production processes and set up a production line to produce Integrated Hybrid Transistor Switches (IHTS) utilizing hybrid circuit techniques and modular construction. A final version of the IPS assembly drawing is shown in Figure 1.

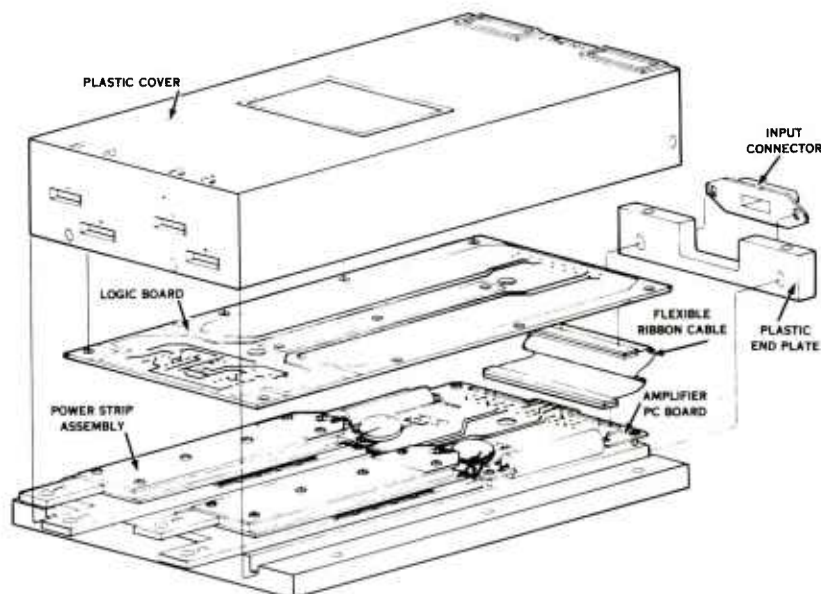


Figure 1 - IPS Assembly Drawing

SUMMARY

Texas Instruments designed the IPS for precision power-conversion equipment operated from rectified and roughly filtered ac lines. The input can be driven by standard DTL or TTL integrated circuits. The IPS contains two half-sections which may be connected for a single push-pull output, or can be operated as two independent, electrically isolated switches. The input is electrically isolated from the power output with a high-speed optically coupled isolator. Internal overload protection circuitry turns off each switch within 3 micro-seconds if its load is short-circuited. Approximately 2.5 milliseconds after turn-off caused by a short-circuit, the switch becomes operational again. Should the short-circuit continue, the switch will turn off again and recycle at a frequency of approximately 400 Hz until the fault is removed. Protection is also provided against overheating, at $T_c = 85^\circ\text{C}$, the IPS is turned off.

For operation in the push-pull mode, the logic and inhibit inputs of each half-section of the circuit are connected to each other. This provides for an inhibit function. A high level at either inhibit input holds the switch of the opposite side off without regard to its logic input. If both inhibit inputs are high, both switches are off, thus avoiding "line shoot-through."

For operation as two independent power switches, both inhibit inputs are connected to logic ground. A high level at a logic input turns that switch on, a low level turns it off. The inhibit function is not used for independent operation. Each switch half-section requires an isolated +6 V power supply. If either one of the supply voltages decreases to 4.5 V, its associated switch section is turned off. The power stage is thus truly either in an "on" or an "off" condition at all times.

Texas Instruments concluded at the end of the initial design phase that thick-film substrates provided the operational feasibility but not the cost effectiveness and reliability of operation required. A subsequent design utilized printed circuit boards.

The following manufacturing techniques were used for the fourth-generation IPS.

- | | |
|------------------------|--|
| - Logic Board | Flow soldered, two-sided printed circuit board with guard ring isolation around each section. |
| - Amplifier Board | Two-sided printed circuit board with power devices sandwiched between heat sink and PC board for better power dissipation. |
| - Output Power Devices | Wafer soldered to tin-plated copper heat sink and lead frame with epoxy filled cap. |
| - Power Stage | Output power transistors sandwiched as follows: heat sink, thermally conductive epoxy, collector bus strip, power transistors, PC board, emitter bus strip and diode contact PC board. |

- | | |
|------------------------------|---|
| - Electrical Interconnection | 50-conductor flat-cable. |
| - Electrical Isolation | Thermally conductive epoxy under power strips and snubber resistors. Nomex paper and silicone grease under amplifier board. |
| - Heat Sink | Extruded aluminum with hard, black anodized surface. |
| - Cover and End Plate | Injection molded, thermoplastic polyester resin. |

BENEFITS

The IPS provides new alternatives to the Army in the area of high KVA per pound in power conversion equipment. The new concept makes possible modular construction of dc and ac power converters for precision and electrical propulsion applications, regulated power supplies, high frequency pulsactors for klystron and laser beam applications, programmable voltage/frequency power supplies, deep submergence and aerospace applications, and others if the cost of the IPS can be significantly reduced with universal use. Other savings result from the simplicity of constructing power conditioners.

IMPLEMENTATION

Although there was no production buy, T.I. offered the IPS as a commercial product. It's design was incorporated into an experimental power conditioner or internal power inverter on contract DAAK-70-C-0076.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Bob Williams, MERADCOM, AV 354-5724 or Commercial (703) 664-5724.

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 273 9696 titled, "Manufacturing Methods for the Production of Arc Plasma Sprayed Phase Shift Element" was completed in June 1976 by the US Army Electronics Research and Development Command at a cost of \$240,000.

BACKGROUND

Waveguide phase shifters are used in C-band and S-band phased array radar antennas. These pencil-size rectangular elements (Figure 1) are composed of a dielectric material encased by a 55 mil thick layer of ferrite. These elements were previously manufactured by machining a rectangular hole in the ferrite and inserting the dielectric, an expensive operation troubled by low yield. Further increasing the cost was the fact that each antenna required 3,000 to 6,000 phase shifter elements.

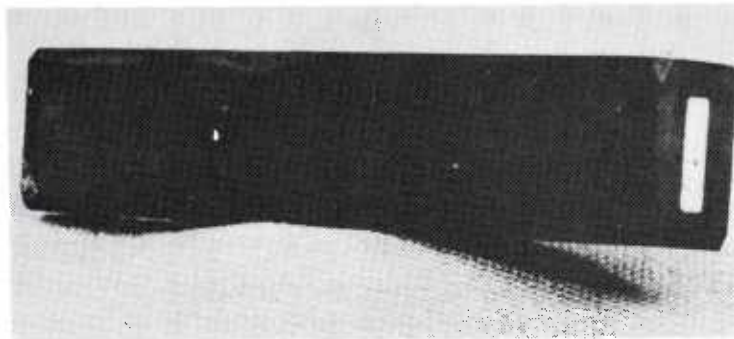


Figure 1 - 3.5 Inch APS S-Band Phase Shifter

Manufacturing cost could be reduced by using arc plasma spraying (APS), a technique for depositing a powder material onto a target. The powder is carried by a gas (i.e., oxygen) through the arc plasma and directed from a nozzle to the target, Figure 2. While plasma spraying of ferrite showed promise of reducing production cost, further work was needed, especially in determining optimum size, shape, and flow characteristics of the ferrite powder.

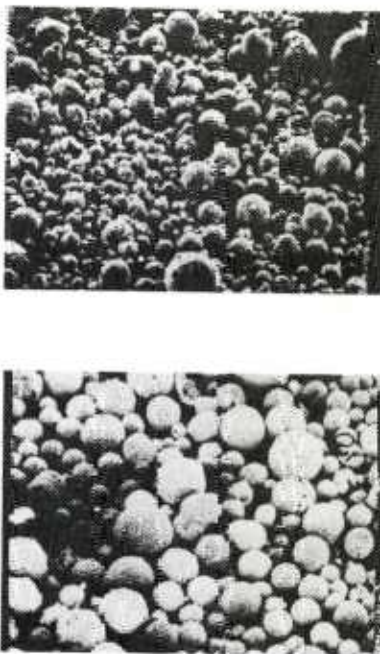


Figure 2 - Spray Dried Ferrite Powder

SUMMARY

Considerable research had been done in refining the APS technique prior to this effort. R&D work at ERADCOM covered several critical areas affecting the quality of the ferrite deposition. Studies showed the need to heat the target substrate during the deposition process. This alleviated strain problems by preventing shrinkage of the molten deposit and also protected the target against thermal shock. Earlier effort also put upper and lower limits on particle size, and defined particle shape, optimum gun-to-target working distance, and other aspects of the APS technique.

This project was conducted by ERADCOM, ET&D Labs and established specification data for obtaining optimum ferrite powders for APS manufacture of C- and S-band microwave phase shifters. By determining ideal particle size, shape, and flow characteristics--properties that affect the deposition rate--the most efficient APS parameters could be attained.

Of the three types of ferrite powders--flame sprayed, fluid bed, and spray dried--the first two were judged to have insufficient particle size to insure high deposition rates. Thus, the work focused on spray dried powder, which was made by combining small individual presintered particles with a binder to produce larger spherical particles. The size of these ranged from 10 to 100 microns, while the smooth shape was found to have good flow characteristics.

For the test program several samples of lithium ferrite powder were purchased from Ampex Corp. and Indiana General Corp. Each was deposited onto several substrates and evaluated for deposition rate, density, particle size, particle variability and magnetic properties. For performance comparison, phase shifter elements were also made using expensive rare earth garnet.

After three years of work, high quality C- and S-band phase shifters were economically produced using the APS technique. Ideal particle size was found to be between 20 and 40 microns with deposition rates as high as 60 mils/min/in². Very high densities, 96% to 97% of theoretical, were also achieved. The lithium ferrite powders chosen for the C-band elements were Ampex spray dried 1202 and 1200 powders. A post anneal was required to optimize the ferrite's magnetic properties. For the more demanding S-band phase shifter, Ampex lithium ferrite 3-750 compared favorably to a commercial S-band Yttrium Iron Garnet phase shifter, with only half the temperature dependence of the garnet element.

BENEFITS

This project established methods for the control of particle size for commercial ferrite powders. It has resulted in improved device performance for phase shifters used in phased array antennas. As a by-product discovery, it was found that ferrite spraying could be used for making microwave circulators in integrated circuits. Cost reduction is anticipated in the following areas:

1. Substitution of low cost lithium ferrite for expensive rare earth compositions.
2. Use of the APS process which is less costly than conventional manufacturing techniques.
3. Elimination of special tooling, making it more economical to fabricate small quantities of rods.

IMPLEMENTATION

A follow-on project will establish the technology and capability to fabricate phase shifter elements by the arc plasma spraying technique. The project number is 275 9441 titled, "Arc Plasma Sprayed Phase Shift Elements".

MORE INFORMATION

Additional information on this effort may be obtained from ERADCOM, Mr. Richard Babbitt, AV 995-2284 or Commercial (201) 445-2284; or Mr. Richard Stern, AV 995-4666 or Commercial (201) 445-4666.

Summary report was prepared by Charles Miller, 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 275 9739 titled, "MM&T - Complex Geometry Photolithographic Techniques for Surface Acoustic Wave Devices", was completed by the US Army Electronics Research and Development Command in June 1979 at a cost of \$225,000.

BACKGROUND

Surface acoustic wave (SAW) devices transmit electrical signals over short distances via an acoustic wave. A typical SAW device is comprised of two interdigitated piezoelectric transducers separated a short distance from each other on single crystal substrate material. A simplified SAW device without matching networks is shown in Figure 1.

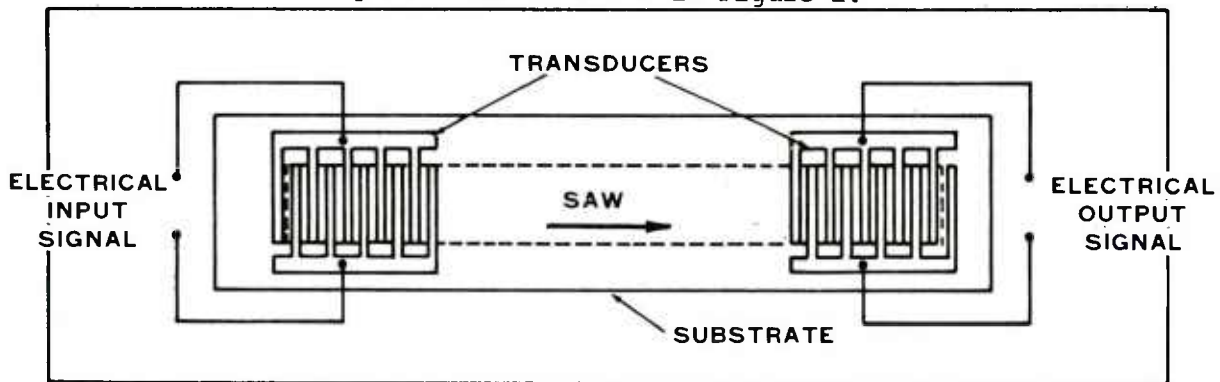


Figure 1 - Typical SAW Device

Electrical signals are converted into acoustic waves at one end and reconverted to electrical signals at the opposite end. The device reduces signal speed by a factor of 10^5 and can be used as a delay line, or with transducer rearrangement as a filter or amplifier.

Previous to contract award, SAW device packaging consisted of non-hermetic machined boxes with slots for the SAW crystal substrate and separate compartments for the matching circuit elements. While this type package is amenable to suppression of spurious electromagnetic feedthrough, its non-hermeticity and high machining cost render it unsuitable for military systems, especially at high production levels.

SUMMARY

The project's objective was to establish a production capability for SAW devices using commercially available platform and butterfly type hybrid packages. The work was performed by Hughes Aircraft Company,

Fullerton, California. It involved suppressing electromagnetic feedthrough and optimizing multiple photomask layouts for crystals whose sizes were determined by vendor availability. Inherent limitations in exchanging insertion loss, bandwidth, triple transit suppression, and VSWR were examined. Results included modification of Hughes' SAW device computer simulation program for transducer geometry.

The technology was demonstrated by fabricating the following six SAW devices on single crystal quartz and lithium niobate substrates:

DEVICE	SUBSTRATE MATERIAL	CENTER FREQUENCY
Linear FM Pulse	ST-QUARTZ	150 MHZ
Compression Filter	Lithium Niobate	150 MHZ
Linear Phase Band-	ST-QUARTZ	100 MHZ
Pass Filter	Lithium Niobate	150 MHZ
Biphase-Coded Tapped	ST-QUARTZ	100 MHZ
Delay Line Filter	ST-QUARTZ	200 MHZ

Crystal Processes included acetone cleaning, evaporation in dry nitrogen steam, photolithographic etching and aluminum metallization. Prior to dicing, the substrates were recoated with resist and baked to provide a protective film. Die were mounted in standard hybrid packages using DOW Corning 3140 RTV and air cured for 24 hours. Crystal substrate wires were attached using pulsed tip gold thermocompression bonding. Toroids used as device tuning elements were installed prior to die attachment, and packages were hermetically sealed by seam welding. A completed linear phase band-pass filter with lithium niobate substrate is shown in Figure 2.

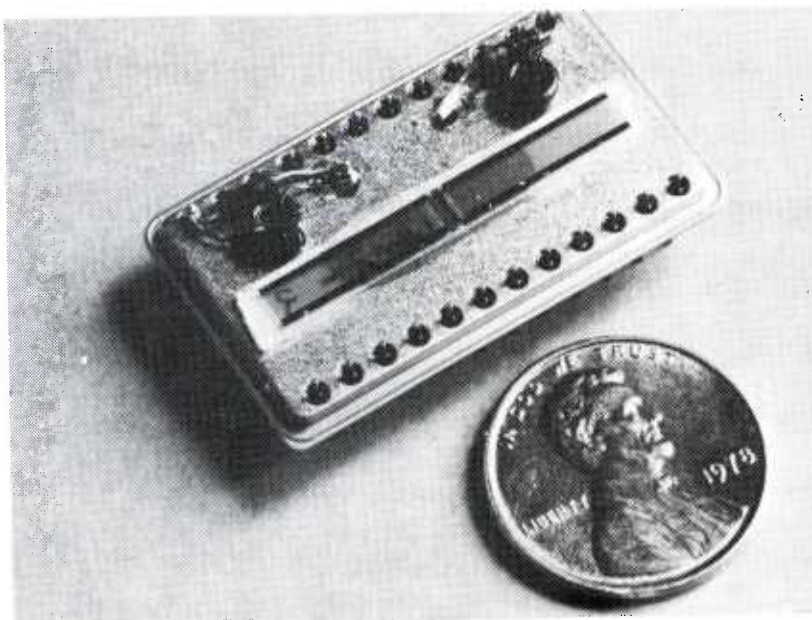


Figure 2 - Linear Phase Band-Pass Filter (Lithium Niobate Substrate)

One hundred fifty SAW devices of each type listed above were successfully fabricated and delivered to the Government. Documentation for a production line capable of producing 500 devices of each type per month was prepared. Personnel, tooling, fixturing and test equipment required for assembly were determined.

BENEFITS

As a result of this contract, a production capability for standard hybrid package SAW devices now exists. Cost reduction depends on the type of the device made; reductions for types produced on this contract were nearly 10 to 1 compared to SAW devices packaged in non-hermetic, machined boxes.

IMPLEMENTATION

Process and packaging techniques developed on this contract were used by Hughes in producing similar SAW devices for the AN/TPQ-36 and 37 Radars.

A detailed final technical report was distributed to both Government and Industry.

MORE INFORMATION

Additional information may be obtained from Mr. Elio A. Mariani, ERADCOM, Ft. Monmouth, NJ, AV 995-2647 or Commercial (201) 544-2647. The contract was DAAB07-75-C-0044.

Summary report was prepared by Stephen 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 274 9744 titled, "Fabrication of Universal Detector Modules", was completed by the US Army Electronics Research and Development Command in January 1978 at a cost of \$895,500.

BACKGROUND

The Universal Far Infrared Sensor, developed with R&D funds, was too expensive and the yield was too low to go into production. An MM&T project was needed to improve the yield of the mercury cadmium telluride detector array and the ceramic feedthru assembly that interfaces the array with the common dewar and bias module. The project's objective was to develop the production processes for fabricating and integrating the detector array and feedthru assembly. The Universal Detector Module can be used in many of the Army's thermal imaging systems.

SUMMARY

Texas Instruments Inc. divided the production design into four major assemblies and performed production engineering on each of them. Work is described here for each of the components. The major sub-assemblies are shown in Figure 1.

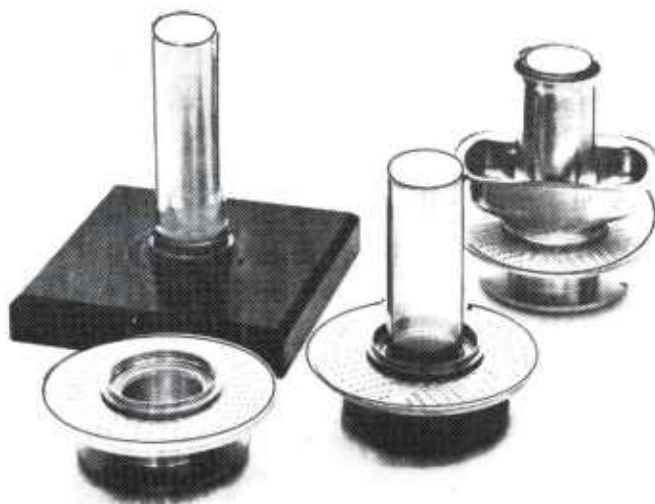


Figure 1- Major Sub-Assemblies of the Universal Detector Module

Inner Stem Assembly

Processing procedures were developed for inspecting, sawing, fire polishing and cleaning the glass stems. Sealing and annealing of Kovar to glass with an RF generator as well as metallizing the stem with chromium and gold and etching the conductor pattern were explored. Metallization was applied before plating and if required, additional plating was applied after etching.

Inner Stem/Feedthru Assembly

Argon plasma-arc welding was used to weld the stem assembly to the feedthru assembly. Gold wire was ball bonded to the conductor on the ceramic feedthru while stitch bonds were made to the metalized conductor on the glass stem. A cap adapter was soldered to the feedthru flange onto which the radiation shield was spot welded.

Vacuum Cover Assembly

Two pieces of the assembly were hydroformed from a sheet of Kovar, drilled, milled and trimmed. A getter feedthru was brazed into the vacuum cover and an infrared transparent germanium window was soldered to the vacuum cover. The inside of the window was aluminized to form a cold shield and give the detector a 75° field of view. Refireable getters were then spot welded to the assembly.

Detector/Dewar Assembly

The detector array and two temperature sensors were bonded to the glass stem with epoxy and manipulated with toothpicks. Gold ball bonds were made to the detector and stitch bonds were made to the stem metallization. The vacuum cover assembly was aligned and projection arc welded to the Inner Stem/Feedthru Assembly. A pinch off tube was installed, the module was pumped down, and the tube was pinched off.

Inspection and testing were performed at many intervals in the fabrication process. Pin holes and oxidation were checked in all welds. Vacuum baking and vacuum leak checks were made to insure minimum outgassing during operation and sustained vacuum without refiring the getters. Electrical tests for continuity, resistance and crosstalk were performed as well as wire bond integrity tests to insure failure-free operation.

Test results of the 10 first article samples and 20 pilot production samples indicated the performance met or exceeded the specifications.

BENEFITS

This project established a pilot production capability for producing Universal Detector Dewar Modules to a firm specification for Hg-Cd-Te photo-

detector arrays. The cost of producing detector dewar modules decreased by approximately 50%. Since the Universal Detector Dewar Module is applicable to a variety of 8-14 micron infrared viewing systems, this represents a large savings for the Army.

IMPLEMENTATION

Texas Instruments is using this pilot line to produce detector modules for the Army's AN/VSG-2 Tank Thermal Sight. The MMT pilot line is the only equipment on which this component can be mass produced.

MORE INFORMATION

Quarterly and final reports are available for contract DAAB07-74-C-0166. The DTIC AD number is ADC 012250L. Requests should be referred to: Commander, US Army Electronics R&D Command, Production Division, ATTN: DRSEL-LE-R, Ft. Monmouth, NJ 07703.

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 277 9812 titled, "Manufacturing Methods and Technology for Split Cycle Stirling Cooler", was completed by the US Army Electronics Research and Development Command in February 1982 at a cost of \$795,000.

BACKGROUND

For man-portable IR viewing systems, a Joule-Thompson Cryostat and a high pressure gas cartridge is used to cool the IR detectors. These systems have a rapid cool down but have less than a two hour mission time. For mission times of longer than two hours, this represents a tremendous logistics and cost problem.

The Night Vision and Electro-Optics Laboratory developed into prototype hardware a Split Cycle Stirling Cooler which could be used for long mission cooling of IR detectors. Since the refrigerator and compressor assemblies are mechanically connected only by a high pressure capillary, it could be implemented on gimbal and periscope-mounted forward-looking infrared systems. This prototype was fabricated using thin metal parts and special finishes. The goal of this project was to develop techniques for producing qualified coolers while maintaining close tolerances and eliminating hand selection of parts.

SUMMARY

Martin Marietta Orlando Aerospace developed the fabrication techniques which allowed the cooler to have a form envelope shown in Figure 1 and 2. This required very small tolerances, hard riding surfaces and good seals. A special selection of materials and processes was also necessary due to the system's intolerance to gaseous and particulate contamination and because Helium, the working fluid, is difficult to contain.

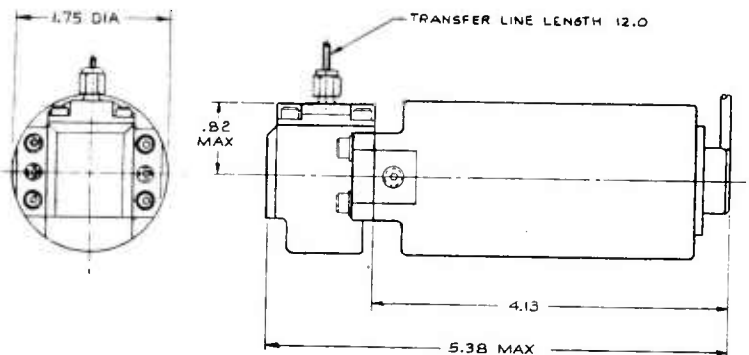


Figure 1 - Compressor Envelope

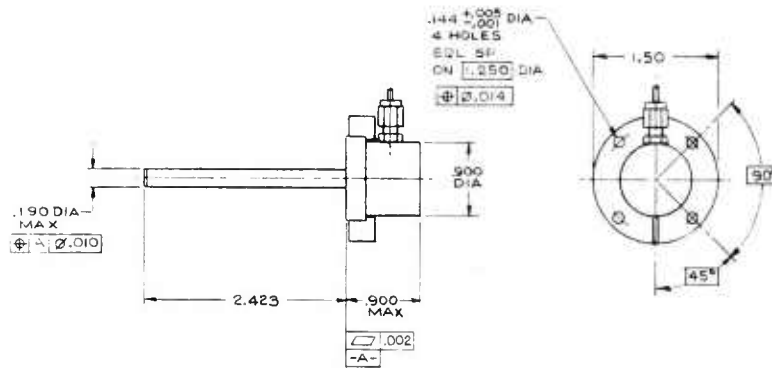


Figure 2 - Expander Envelope

The motor housing was machined from 6061-T6 aluminum bar. This is more cost effective than casting or forging because of the simplicity of design and minimum leakage. The crankshaft is made of 440C CRES that is hardened to provide an inner race for both the eccentric bearing and the main shaft bearing. A copper-tungsten flywheel was pressed onto the shaft to provide sufficient inertia and to counter-balance the piston. The stator and commutating electronics are clamped in place by the end cap, which facilitates access and subassembly level testing.

The crankcase housing was machined from 6061-T6 aluminum bar for the same reasons as the motor housing. The cylinder head is machined from 17-4PH CRES plate which is hardened and honed for the compression piston seal riding surface. The piston cap and base are machined from 7075-T6 aluminum and are connected by a single screw. The end of the piston opposite the compression seal contains a gland which houses a guide. The riding surface for the guide is a 17-4PH steel insert which has been hardened, polished and pressed into the crankcase housing. The connecting rod is machined from 17-4PH steel and heat treated. It uses a needle bearing and roller bearing as interfaces. The crankcase support is a roller bearing that rides on a bushing. The bearing lubricant has a wide temperature range, low outgassing characteristics and high resistance to separation.

The regenerator assembly in the refrigerator has a glass-epoxy body, a matrix of 80 micron nickel spheres and two sintered stainless steel discs on either end of the body to contain the matrix. A seal housing is bonded to one end of the body and contains the Rulon J seal in a spring-reinforced lip configuration. The pneumatic seal spool and sleeve are machined as a matched pair from 400C steel and are given a hardness of RC 58-60. The warm head of the refrigerator is composed of two 321 CRES parts and a modified tube fitting that are brazed together. The cold cylinder is fabricated by brazing a 321 CRES flange on one end of a high strength, low thermal conductivity cobalt alloy tube (L605) and electron-beam welding a 321 CRES cap to the other end.

All of the parts undergo a combination of passivation, anodizing, degreasing and vacuum baking. Due to the careful selection of materials and processes, the cooler's problems were all minor and easily resolved. The performance exceeded the specification in all facets except for the life which was measured to be 750 hours MTBF. The 1000 hour MTBF is felt to be achievable with modification of the design.

BENEFITS

This lightweight, low power consumption cooler is currently in production with a unit price of about \$4000, which is \$400 less than the anticipated unit price at the outset of this project. Benefits have been realized by the simplification of logistics for long operating missions and maintenance.

IMPLEMENTATION

Many programs are currently using this cryogenic cooler including: RPV, XM21, XM32, FES and laser range finders. Research and development is now ongoing for a cheaper cryogenic cooler for missile programs. At the end of R&D, an MMT project is planned for the "Linear Resonance Cooler" using the results of this MMT project as a process base line.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Stewart Horn, ERADCOM, AV 354-1345 or Commercial (703) 664-1345.

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 277 9857 titled, "Automatic Separation, Carrier Mounting and Testing of Semiconductor Dice" was completed by US Army Electronics R&D Command in February 1982 at a cost of \$1,275,000.

BACKGROUND

Semiconductor integrated circuits are made on a silicon wafer, hundreds at a time, spaced closely together. The glass-like wafer must be stored, broken apart and the circuits bonded and wired into a small package. At the time this project was started, these operations were done by hand while the operator observed his work under a microscope. Several different pieces of equipment had been developed to diamond score the wafer between rows and columns of circuits, to fracture the wafer into hundreds of circuit chips, to adhere the chips to an elastic membrane that could be expanded to separate the chips, to pick up each chip and place it on a package substrate, and to wire between each pad on the chip periphery to pins or pads on the substrate. However, the units of equipment had not been automated nor assembled into a system that could replace hand operations.

SUMMARY

Honeywell Avionics Division, St. Petersburg, Florida, was awarded contract DAAB07-77-C-0526 to develop equipment that would perform the operations described above. Honeywell established a mechanized system to separate the wafer into individual circuit chips by etching between the circuits, and to orient and bond each chip to a 35mm metallized film. The film may be reeled or individual frames may be placed in 35mm slide frames to form carriers. The film is previously custom etched to form metal paths that make connection between pads on the chip and pads metallized on the package substrate. Substrate handling equipment is shown in the accompanying photograph. See Figure 1. Both mechanical and air feed systems were pursued.

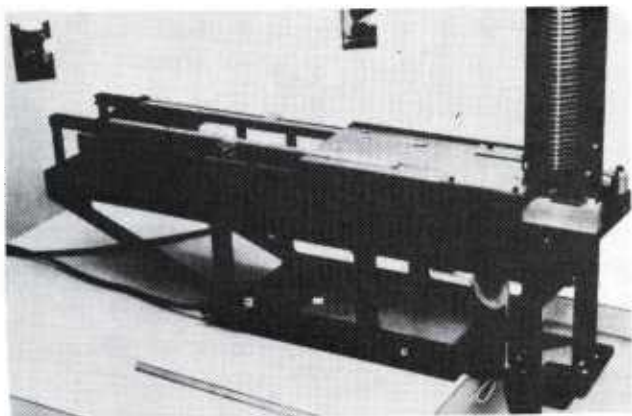


Figure 1 - Mechanical
Substrate Handling System.
Close Up Of Substrate Track

The film carriers with circuits attached may be stacked or may be automatically moved to test or assembly positions. Good units may be "burned in" on an electric test rack, retested, and if up to specifications, bonded to a circuit package or hybrid substrate. The film and slide carrier provides a means for completely automating chip handling, testing, burn-in, and assembly operations. Assembly is accomplished by incising the leaded chip from the frame and bonding it to the hybrid substrate.

To demonstrate the tape carrier system, the contractor assembled a pilot hybrid circuit manufacturing line consisting of a substrate screening and firing facility, automatic substrate handling equipment, a chip taping capability, and a chip-to-substrate bonding facility. Using this line, Honeywell built 1,200 circuits for use in the B-52 navigation system, the Precision Navigation System, and several other programs. ERADCOM tested sample circuits and found that burn-in of semiconductor chips prior to assembly to the substrate improved their quality about 40 percentage points by eliminating almost all of the defective chips. A comparison is as follows:

<u>ASSEMBLY METHOD</u>	<u>% GOOD CIRCUITS</u>
Chip and wire circuits (chips DC probed only)	52
Tape automatic bonding of pretested chips	86
Tape automatic bonding of burned-in chips	93

BENEFITS

The principal benefit of this contract was the establishment of a mechanized system for separating semiconductor wafers into chips, for attaching each chip to a metallized film carrier, for mounting film carriers into 35mm slide frames and for testing each framed chip. See Figure 2. After testing, the chips may be incised from the film carrier and bonded to a substrate. Test of chips prior to attachment to the substrate eliminates defective chips and substantially improves assembly yield.

A secondary benefit was the development of a material handling system that mechanized the flow of ceramic substrates thru the screening process, and into an automatic belt furnace that preheats, fires and cools the substrates. A material handling system is necessary if the new method is to be adopted into commercial production.

A side benefit of ERADCOM's contract with Honeywell was the availability of six types of hybrid circuits: an electronic commutator, a random access memory, a synchronous counter, a discriminator, a crystal oscillator, and a temperature controller. Each of the circuits had an application in an ERADCOM end item under development.

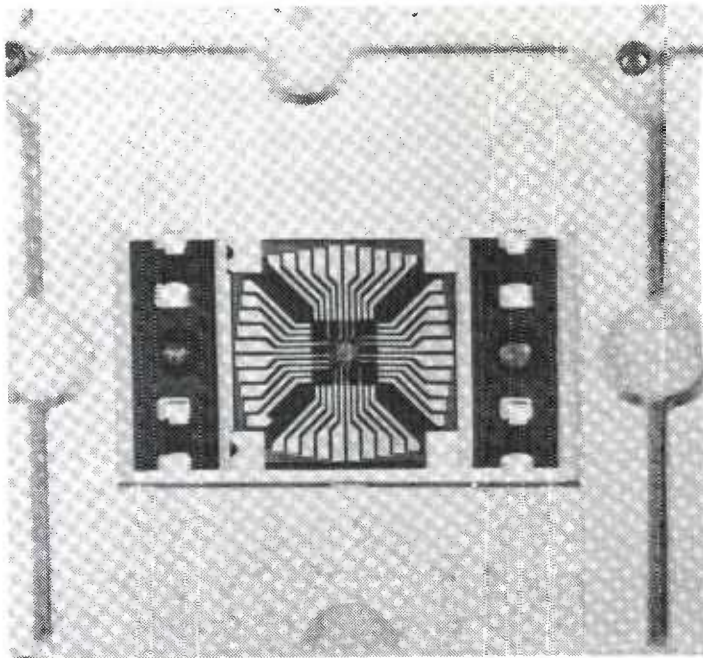


Figure 2 - Chip on a Single Frame Mounted in a Slide Carrier

IMPLEMENTATION

The tape chip carrier and tape automated bonding equipment developed on this contract and on a contract with US Army Missile Command has been used at Honeywell to package circuits for the Patriot missile guidance system, a precision navigation system for B-52 retrofit, the NSA Program, and the Stinger POST Missile. Commercial computer applications in 1981 included 300,000 circuits in the United States and 600,000 circuits in France. By 1983, these numbers are expected to quadruple.

Westinghouse Defense and Electronics Division, Baltimore, also employed tape automated bonding (TAB) and/or tape carriers to assemble sixteen 2K memory chips onto each of a number of hybrid circuit substrates for the 8K Block Operated Random Access Memory (BORAM) for Army and Air Force applications.

Also, McDonnell Douglas at Huntington Beach, CA, used tape carriers to assemble the electronics for the Delta space shuttle booster, for Air Force Hercules missiles, for Navy Harpoon missiles, and for AMARV reentry vehicles. To accomplish the above, McDonnell Douglas bought and installed two Jade 4810 tape bonders for use in their tape automated bonding (TAB) system.

The Electronic Products Division of 3M Company, St. Paul, MN, is marketing several sizes of metallized tapes in various combinations of materials for different applications of the TAB system. Their aggressive advertising program should convince potential users to try the new technology. It is already being used in several military and commercial applications.

MORE INFORMATION

Additional information may be obtained from the project engineers at US Army Electronics R&D Command, Mr. Owen Layden and Mr. Isaac Pratt, AUTOVON 995-2308 or Commercial (201) 535-2308. The contract was number DAAB07-77-C-0526.

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 R78 3133 titled, "Production of Lithium Ferrite Phase Shifter for Phased Array Radars," was completed by the US Army Missile Command in February 1982 at a cost of \$325,000.

BACKGROUND

Raytheon completed prior year project R77 3133 by developing a lithium ferrite having performance characteristics of the more expensive garnet presently used in phase shifter toroids shown in Figure 1. The LTZNC-61-05-005 composition was calcined, sintered, and spray-dried to achieve a free-flowing powder suitable for compression molding. The powder was isostatically pressed at 15,000 psi around a steel pin using a flexible rubber bag. After firing the toroids in a kiln, they were tested for dimensional accuracy. A pin drop test revealed bowing, and ultrasonic measurements indicated wall thickness variation. The goal of this FY78 project was to solve these problems, develop pilot line production of 200 ferrites, and test them.

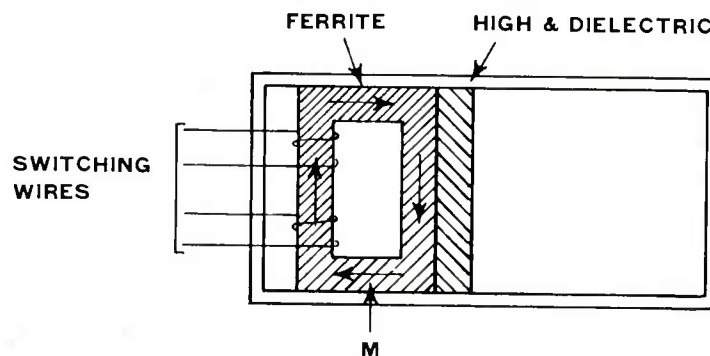


Figure 1 - Non-Reciprocal Latching Phase Shifter - Side Loaded Geometry

SUMMARY

Raytheon engineers at first thought that the distortion during firing was caused by pin flexing. Carbide firing pins were purchased because they have three times the stiffness of tempered steel and will break rather than take a permanent set. Also, after detailed experimentation, it was found that thicker-walled green toroids are more likely to have minute departures from uniform compaction and therefore non-uniform shrinkage and bowing. Since any departure from straightness in the hole will translate directly into variation in machined wall thickness, this discovery alleviated the wall thickness deviation problem. External grinding is done to achieve the flatness required to mate the toroid with the dielectric rib and the metal waveguide. This is done with respect to the inner wall surfaces at the extreme ends of the phaser. The total spread in average deviation has been held within $\pm .002$ inches per 5 inch length.

BENEFITS

Rare earth oxides cost between \$40 and \$50 per pound, 10 to 20 times the cost of the non-iron constituents of lithium ferrite. As a result, a factor of 10 difference in the raw material cost is available. Based on several reasonable cost and production assumptions, a comparison between lithium ferrite and garnet materials provides a savings of \$183,500 per 100,000 toroids, or \$1.84 per toroid.

IMPLEMENTATION

Development of lithium ferrite toroids was too late for current Patriot production but the material is a desirable alternative for future production and other radar systems.

MORE INFORMATION

For additional information contact project officer Mr. Phillip Ormsby, MICOM, AV 746-4933 or Commercial (205) 876-4933. The contract was DAAK40-78-C-082.

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 R79 3146 titled, "Fine Line Hybrid Substrates", was completed by the US Army Missile Command in December 1981 at a cost of \$350,000.

BACKGROUND

Army missile guidance systems utilize high quality hybrid multilayer circuits. Current thick film hybrid technology generally is limited to ten mil (.010-inch) lines and spaces and twelve mil (.012-inch) vias (holes).

This project was funded to investigate optimum materials, processes and conditions necessary for reducing conductor line widths and spaces on multilayer ceramic substrates. Goals were to reduce circuit space, weight and cost, and increase performance and reliability.

SUMMARY

Microelectronics Engineering Corp. developed manufacturing techniques for thick film multilayer conductor structures with dimensions as small as 2-mil lines and spaces. Production processes were established using commercially available materials and equipment. Substrates were obtained from Coors, 3M and Kyocera, and consisted of 96% alumina with a minimum 9.0 dielectric constant. Nine thick film pastes were evaluated for solid particle size content, printing and firing characteristics, conductivity, and line resolution. Four pastes, Plessey 5754, DuPont 4290, EMCA 6360-2B and AEP 4087, were selected to fabricate hybrids for the project. All materials were fired at 925°C profile for 10 minutes. Fine line conductivity was measured as follows:

- (a) Five mil lines and spaces - 3.9 milliohm/square at fired thickness of 11 to 12 microns.
- (b) Three mil lines and spaces - 4.5 milliohm/square at fired thickness of 8 to 9 microns.
- (c) Two mil lines and spaces - 5.8 milliohm/square at fired thickness of 6 to 7 microns.

Screens were investigated for minimum dimensions, wearability and emulsion compatibility. It was determined that the most suitable screens for fine line conductors were 325 mesh stainless with .0009 and .0007-inch wire diameter. Open area for these screens was 50% or greater. Results showed that 280 mesh stainless screen with .0012-inch wire diameter provided optimum dielectric printing. Dielectrics were judged on breakdown strength, "via" resolution, and surface topology. Good via definition was achieved with 5-mil vias for 3-mil lines and spaces, and 7-mil vias for 5-mil lines and spaces.

Figures 1 and 2 depict the screen printer and firing furnace equipment used in this project. Hybrid artwork was generated by a computer aided design-plotter system.

Several emulsions were evaluated for application control, washout ease, pin holes, wear characteristics and definition during printing. It was determined that a 1-mil direct-indirect emulsion was the most consistent.

Maximum line lengths found to be best for yield and reliability were 100-mils for two mil lines and spaces, and 300-mils for three mil lines and spaces. Five mil lines and spaces could be used at arbitrary length on all layers. Two mil lines and spaces on the dielectric should not exceed 25-mils length due to surface finish considerations.

A total average yield of 71% was obtained for a fine line multilayer substrate with three metallization layers, all having line widths of 5-mils or less.



Figure 1 - Screen Printer

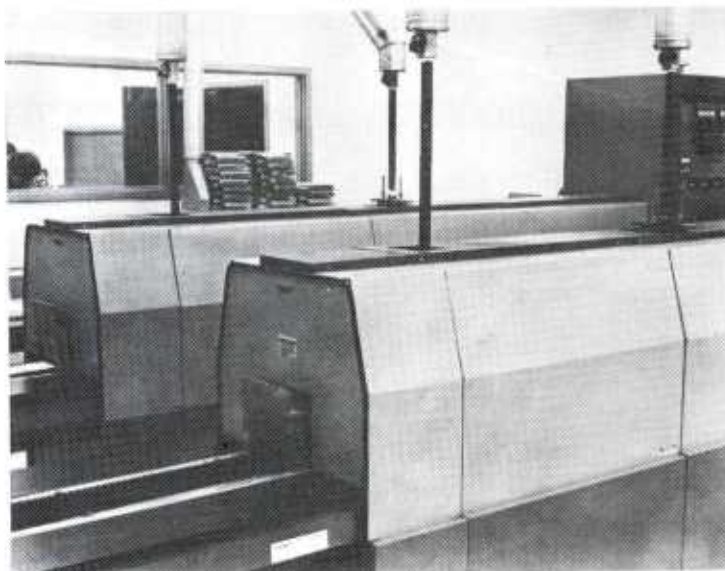


Figure 2 - Firing Furnace

BENEFITS

A cost comparison for a standard substrate using 10-mil lines and a fine line substrate is shown below in 1981 dollars. Material costs were halved and area reduction of 2:1 was achieved. Substrate area used for the standard was 1.21 square inches and for the fineline, 0.64 square inches.

	<u>STANDARD</u>	<u>FINELINE</u>
Metallization	\$4.32	\$2.52
Dielectric	\$.92	\$.56
Labor	\$.31	\$.67

IMPLEMENTATION

Fine line technology has application in low volume, lightweight, high performance electronic devices. These include cannon-launched guided projectiles, safe and arm fuzing, impact penetration vehicles, hypervelocity missiles, and high density-high speed computers.

A presentation on the project was made to the International Society of Hybrid Microelectronics (ISHM) in October 1981.

The technology is being coordinated for possible use in the Electronics Computer-Aided Manufacturing (ECAM) Program.

MORE INFORMATION

Additional information may be obtained from Mr. Gordon D. Little, US Army Missile Command, Redstone Arsenal, Alabama, AUTOVON 746-3604 or Commercial (205) 876-3604. The contract was DAAH01-80-C-0057.

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 Projects R77 3160 and R79 3160 titled, "Establishment of Production Cleanliness Criteria and Processes for Printed Wiring Boards and Assemblies," were completed by the US Army Missile Command in December 1981 at costs of \$83,000 and \$280,000, respectively.

BACKGROUND

Contaminants on printed wiring boards (PWBs) and assemblies cause electrical malfunction and/or failure. The most harmful class of contaminants are ionic species. During production, many different ionic species appear on the PWB surfaces. Ideally, these contaminants are removed by cleaning processes during fabrication and assembly. Ionic materials which remain on the PWB surface after final cleaning are undesirable because they may cause corrosion and vesication (blisters) between substrate material and conformal coating, and/or produce electrical currents which disrupt proper electrical signals.

SUMMARY

These effort's objective was to develop improved methods for detecting and quantifying PWB surface contamination. The work was performed by Martin Marietta Corporation at Orlando, Florida and was divided into two phases.

Phase I was an investigation into current state-of-the-art testing for contaminants remaining on PWB surfaces after processing. The only methods even slightly quantitative were the extract resistivity test (ERT) and the insulation resistance test (IRT). These methods measure parameters whose value is dependent upon the gross amount of ionic material. Both indicate ion presence and affect a rough order magnitude of the ionic concentration but neither identifies the specific ionic species causing degradation. The methods can be characterized as quasi-quantitative and non-specific. Neither method is ion-specific and neither can be used for detailed ionic species profiling. In addition, neither can be used to detect non-ionic species.

Temperature/humidity cycling was also evaluated and found not ion-specific nor even quantitative. Phase I concluded by recommending a systems approach for both detecting contaminants (qualitative analysis) and measuring their concentrations (quantitative analysis).

Phase II built upon the previous recommendation and assembled and integrated a contaminant profiling (C/P) system for detecting and quantifying contaminants on PWB surfaces. Figure 1 shows the inclusion of the C/P system into a typical manufacturing process for double-sided PWBs.

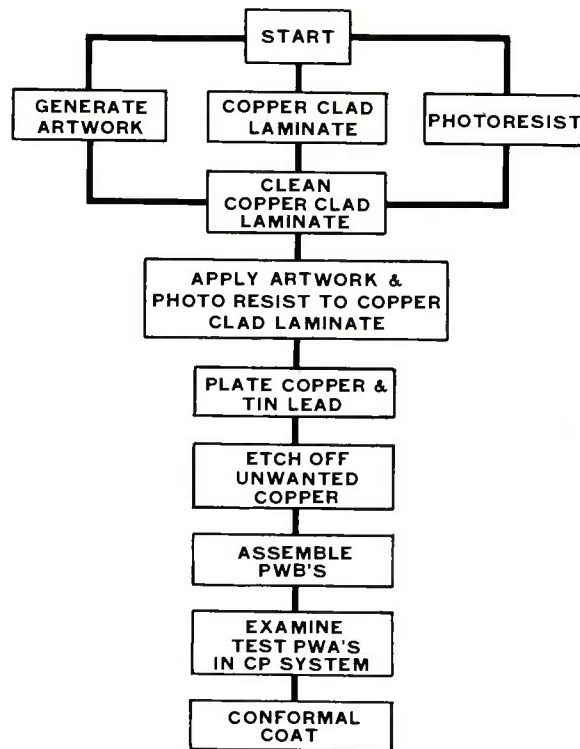


Figure 1 - Position of Contaminant Profiling System in Double-Sided Printed Wiring Manufacturing Line

The C/P system was developed utilizing the following hardware which existed previously but as separate entities.

1. Inductively-coupled plasma spectrophotometer/graphite furnace.
2. Ion chromatograph.
3. Minicomputer and computing integrator unit.
4. Extraction tank/pumping unit.
5. Water purification unit.

A schematic of the C/P system is presented in Figure 2. The inductively-coupled plasma spectrophotometer/graphite furnace unit detects and quantifies the levels of metallic and quasi-metallic elements. They are copper, tin, lead, chromium, phosphorus, silicon, etc. which are routinely found in extracts made from production PWBs.

The ion chromatograph detects and quantifies anionic species, such as the chlorides, fluorides, sulfates and small organic acid anions appearing in resin and water based fluxes. The extraction tank/pumping unit contains the PWB during the extraction phase of the test cycle. The water purification unit insures highest purity water for PWB extracts.

The computing integrator assists in processing chromatograph data. The mini-computer provides C/P system control, data handling and analysis, and total system integration.

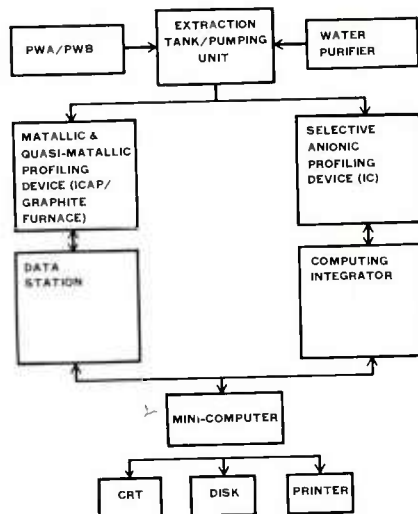


Figure 2 - Schematic Diagram of the Mini Computer-Controlled Contaminant Profiling System

Data and programs are displayed on the CRT. Data handling and analysis include statistical treatment of all cleanliness data generated, insuring a secure data base foundation. Advantages in addition to qualitative and quantitative analysis include:

1. Cause/effect correlation by determining species source and species related latent failures.
2. Water soluble flux application, since contaminant levels can now be precisely determined.

BENEFITS

This effort provided the ability to detect ionic and non-ionic PWB contaminants and measure their concentration in parts-per-billion (ppb) or micrograms per square centimeter of board surface ($\mu\text{g}/\text{cm}^2$).

Estimated savings averaged over a 10 year period, amounted to \$965,702 per year.

IMPLEMENTATION

The contaminant profile system developed by this effort has been implemented into the Martin Marietta PWB Manufacturing Facility at Ocala, Florida. All Martin Marietta programs involving PWBs will be affected.

MORE INFORMATION

Additional information may be obtained from Mr. Robert Brown, US Army Missile Command, Redstone Arsenal, AL, AV 746-5742 or Commercial (205) 876-5742. The contract was DAAK40-78-C-0114.

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 Projects R77 3183 and R78 3183 titled, "Improved Manufacturing Processes for Inertial Quartz Flexure Accelerometer", were completed by the US Army Missile Command in June 1981 at costs of \$165,000 and \$180,000, respectively.

BACKGROUND

The predominant source of error in Army inertial guidance missiles is due to accelerometer deficiencies. Preliminary studies revealed accelerometer problems in two major areas: bias stability and scale factor stability. The cause of the bias instability was identified in Army R&D Project 1X222251D231. An initial scale factor investigation was performed on an Air Force R&D Contract, F33615-75-C-1281. The quartz flexure (Q-Flex) accelerometer, used as a backup for Lance and in other missiles is comprised of two major subassemblies: (1) the quartz flexure sensor and, (2) the hybrid servo electronics. See Figure 1. The sensor uses quartz flexures

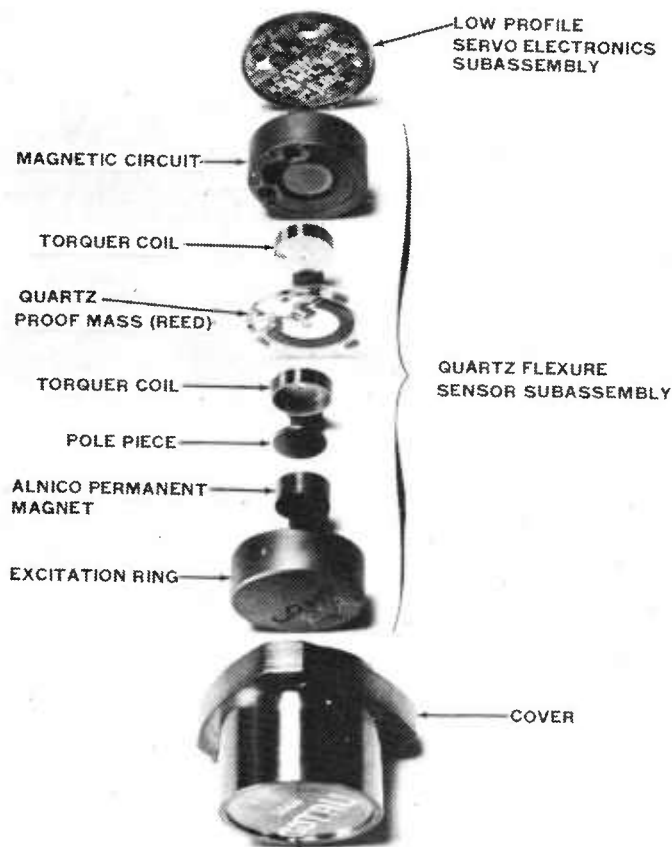


Figure 1 - Sunstrand QA 2000 Quartz Flexure Accelerometer

for suspending its proof mass. This avoids metal flexure inelastic hysteresis and the turn-on hysteresis and vibration errors associated with jewel-pivot systems. The servo electronics includes an excitation oscillator, a precision differential proximity detector, a servo amplifier and a feedback servo compensation circuit. Figure 2 shows a simplified accelerometer functional diagram.

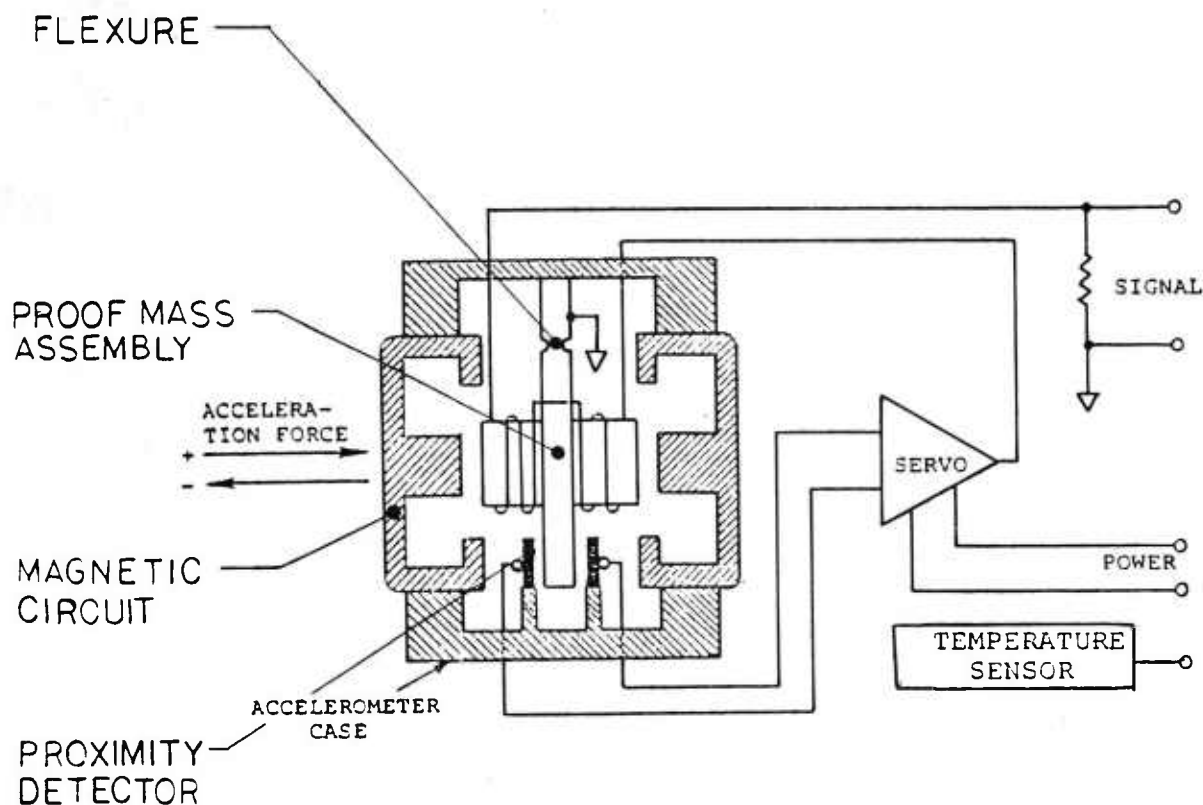


Figure 2 - Accelerometer Functional Diagram

SUMMARY

The purpose of this effort was to build upon the previous work and establish new materials and fabrication methods which would significantly increase yield and reduce cost.

Two contracts DAAK40-77-C-0144 and DAAK40-78-C-0274 were awarded to Sundstrand Data Corp. at Redmond, Washington. Tasks were to improve QA 2000 Q-Flex accelerometer bias stability in the first contract and scale factor stability in the second. Short term (40 hour) stability goals were 30 μ g for bias and 30 ppm for scale factor; one year goals were 100 μ g and 100 ppm respectively.

All goals were attained by modifications to the proof mass and magnetic circuit of the Quartz flexure sensor. Two proof mass changes furnished

the bias improvement. They comprised relocation of the mounting pads and addition of a circular arc cut through the quartz around the bobbin mounting area.

Scale factor stability improvement was achieved by changes in the magnetic circuit, coil form anodize from strong sulfuric acid to weaker chromic acid, and top assembly sealing methods.

Low expansion bobbins, a welded stack assembly and a change in the Chrome/Gold (Cr/Au) metallization were investigated but found unnecessary to achieve the MMT goals or LANCE requirements.

The original chrome/gold deposition process was improved by enhanced quartz cleaning and reducing the moisture content in the residual gas within the vacuum deposition chamber. Also, gold thickness was increased which virtually eliminated moisture sensitivity. A new tooling and vacuum deposition system combination permitted metallization of more proof mass quartz surfaces in one run than was previously possible in an entire day.

BENEFITS

As a result of the work performed, Q-Flex accelerometers that meet high stability requirements are now available in production quantities. The methods used to improve the Q-Flex accelerometer have general application in servo accelerometer and transducer manufacture.

IMPLEMENTATION

The Q-Flex accelerometer is presently being qualified as the backup control accelerometer for the LANCE missile and has successfully flown in this missile four times. It was also flown as the control accelerometer on all SIG-D flights. The accelerometer is now used on the Assault Breaker T-22 Program and will be a prime candidate for the Corps Weapon System. The device also has application in the Navy Harpoon Missile and in the Boeing 767 aircraft.

MORE INFORMATION

Additional information may be obtained from Mr. Joe Hunter, US Army Missile Command, Redstone Arsenal, AL, AV 746-8331 or Commercial (205) 876-8331.

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 376 3227 titled, "Low Cost Production Methods for Handling Hybrid Chips Via Tape Carrier Lead Frames", was completed by US Army Missile Command in August 1981 at a cost of \$572,500.

BACKGROUND

When this project was first conceived, integrated circuit chips were being hand-wired onto hybrid circuit substrates. Some of the work was being done off-shore to take advantage of low cost labor. The numerically-controlled wire bonder had not yet been invented. The tape carrier had just recently been developed by General Electric Bull of Great Britain and examples of Fairchild's tape carrier work for Eastman Kodak were seen as a way to make chip and circuit packaging more economical and reliable.

SUMMARY

Honeywell Avionics Division, St. Petersburg, Florida, was awarded a contract to develop production technology for tape automated bonding (TAB). Honeywell first conducted an industrial survey of methods and systems for handling hybrid chips via tape carrier. They also evaluated thick and thin film hybrid circuit processes and studied methods for bumping semiconductor wafers. They then were able to characterize production methods for producing thick and thin film circuit substrates and for bumping semiconductor wafers.

With Microplate, Inc., and the Jade Corporation, Honeywell corroborated on several new machines to be used in the TAB system. These include a Lead Frame Plater, an Inner Lead Bonder, a Manual Tape Test Handler, an Outer Lead Bonder, and an Automatic Tape Test Handler. Some of this equipment is shown in the accompanying figures. Using these machines, the contractor fabricated and qualified two types of hybrid circuits; a relatively complex 18 GHz synchronous counter, and a simpler standard circuit. Cost models for producing 1,000, 5,000 and 10,000 of each type circuit were then developed. The break-even point for the complex circuit was 200 units and for the simple circuit 1600 units, both lower than anticipated.

In another contract, Dextex Systems designed and prototyped a Diagnostic Production Test Set. For missile systems, it employs computer automated test methods to isolate faults in electro-mechanical subsystems, and was used to test complex chips on tape prior to assembly to the substrate.



Figure 1 - Continuous Tape Plater

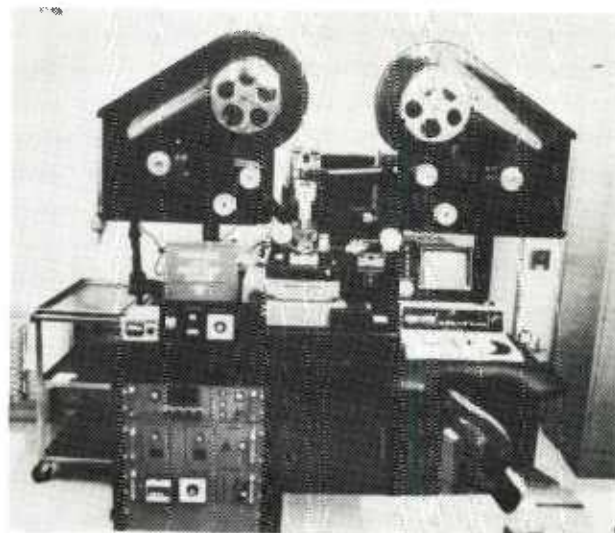


Figure 2 - Inner Lead Border (ILB)
Jade I-1000



Figure 3 - Jade 4810 Outer Lead
Bonder

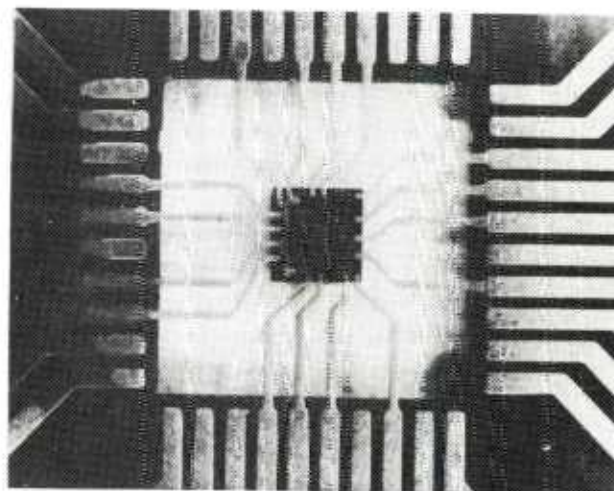


Figure 4 - Close-Up of 161A Chip or Tape

The synchronous counter circuits assembled on this project were qualified under three different programs for three different users. The programs were Patriot fuze, B-52 retrofit, and a MICOM circuit. The users/qualifiers were Army Electronics R&D Command, US Air Force, and Army Missile Command. MIL-STD-883A was the basic specification but each program had its own additional requirements.

BENEFITS

The principal benefit of this contract was the establishment of proven production methods and equipment for bumping semiconductor wafers, applying lead frames, testing the leaded devices, and attaching tested devices to hybrid substrates.

A side benefit of the work was the availability of two hybrid circuits for use in several ongoing military programs - Patriot and B-52 retrofit. Cost data developed herein showed that the number of components needed to justify the startup cost of lead-frame designs and tooling construction was lower than expected and occurs at only several hundred to a thousand units.

Other benefits derived here include the availability of specifications for the carrier tape for metallizing semiconductor wafers, die separation, thick and thin film substrate manufacturing, defining the inner and outer lead bond, testing dies on the tape carrier, and for rework techniques. These clearly drawn manufacturing specifications enable other firms to practice the technology. The availability of processing equipment from Jade, Microplate, and others should greatly aid in transitioning the technology to other firms. One of the main advantages of the tape carrier is its ability to permit pre-testing of chips prior to mounting into a large scale hybrid circuit. Other advantages include simpler alignment, stronger bonds, increased reliability, and cost effectiveness with adequate volume. Tape carriers may also be used to assemble chips into chip carriers.

IMPLEMENTATION

The Tape Automated Bonding system has been implemented at Honeywell, St. Petersburg and Denver, and is in use at these locations. Also, McDonnell Douglas at Huntington Beach installed two Jade 4810 tape bonders for use on the Delta missile booster, Hercules and Harpoon missiles, and AMARV reentry vehicle electronics.

MORE INFORMATION

Additional information on tape carriers is available from the project engineer, Mr. Paul Wanko at US Army Missile Command, AV 746-3848 or Commercial (205) 876-3848. The Final Technical Report for Honeywell contract DAAK40-76-C-1079 is 77-1079-F; Volume I covers Assembly and Test, and Volume II consists of Qualification Data.

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 R79 3253 titled, "Manufacturing Methods for Thin Film Field Effect Cathode", was completed by the US Army Missile Command in February 1982 at a cost of \$251,018.

BACKGROUND

Sperry Univac completed project R78 3253 in December 1980 by developing a fabrication process for the Thin Film Field Effect Cathodes (TF FEC). The work focused on refining emitter cone fabrication methods using optical lithography and gas etching to improve emitter cone uniformity and reduce surface contamination. Figure 1 shows an idealized cone configuration. In operation, the cone to gate potential pulls electrons from the tip of the cone and supplies a cloud of them which is attracted by the collector. The goal of this project was to find solutions to the fabrication process problems so that greater reliability and higher current density could be attained.

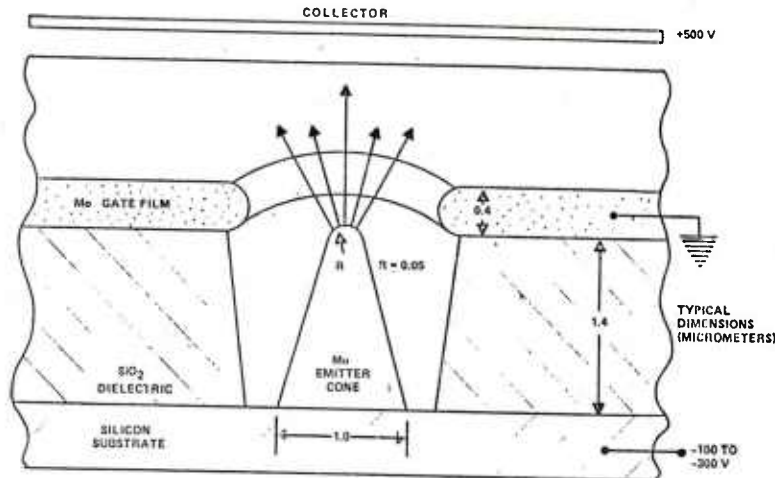


Figure 1 - Thin Film Field Effect Cathode

SUMMARY

Many of the problems associated with the processes shown in the process flow chart, Figure 2, were solved. The stress that developed during deposition caused the moly gate layer to peel. A study of the problem lead to the use of a higher substrate temperature during deposition, curing the problem. Also, in etching the moly gate layer in a barrel plasma etcher, undercutting of the

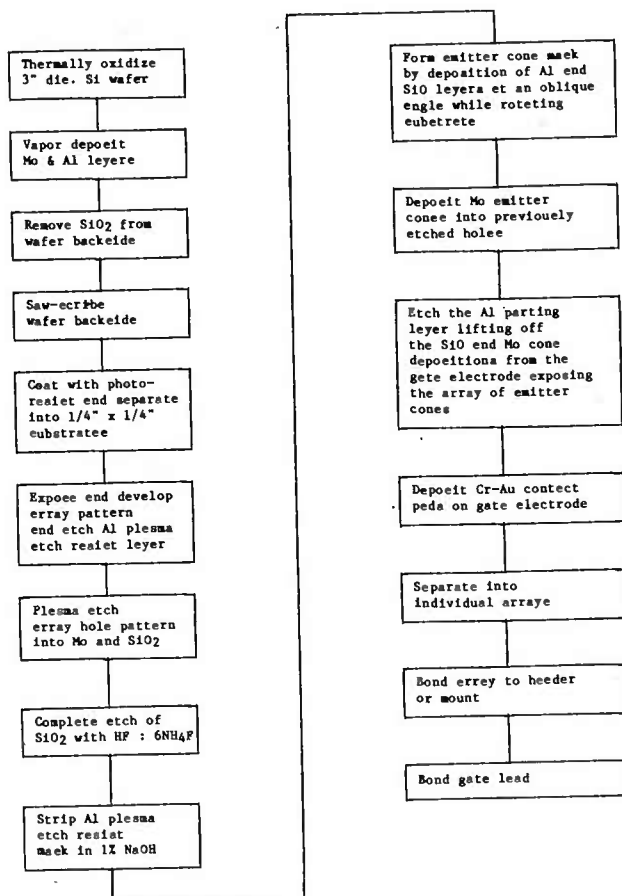


Figure 2 - Process Flow Chart

aluminum mask layer was a problem. This problem was resolved by using planar plasma etching while controlling the RF power input to regulate mask pitting. In general, the absolute etch rates for reactive ion etching are dependent on RF power, etch gas flow rate, substrate temperature, chamber temperature, and active area. These variables were determined, monitored and controlled in order to establish the desired etch characteristics.

The results of the tests demonstrated that a current density of .18 amp/cm² is possible using 12.7 micron emitter centers. By increasing the emitter cone density, the current density can be projected to 1 amp/cm². A number of recommendations were made to increase the performance and economize the process.

BENEFITS

A process now exists for producing uniform 1.4 micron emitter cones, clean etched holes without undercutting and increased emitter cone density. This will serve as a baseline for future manufacturing technology projects.

IMPLEMENTATION

A final technical report was distributed to government agencies and industry. Because of the remaining process improvements to be made, no immediate implementation is planned.

MORE INFORMATION

Further information may be obtained from Mr. Richard Dean, Sperry Univac, Commercial (612) 456-3439. The contract number was DAAK40-70-C-0321.

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 R78 3372 titled, "Manufacturing Methods for Magnetic Components", was completed by the US Army Missile Command (MICOM) in February 1980 at a cost of \$400,000.

BACKGROUND

Electromagnetic devices represent a substantial portion of the cost of present and planned missile systems. The current design activity is also requiring these magnetic devices with weight and volume requirements reduced by factors of 3 to 6. Application of the current manufacturing processes which have been essentially unchanged for 50 years, is inadequate for the newer devices. The result is an expensive product with marginal reliability. This project was initiated to evaluate the various production processes and provide newer, more efficient means for production of these devices.

SUMMARY

The five areas selected for investigating and recommending improvements to the manufacture of magnetic components were as follows:

Potting/Encapsulation

An investigation of 40 encapsulation compounds was made to identify those that would have the optimum parameters for encapsulating or potting of electromagnetic components for missile applications. Values for 36 parameters were established, against which each compound was evaluated. No one resin is a universally 'best' encapsulation material, therefore, tradeoff of parameters and properties are required for each application. The five materials judged to have the most acceptable combination of parameters for missile applications were: EPON 825 with HV hardener, SCOTCHCAST 225, ECCOSEAL 1218, HYSOL C-60 and HYSOL C15-015.

Controlled Winding

Four areas were addressed in this task: wire handling, contamination, solenoid and transformer (bobbin) winding and toroid winding. The most obvious observation was that in order to produce a reliable component, the materials must be of high quality. The handling and contamination investigation concluded that spools of wire, especially the fine and ultrafine gauges, should be encased at all times (prior to winding) in foam plastic protection and inserted into plastic bags. The smaller sizes are especially susceptible to spool damage from dropping. Exposure of the spools to

contamination and handling without gloves will degrade the subsequent encapsulation process. In all of the facilities that were visited, no special precautions were taken to protect the spools of wire, in most cases the wire was simply stacked in open stockrooms.

Interconnection Techniques

Five areas were covered in this task, namely, stripping of wire insulation, joining of ultrafine wires to the larger intermediate leads, requirement for intermediate lead size, ultrafine wire terminations and special considerations for high voltage applications.

A survey of heat, abrasive, laser and chemical means of wire stripping did not uncover a method that did not have significant disadvantages. An air-grit blast method seemed promising at first, and does work well on larger wires, however, on fine wires solderability and mechanical properties are degraded.

Techniques for connecting fine and ultrafine magnet wires to intermediate lead wires were investigated. As a general rule, wire sizes smaller than AWG 36 should not be routed through encapsulation materials for any distance because thermal expansion of the material can cause breakage. The normal procedure is to connect an intermediate wire to the coil wire. This intermediate wire is then routed through the encapsulant to the external terminals.

Tin-lead solders are capable of dissolving fine copper wire, therefore, other solder formulations as well as other methods such as welding, laser welding, crimping and conductive adhesives were investigated. It was concluded that conventional soldering with careful control of parameters such as temperature, time and soldering iron size will result in satisfactory joints without significant dissolution.

When encapsulating high voltage windings, care must be taken to prevent voids in the encapsulants and sharp points on the conductors which are sources of destructive corona effects. A sharp point in a high voltage winding may create a voltage gradient sufficient to cause a void where none occurred originally. A method of solderballing or putting a conductive sphere over the joint to control the gradient was investigated.

Encapsulation

This task addressed three areas: equipment and tooling for encapsulation, automatic mixing and metering and implementing a continuous process for potting and encapsulation. The major constraints in the design of the molds were to minimize hand labor and to provide an outer surface. For small or medium production runs, slush-type molds of reuseable low melting temperature metal or silicone rubber were developed. For high production rates a liquid injection molding process was investigated. Acceptable parts with a minimum of hand labor and very consistent quality were produced, but the production rate was limited by the long cure time of the compounds. A fast cure material, meeting the other parameters, is required to increase production rates.

Structural Parts

This task addressed four areas: shielded bobbins for high voltage transformers (bobbin shown in Figure 1), thermoplastic and thermosetting plastics for coil supports, anchoring of windings within transformer coils and C-core assembly techniques.

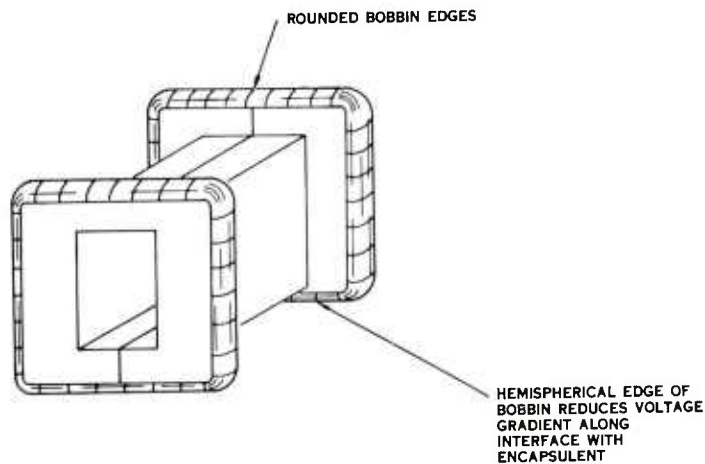


Figure 1 - Improved Bobbin

The use of fine and ultrafine wires in high voltage windings increases the maximum voltage gradients in the encapsulation materials making them more susceptible to breakdown. Controlling the spacing of wires that have high voltage differences is difficult, consequently, the use of electrostatic conductive shields is employed in the bobbin construction. Using this construction, the location of separate wires is not critical in controlling voltage gradients.

No acceptable means of using thermoplastic materials was found. The major problem encountered was softening of the material when soldering to the terminals. This problem can be overcome by pulse welding but the additional complications overshadowed the advantages.

Small pieces of mylar tape are often used to anchor the wire at various locations during the winding of a coil. The presence of this tape provides stress points in the encapsulant and can cause it to crack under thermal cycling, creates the possibility of entrapped air and causes a lack of adhesion of the encapsulant to the tape itself. It was found that quick-setting adhesive materials could be used to replace the tape thereby avoiding the problems.

Conventional banding operations of C-cores into windings uses a metal clip and a soldering operation to anchor the band. By welding an auxiliary pull tab on the band, a method of welding was developed which required no slip and no soldering operation. The pull tab and excess band are then cut off resulting in a profile of only twice the band thickness.

BENEFITS

This project has identified several production techniques for improving the reliability of miniature inductors and transformers. The primary emphasis of the program was to determine those manufacturing processes and procedures that contribute to subsequent part unreliability and propose modifications to correct them. Improvements in several areas, as noted above, were proposed to reduce incipient failure modes.

IMPLEMENTATION

Dissemination of the information is on an "as you go" basis rather than waiting for completion of the entire MM&T. During the program, several representative magnetics manufacturers were contacted and presentations made to some of them. All have expressed a desire to be kept informed regarding new developments. These contacts will be maintained during the follow-on effort.

MORE INFORMATION

Additional information on this phase of the effort is available in a two volume report titled "Manufacturing Methods and Technology for Electro-magnetic Components", Volumes I and II, dated December 1980, Contract No. DAAK40-78-C-0271. The project officer is Mr. Richard Kotler, US Army Missile Command, AV 746-2065 or Commercial (205) 876-2065.

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 R79 3410 titled, "Production Methods for Heat Pipes for Hybrid Microcircuits", was completed by the US Army Missile Command in June 1981 at a cost of \$250,000.

BACKGROUND

Complex new electronic systems have given rise to increased chip densities in hybrid circuit packages with resulting higher cooling requirements. A heat pipe is an enclosed shell housing a wick and a specific amount of working fluid. These devices can reduce the junction temperature of hybrid chips by providing a low resistance heat flow path internal to the package.

A conceptual sketch of a wick-enhanced, closed-cycle evaporative cooling package is shown in Figure 1. Reducing this heat pipe concept to manufacturing practice with optimum electrical, mechanical and chemical compatibility was this project's principal consideration.

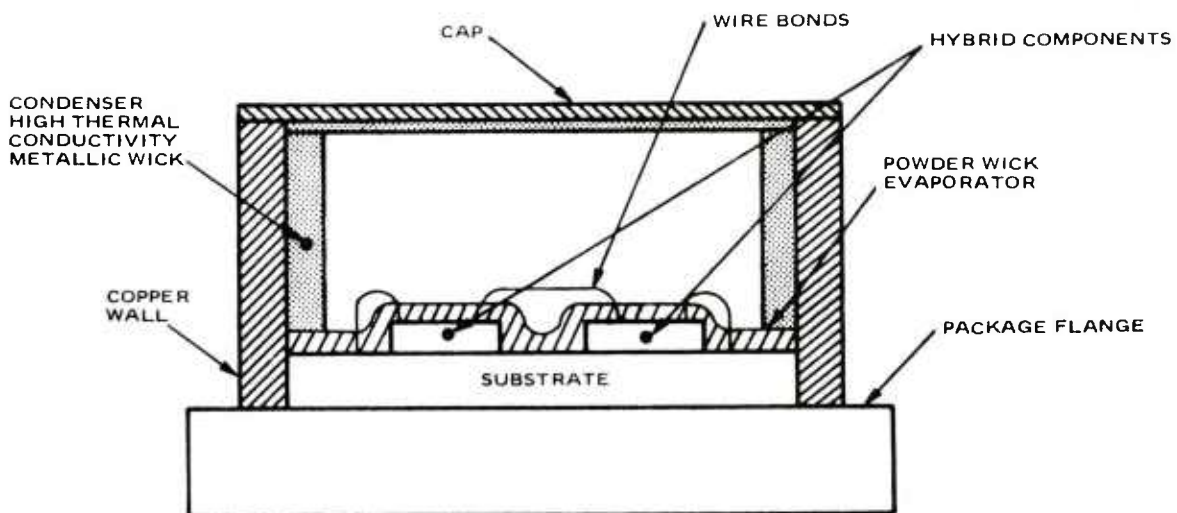


Figure 1 - Sectional View of Hybrid Packaging Concept for Wick-Enhanced Closed-Cycle Evaporative Cooling

SUMMARY

Hughes Aircraft Co. established low cost volume production techniques for fabricating heat pipe cooled microcircuit packages. The technology was demonstrated by building the two types of hybrid package shown in Figures 2 and 3. Extensive analysis and testing were performed to determine optimum heat pipe materials and assembly methods.

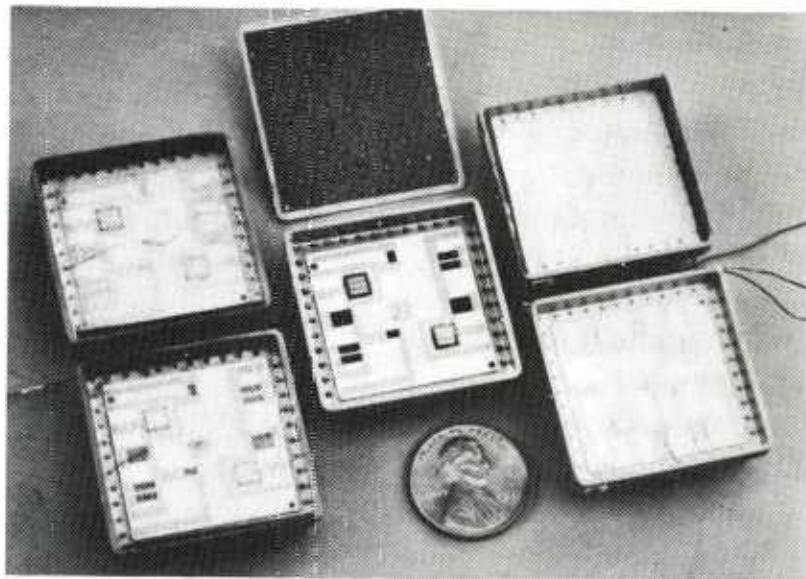


Figure 2 - Experimental Hybrid Packages With and Without Evaporator Wicks. Center Hybrid is without evaporator wick. Copper mesh condenser wick is on inside of the step cover.

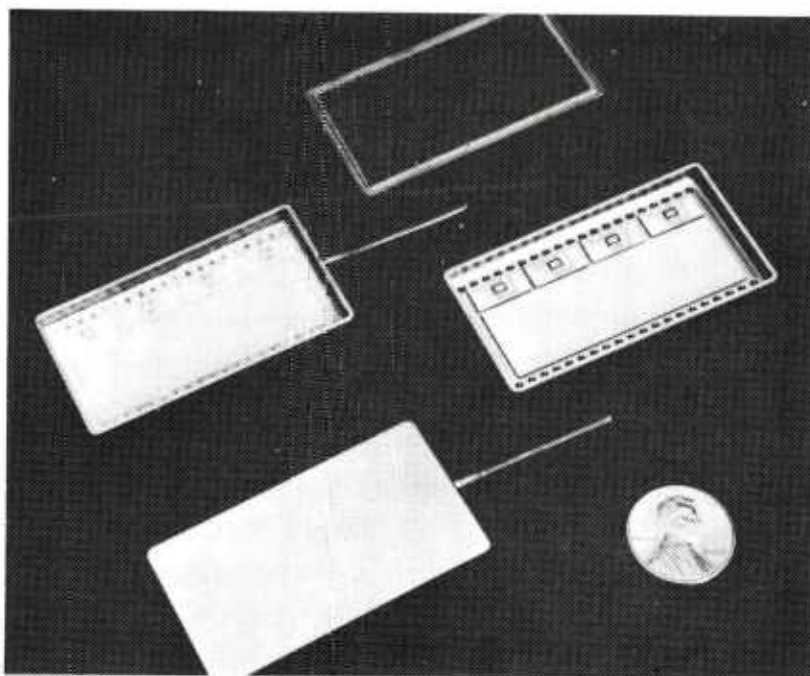


Figure 3 - Pulsar Hybrid With and Without Evaporator Wick. Bottom: Sealed hybrid. Top: Condenser wick on inside of the step cover.

Evaporator wicks .010 inch thick were formed by pouring glass fibers suspended in a methyl alcohol solution over microcircuit components on the substrate. Condenser wicks were made from 50 mesh copper screen and were spot welded to the hybrid cover. Hexane was selected as the fill fluid. Standard bathtub type hybrid packages were found to be most compatible with wick material and shape, fill fluid pressure and the package parallel-weld sealing method.

A helium leak test fixture which included a mass spectrometer was developed for leak testing the hybrid packages before hexane fill. A multiple fill station was used for both package vacuum evacuation and hexane vapor fill. Final testing comprised both thermocouple measurement and electrical performance check.

BENEFITS

As a result of this effort, a contractor will be capable of assembling, evacuating, filling and sealing hybrid microcircuit heat pipe packages at a production rate of 15 per hour.

Heat pipe cooled packages lowered transistor chip junction temperature 50% compared to non-heat pipe cooled versions of the same package.

The significant thermal resistance reduction could be exploited to increase power densities, resulting in fewer chips and hybrid packages per circuit. The potential exists for decreased weight, space and cost in military applications.

IMPLEMENTATION

Copies of the final report have been distributed to private industry and all military services. The results of this project have been well documented and are available for implementation.

MORE INFORMATION

Additional information may be obtained from Mr. Paul Wanko, MICOM, Redstone Arsenal, AL, AV 746-7097 or Commercial (205) 876-7097. The contract was DAAK-40-79-C-0141.

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 579 4332 titled, "MMT - Improvements For Potting Electronic Assemblies For Gator Mine", was completed by the US Army Armament Research and Development Command in October 1980 at a cost of \$83,000.

BACKGROUND

At the time of contract award, the electrical assembly for the BLU92/B Gator Mine used potting materials and processes that were difficult to apply, handle and cure, resulting in an expensive product. Improved potting materials and fabrication techniques were needed to replace manual assembly methods.

SUMMARY

Aerojet Ordnance Company performed an extensive review of current BLU92/B electronics hardware specifications to determine compatibility with various potting materials and procedures. Several approaches were evaluated: open molding, injection molding, integral encapsulation, and closed molding, along with different epoxy materials. Selection of the new method was based on (1) lower assembly/inspection cost, (2) lowest startup (tooling) cost, (3) greatest structural integrity, and (4) lowest production cycle time.

The integral encapsulation method was selected because it provides the most significant advantages in these areas. The electronics assembly is potted after insertion in the mine body rather than being potted as a separate unit.

Arnco Co. #T70D/PRO 200A, Fastcast Epoxy was selected as the optimum potting material. Figure 1 shows the body assembly and tooling required to keep the potting confined to the electronics assembly region and out of the centrally located safing and arming device and explosive lead areas. Figure 2 shows a sectioned body assembly after potting.

Four units were fabricated and subjected to thermal shock and impact survivability tests with excellent results. Electronic tests were performed before and after assembly operations and after failure mode environments (thermal shock and impact) with no functional failures noted.



Figure 1 - Unencapsulated Body Assembly and Feasibility Tooling

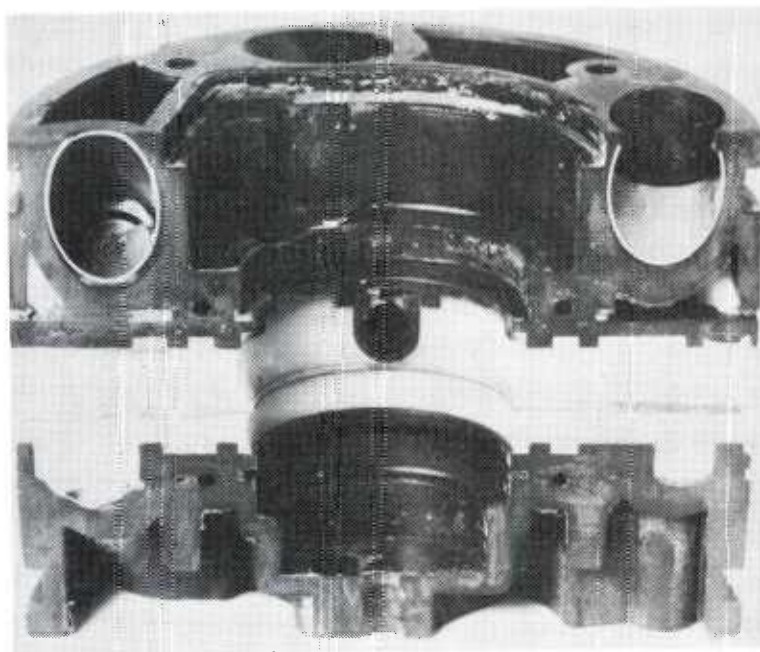


Figure 2 - Sectioned Body Assembly Showing ARNCO T700/PRO 20A
Fastcast Epoxy

BENEFITS

Cost reductions were realized in several areas:

- a. Preparation and handling time was reduced from approximately 3 hours to 20 minutes.
- b. Conformal coating of the electronics, potting of sensor to housing, and mold assembly and cleaning operations were all eliminated.
- c. Electronic analysis and rework could be performed to completion of the mine body assembly.
- d. The encapsulant provided improved device structural support.

IMPLEMENTATION

Plans have been made to incorporate the new integral encapsulation method into GATOR production as a PIP effort following successful Operational II mine testing.

MORE INFORMATION

Additional information may be obtained from Mr. Robert Wade, ARRADCOM, Dover, NJ, AV 880-5681 or Commercial (201) 328-5681. The contract was DAAK10-80-C-0005.

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 Projects E78 3606 and E79 3606 titled, "Transcendent High-Power Rectifier", were completed by the US Army Mobility Equipment Research and Development Command in January 1981 at a cost of \$360,000.

BACKGROUND

Semiconductor rectifiers used in high current power conditioning equipment require large heat sinks having fins for conducting the heat to an outside air stream. Their bulkiness is a hinderance to good clean design and small package size. Heat pipes are a new innovation and make use of the large heat-absorbing capacity of an evaporating fluid. Freon or water is used in the devices where it is fed to the heated surface to evaporate and cool the area; the vapor is then conducted to a cooler area where it condenses and returns by capillary action to repeat the cycle. This is done in a heat pipe with porous copper wicking and requires no moving parts.

SUMMARY

The contractor developed specialized fixtures and procedures for rapid fabrication of heat pipes and for bonding the bases of two heat pipes to opposite sides of the silicon rectifier wafer. High temperature brazing of the heat pipe body, sintering of porous copper wick, and ceramic-to-metal sealing were production engineered to permit volume manufacture. Plating, lapping and soldering methods were tailored to obtain blister free, void free metal joints between the heat pipes and rectifier wafer.

The heat pipe used in this contract includes a molybdenum disc that contacts the silicon rectifier wafer, a cylindrical porous copper body which serves as the wick, a copper end closure, and a spiral fin assembly that forms the outside walls. The cutaway diagrams, Figure 1, depicts this assembly. Shown in the figure are the rectifier wafer, the ribbed wicking, the circular fins, and the end closures. All must be aligned exactly and maintained that way during welding to insure uniform distribution of current throughout the silicon chip. Tooling was developed to achieve this precise alignment, and test equipment was built to assure it.

Shown in Figure 2 is a cross-section of the rectifier wafer illustrating the metallization on both sides and the contoured edges. The contour is formed by abrasion with fine aluminum oxide particles driven by high pressure air from a precision nozzle while the rectifier disc is spun on a mandrel. The disc is then fluxed and dipped in a solder pot to pre-tin the metallized surfaces which form the bond to the heat pipe halves.

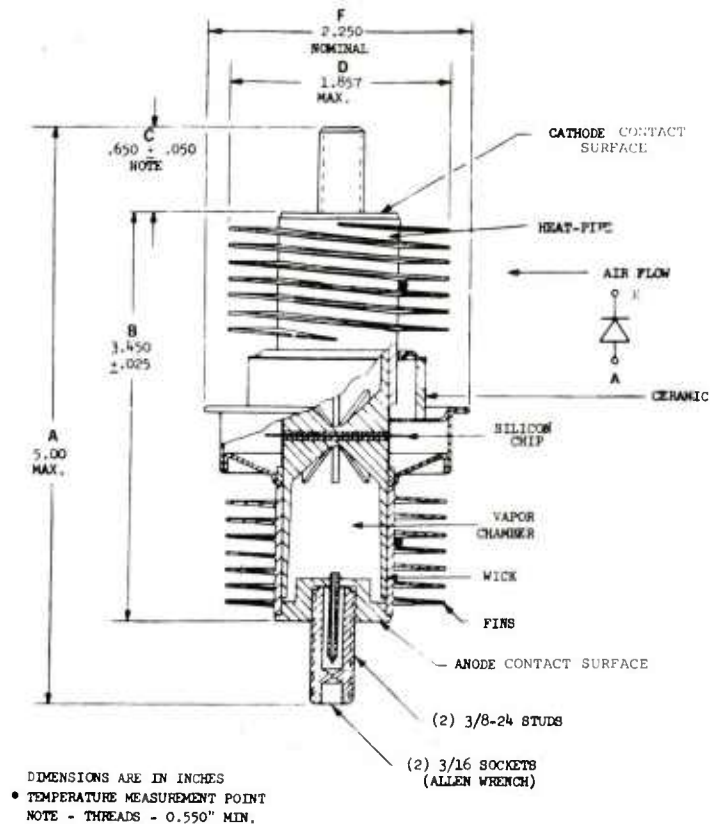


Figure 1 - Transcaltent Rectifier Type J15401 Cross-Section Drawing

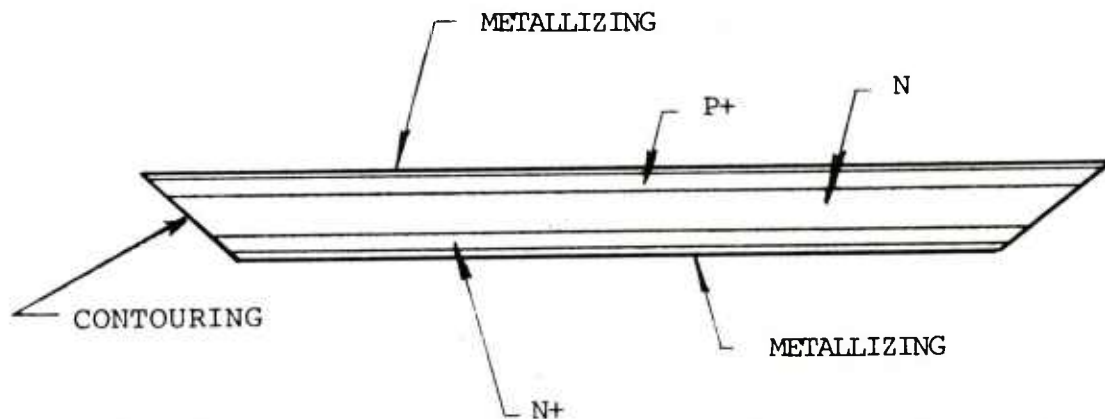


Figure 2 - Cross Section of the Metallized and Contoured Rectifier Wafer

An improvement was made to the heat pipe halves by brazing on a molybdenum disc to both close the heat pipe and to form the joint with the metallized semiconductor wafer. The moly discs are lapped after brazing so that they present a flat surface to the pretinned semiconductor wafer.

BENEFITS

The use of heat pipes extends the current switching capability of a semiconductor by cooling its junction to permit higher current density without damage to the device. This rectifier is able to switch 250 amperes continuously without overheating. Cost of a typical high power rectifier was reduced from \$350 when built on a laboratory scale to \$80 when produced in volume. The

double sided heat pipe is inherently rugged and can be installed in field type equipment. Torquing the device is not a problem as it is with the hockey-puck type rectifier it replaces, and relaxation of clamping force thru creep of copper or aluminum parts does not occur.

Patent rights to the tapered metallization were secured on an earlier R&D project and RCA may retain rights for commercial production although they have agreed to instruct another manufacturer on how to build the devices.

IMPLEMENTATION

Transcalent rectifiers have been demonstrated in the 15KVA power conditioner shown in Figure 3. Heat pipe rectifiers replaced the older heat-sink rectifiers and performed well for many thousands of hours. The heat pipe can also absorb surges that would damage older rectifiers.

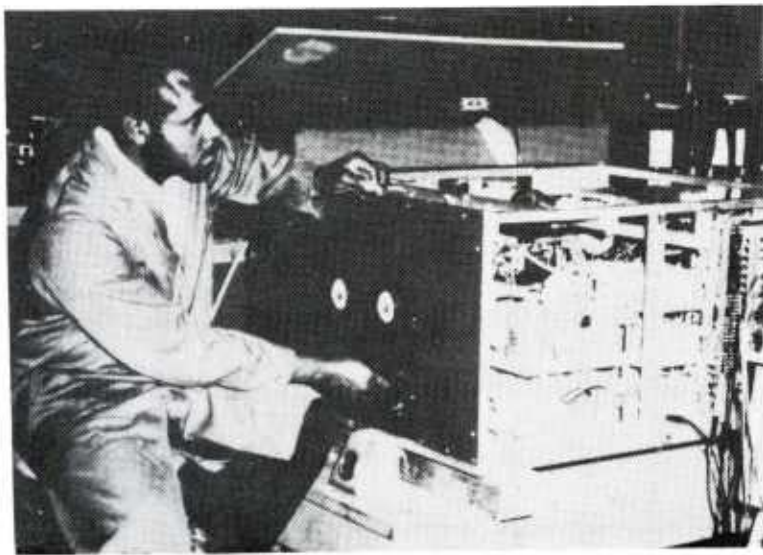


Figure 3 - 15 KVA Power Conditioner With Transcalent Rectifiers

MERADCOM has several sample high power rectifiers available to loan to potential users who wish to determine their suitability in items being developed for the Army. This includes military power conditioners and welders.

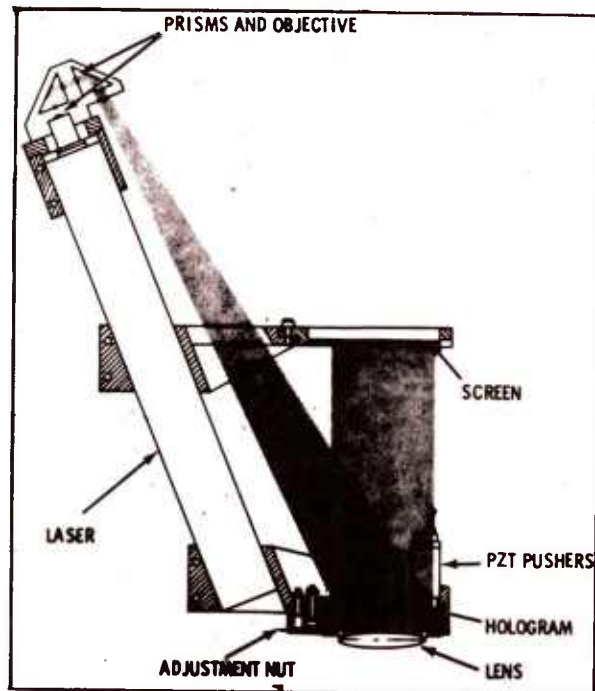
A brochure highlighting features of transcalent devices was developed by MERADCOM and circulated. RCA has developed a commercial version of the heat pipe rectifier for industry use and has published data sheets and video tapes on the units.

MORE INFORMATION

A final report on contract DAAK 70-78-C-0120 titled, "MM&T Measure For Fabrication of Silicon Transcalent Rectifier", is available from RCA Corporation, Solid State Devices, New Holland Avenue, Lancaster, PA 17604. The project engineer at MERADCOM was Mr. Frederick G. Perkins, AV 354-5724 or Commercial (703) 664-5724.

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

INSPECTION AND TEST



OPTICAL HOLOGRAPHIC TEST EQUIPMENT

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project T78 6035 titled, "MM&T Establish On-Line Non-Destructive Test Procedures for Tracked Combat Vehicles", was completed by the US Army Tank-Automotive Command in April 1981 at a cost of \$1,832,000.

BACKGROUND

Extensive in-process non-destructive testing of many M1 Tank components will be required during production to assure compliance with quality specifications. Proper selection of NDT methods and application techniques will require prior planning and evaluation to achieve an adequate confidence level. Failure to provide these elements causes a lowering of quality sensitivity to a level where significant flaws escape detection and create serious problems in subsequent manufacturing operations. A practical solution is to provide a quality assurance NDT system adaptable to an on-line production situation.

Similar efforts have been undertaken by other Government agencies and private industry. However, the product and quality requirements are so dissimilar from the majority of NDT procedures, they are not applicable to the M1 Tank. The M1 vehicle's weldment is a unique design which requires establishment of special ultrasonic application techniques.

SUMMARY

The objective of this contract was to formulate and implement a non-destructive test program to establish effective non-destructive test processes for the M1 hardware acceptance. This includes identification of items to be tested, selection of appropriate NDT methods and application techniques.

To accomplish this objective, the contractor conducted various tasks; vital ones are listed below:

- Review M1 quality control requirements.
- Select appropriate NDT method and application technique.
- Identify and procure inspection equipment.
- Document test methods and prepare position charts for radiographic and ultrasonic inspection.

- Evaluate and establish an automatic ultrasonic inspection system for armor assemblies.
- Prepare a manual on ultrasonic inspection procedures and standards for armor welds.

The results of this contractor-developed program is an efficient NDT inspection system for the M1 Tank program. This system is capable of inspecting castings, forgings, and armor welds. The contractor established inspection methods and operating procedures for ultrasonic, radiograph, liquid penetrant, magnetic particle, and eddy current for use directly on-line. Also, the contractor developed a nuclei of highly trained and efficient NDT engineers and technicians who, with their combined effort, will continually update and improve the quality of NDT inspection methods.

BENEFITS

The most significant benefit derived from this program will be the development of an ultrasonic inspection procedure and standards manual for armor welds. It is estimated that application of ultrasonics as a weld inspection method could reduce inspection cost about one-third of that required for radiography. This estimate will be realized once the acquisition phase is completed.

IMPLEMENTATION

It is expected that this inspection program will be implemented in July of this year at the Detroit and Lima Tank plants.

MORE INFORMATION

More information on this project may be obtained from Mr. Ed Nader, AUTOVON 786-6347 or Commercial (313) 574-6347.

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 576 6628 titled, "Automated Inspection of Mechanical Time (MT) Fuze Components", was completed by the US Armament Research and Development Command in December 1980 at a cost of \$250,000.

BACKGROUND

Previously collected information from current fuze producers indicated that on the average, approximately 70 hours are required to inspect a sample of 200 M572 No. 1 plate assemblies. The size and location of the pivot holes in these plates, and the remaining plates, is critical to the acceptability of the fuzes. Using past information, assuming a production rate of one million fuzes per year, the cost of inspecting the plates alone would be approximately \$210,000. This expense is attributed to inspection time and the contractor's cost for frequent shut-down while awaiting release of parts from inspection stations.

Since there were no known similar efforts being conducted by private industry and/or other Government agencies, a one-year effort to establish an efficient automated inspection system and associated prototype equipment, was initiated.

SUMMARY

The objective of this project is to make available a prototype automated inspection station for the inspection MT fuze movement plates.

Prior to actual award of a contract, Army Engineers conceived an improved inspection method during the manufacture of the M572 Fuze. The concept was a completely automatic non-contact inspection machine. With the concept and a dual goal of high quality and cost reduction in mind, Frankford Arsenal awarded a contract to Bulova S&I.

Bulova's initial concept for the prototype has two modes of operation. The first would quantize the entire optical image of a lens system. The other mode would use the inherent accuracy of a precision X-Y table, together with optical transition signals to establish distances outside the field of view of the lens system.

The final prototype developed was an automatic non-contact inspection machine for thin movement plates. The machine consists of:

- image digitizer (VIDICON)
- precision X-Y table
- computer control system (NOVA 3)
- illumination system

The back light source was a problem area and a 250 watt Tungsten-Halogen lamp proved superior to a low power laser. A low power laser is the light source for depth or projection measurements using a split beam technique. All linear measurements are made using a software program which causes a line scan across any selected area of a part. As the scanning point passes through an intercept on the part being inspected, this intercept is stored as a digital address in the computer memory. After this single line scan is complete, the computer calculates the straight line distance between two points or intercepts of interest and displays or stores this dimensional information in units or millimeters as calibrated.

An intercept is a transition from a light area to a dark area. Two intercepts are needed to form the length of a line by calculating the straight line distance between the transition points. Any edge or transition may also be defined as components of a feature. Each component must have assigned limits for tolerance determination. A non-circular hole may be inspected in this manner. Figure 1 below illustrates schematically typical position of equipment and the measuring of two critical features, i.e., depth and width of hole.

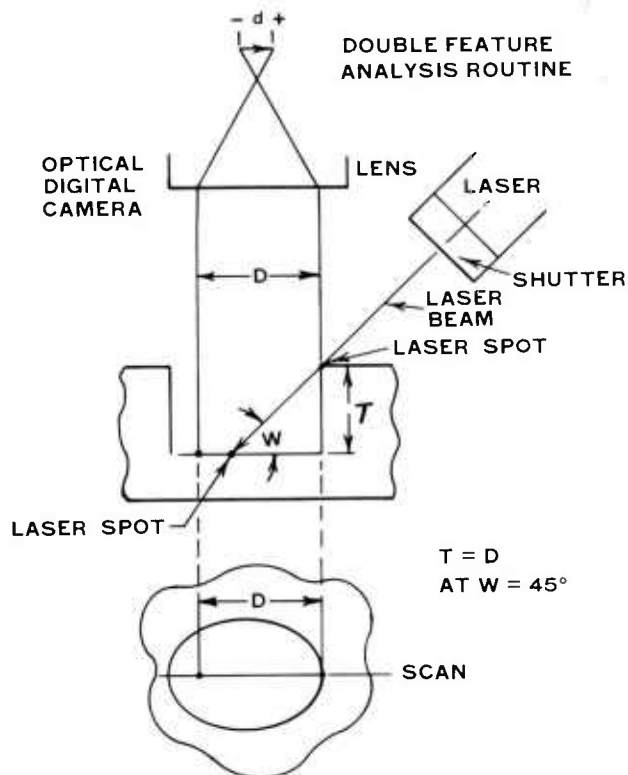


Figure 1 - Depth Measurement Diagram

This inspection machine was designed primarily for the M571, Plate No. 1, First Lamina. The inspection time for both sides is under 30 seconds. Also, the computer control program can inspect a part which has 30 different hole configurations, i.e., counterbores, countersinks, partial holes, grooves, slots. The computer program was written with true position tolerance calculation sub-routines.

In addition, a feasibility study using soft fixturing was conducted for the inspection of M577 MTSQ Fuze components. The machine inspected adequately all of these components except Plate No. 1, where the depth exceeded the lens depth of field. During the study, the computer control program problems caused two significant delays. The computer program was written in machine language due to funding limitation. Another unsolved problem was a compensation method/device to correct the slight daily differences in vidicon tube performance. This requires the periodic use of master plates and limits the usefulness of this measuring device since it cannot be switched to a different piece part without an inspection of a part whose dimensions have been determined.

BENEFITS

This inspection machine has demonstrated the feasibility of non-contact inspection of a complex plate at a rate exceeding 100 plates/hours.

IMPLEMENTATION

The machine was returned to ARRADCOM and used to demonstrate non-contact inspection possibilities. No further implementation plans are scheduled at this time because of the studies findings. The findings were: (a) the control program is not flexible enough because it's written in machine language, (b) the machine is incapable of properly handling the Z-axis (depth) when the depth exceeds the lens depth of field.

MORE INFORMATION

Additional information may be obtained from Mr. Thomas McKimm, ARRADCOM, Dover, NJ, AV 880-5839 or Commercial (201) 328-5839. The contract was DAAA25-76-0344.

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 576 6640 titled, "MMT - Production Control and Quality Assurance of Shaped Charge Liners by Automated X-Ray Analysis," was completed by the US Army Armament Research and Development Command in December 1979 at a cost of \$133,000.

BACKGROUND

The acceptance criteria for shaped charged liners is based on a combination of tests - a destructive x-ray inspection and ballistic penetration test. Both of these tests are performed on a sampling basis. The amount of armor defeated by the shaped charge liner depends on the continuity and quality of its jet. The jet quality depends on the collapse mechanism of the metal grains comprising the jet producing portion of the liner. A major reason for poor ballistic performance is the existence of non-optimum grain orientations in the liner. The current Government x-ray inspection requirement and methodology is of questionable value, and provides insufficient data. In a prior effort under RDT&E program 1Y665702D650 a computerized x-ray method was developed to automatically produce and evaluate grain orientation texture maps for liners. This effort was undertaken to establish techniques to adapt the laboratory proven method for production and to monitor production and predict ballistic performance.

SUMMARY

The objective of this effort was to establish a manufacturing process and inspection procedure for the manufacture of shaped charge liners with consistent and improved ballistic performance. The approach was to (1) fabricate shaped charged liners under various controlled conditions, (2) test random samples of these liners using the new computerized x-ray method, (3) test random samples of these liners for armor penetration capability, (4) analyze test results and establish useability and reliability of x-ray test results to predict armor penetration. The system that was used to perform the x-ray analysis and generate grain orientation texture maps is illustrated in figure 1.

Six hundred shaped charged liners for 105mm Ammunition were fabricated from copper blanks using various spinning techniques. Process parameters varied under controlled conditions included rolling direction of starting material, chemical purity of starting material, coolant (full flow or mist), mandrel speed, and roller feed rate. Static spin tests indicated acceptable armor penetration results were obtained. Flash radiographs from the static spin tests were evaluated for jet tip velocity, jet break-up time, average jet particle length, and total jet length. Texture maps were obtained on each categorize of liners fabricated.

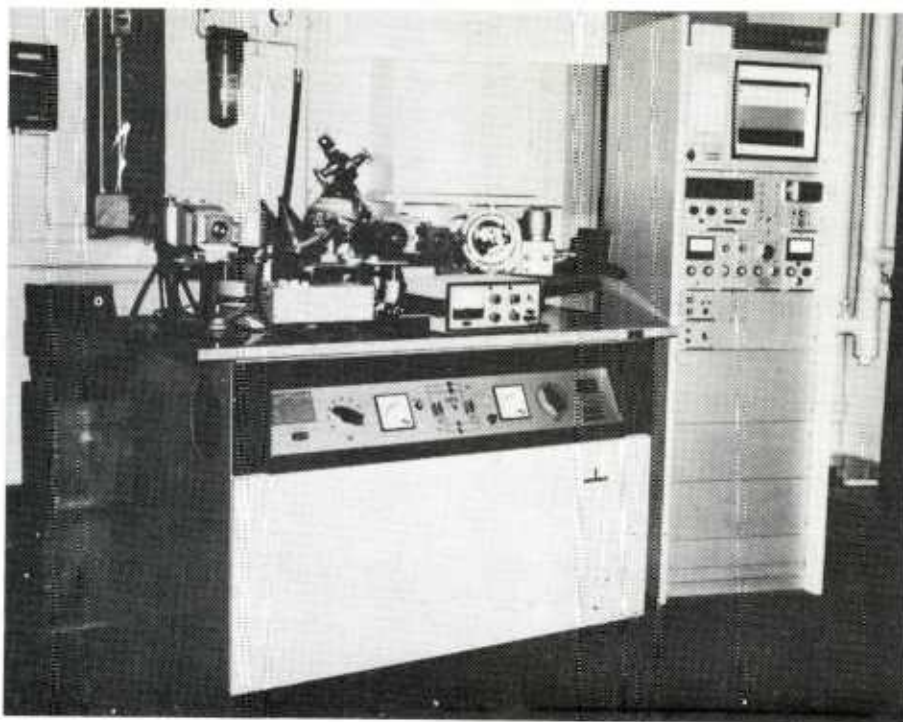


Figure 1 - X-Ray Unit for Shaped Charge Liner Analysis

BENEFITS

The major benefit from this effort will be the assurance of consistent quality of shaped charge liner in munitions. Improved assurance of product reliability will translate into a reduced need for continued ballistic and informational test firings.

IMPLEMENTATION

The results of this project were applied to Manufacturing Methods and Technology Project 577 6640. The x-ray inspection system is now available for use at ARRADCOM, Dover, NJ.

MORE INFORMATION

Additional information can be obtained from the project officer, a technical report is being prepared. The project officer is Mr. Fred Witt, ARRADCOM, AV 880-4225 or Commercial (201) 328-4225.

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 577 6640 titled, "MMT - Production Control and Quality Assurance of Shaped Charge Liners by Automated X-Ray Analysis," was completed by the US Army Armament Research and Development Command in September 1981 at a cost of \$181,000.

BACKGROUND

The acceptance criteria for shaped charge liners is based on a combination of tests. A destructive x-ray inspection, static and ballistic penetration tests evaluate the armor penetration capability of the liner. These tests are performed on a sampling basis. The amount of armor defeated by the shaped charge depends on the continuity and quality of its jet. The jet quality depends on the collapse mechanism of the metal grains comprising the jet producing portion of the liner. The current government x-ray inspection requirement and methodology is of questionable value and provides insufficient data. In a prior effort, under RDT&E program LY665702D650, a computerized x-ray method was developed to automatically produce and evaluate grain orientation texture maps for liners. The x-ray computer system capability was enhanced under MMT Project 576 6640. In addition, texture maps and penetration tests were completed for liners fabricated under controlled conditions.

SUMMARY

The objective of this effort was to establish a manufacturing process and inspection procedure for the manufacture of shaped charge liners with consistent and improved ballistic performance. The approach was to (1) continue the evaluation of test results from prior MMT Project 576 6640, (2) fabricate additional liners with different starting materials and with precision machined sidewall thickness, (3) test random samples of these liners using the enhanced computerized x-ray method, (4) test random samples of these liners for armor penetration capability, (5) analyze tests results and establish useability and reliability of test results to predict armor penetration.

Two hundred shaped charged liners for 105mm Ammunition were fabricated from copper blanks using various spinning techniques. The rolling direction of the starting material (unidirectional and cross rolled) and precision machining of sidewall thickness were varied under controlled conditions. Static spin tests indicated acceptable armor penetration results were obtained. Texture maps, flash radiographs, and penetration results were obtained and analyzed along with other data for each category of liners fabricated. A technical data package was prepared for the equipment used to x-ray inspect the liners. The x-ray system has been used to inspect liners for other munitions such as 120mm shaped charge liners and several improved conventional munitions liners. The enhanced

x-ray inspection system was established and can generate highly detailed color texture plots of the grain orientation of shaped charge liners.

The fixture that was used to generate grain orientation texture maps is illustrated in Figure 1.

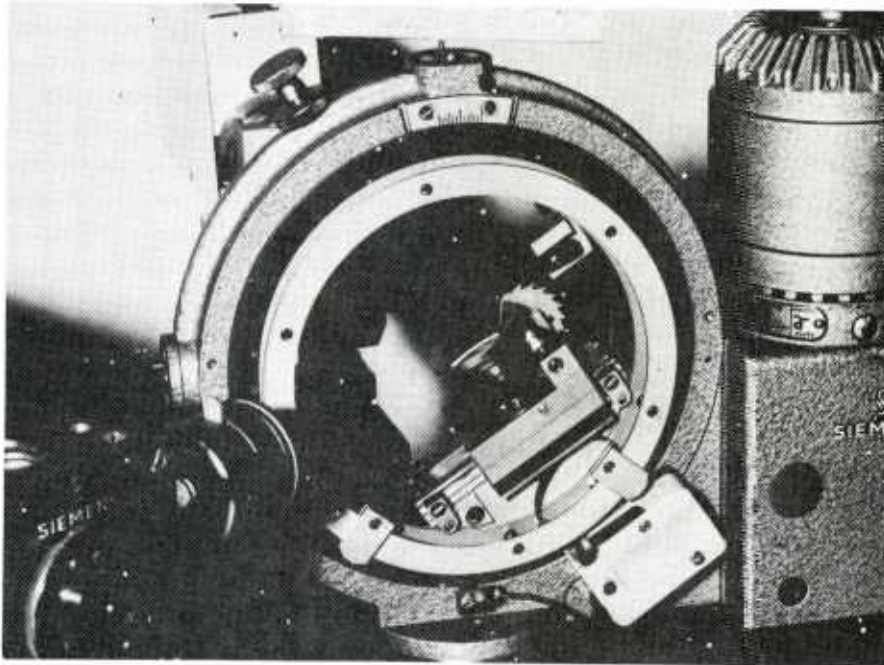


Figure 1 - Sample Holder for Texture Analysis of Shaped Charge Liners

BENEFITS

The major benefit from this effort will be the assurance of consistent quality of shaped charge liners in munitions. The inspection system has been used to predict and evaluate the properties of liners used on other tank and artillery ammunition for 120mm, 155mm, and 8 inch weapon systems.

IMPLEMENTATION

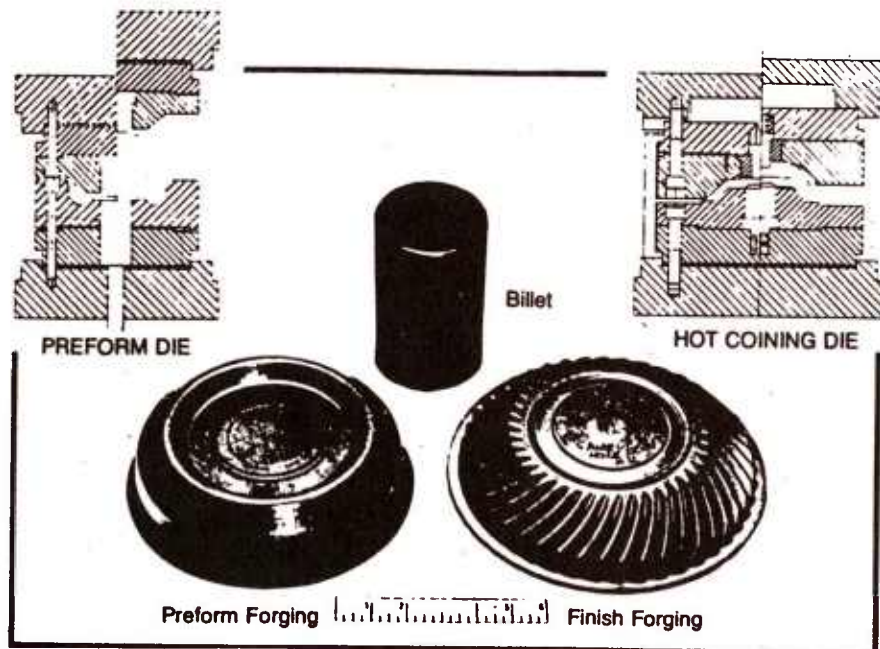
The x-ray inspection system is now available for use at ARRADCOM, Dover, NJ. Key results of this effort were presented at the American Society for Metals Conference on Texture - Mechanical Properties Relationships.

MORE INFORMATION

Additional information can be obtained from the project officer. A technical report is being prepared. The project officer is Mr. Fred Witt, ARRADCOM, AV 880-4225 or Commercial (201) 328-4225.

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

METALS



TWO-HIT FORGING PROCESS

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

Manufacturing Methods and Technology Project 175 7070 titled, "Cast Compressor Components", was completed by the US Army Aviation Research and Development Command in November 1981 at a cost of \$195,000.

BACKGROUND

The Solar Titan T62T-40 gas turbine auxiliary power unit is a high performance engine, widely used in DOD systems. The three major applications are the Army Blackhawk Helicopter (UH-60A), the Air Force F-16 Aircraft, and the Navy LAMPS Helicopter. Total production requirements are expected to exceed 10,000 units over the next few years.

The engine employs a single stage, radial compressor impeller, approximately six inches in diameter (Figure 1). Engine speed is 61,248 rpm and the compression ratio 4.3/1. Early models of the engine employed a cast 17-4PH stainless steel compressor impeller. Upgrading to the present configuration required a material change to Ti-6Al-4V, lowering weight and starting inertia. Manufacturing procedure for this impeller was by machining a 22 pound titanium alloy pancake forging to generate the 2.6 pound impeller, at a cost of approximately \$2200 each.

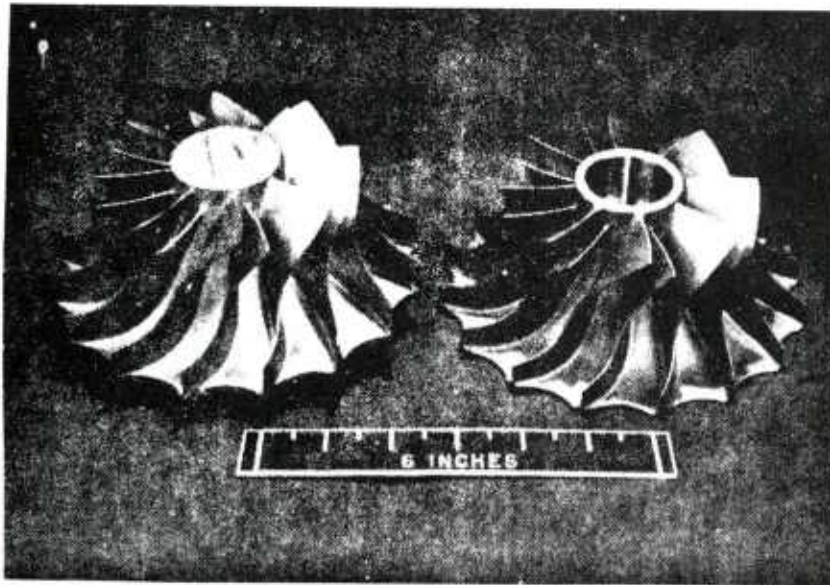


Figure 1 - As-Cast and Finished Machined Impeller

SUMMARY

This program began in May 1976 at Solar Turbine International to investigate the feasibility of producing the impeller as a near net shape by investment casting. The program was conducted in three phases:

1. Evaluation of foundry capability and casting properties in a low cost test piece simulating the compressor impeller.

2. Design and procurement of prototype impellers, based upon the characterization of cast titanium alloy.

3. Metallurgical evaluation, rig testing, and engine testing of the prototype impellers and definition of procurement and process control specifications.

Phase I - Evaluation of Straight Vane Wheels

The investment casting industry was surveyed for foundries experienced in casting of titanium alloys. Four foundries were contracted to cast 20 parts each of a simple straight vane wheel test shape. Based upon visual, mechanical and nondestructive evaluation tests of the castings, two foundries, Precision Castparts Corporation (PCC), Portland, Oregon and REM, Albany, Oregon were selected for producing acceptable quality parts. Evaluation of internal quality requirements of the impeller in dynamic service versus actual quality of the as-cast parts dictated that hot isostatic pressing (HIP) would be required to insure integrity of the product.

Phase II - Procurement of Rotor Castings

Precision Castparts Corporation was selected on the basis of quality and competitive bids to produce prototype quantities of the Titan impeller for test. The design was patterned after the machined forged impeller and does not compromise the efficiency of the compressor in any way. Production processes developed in the analyses of Phase I castings were codified as the process control specification incorporating the developed HIP, heat treatment, and aging cycles. A total of eight castings were produced, four in each of two pours. These were HIPed, by Industrial Materials Technology (IMT), Woburn, Massachusetts, and subsequently heat treated and aged by Solar. The castings were evaluated by tensile tests of specimens trepanned from the bore of the first four; and by destructive metallographic, tensile and fatigue tests of one of the second lot (which was damaged in rough machining). Testing confirmed the expected benefits from the developed thermal treatments.

Phase III - Qualification Testing

Four of the castings were finish machined, balanced, and proof spin tested at 73,500 rpm, 120 percent of engine operating speed, with negligible dimensional growth or distortion. One was spin tested to 106,000 rpm, or 173 percent overspeed and 300 percent overstress, and exhibited ductile growth only at the highest speeds of rotation and did not burst. Permanent diametral growth of approximately 1.0 percent was observed at the inner bore diameter, confirming stresses in excess of the material yield strength at the highest speeds. Based upon these results, a second machined cast impeller

was installed in an engine and has sustained over 200 hours operation and 1124 start/stop cycles without impairment and at full engine efficiency.

BENEFITS

Cost of the cast impeller, including hot isostatic pressing, heat treatment, and machining is about 50% of the equivalent part machined from a forging. Savings per part are very much a function of production quantities. Adding the various costs involved in production of the cast and machined impellers, the overall is seen to be about \$900 less than the hogged out forging for equivalent high volume production in lots of 50.

IMPLEMENTATION

Solar Turbine International believes that the processes developed for the production of the Titan wheel are applicable to any radial impeller of comparable size. These data were presented to the DOD/MTAG Casting Technology Workshop in Arlington, Texas in March 1978 and at the industry/government end-of-contract demonstration in San Diego, CA in January 1980. Implementation is planned for the current follow-on program in cast titanium impellers.

MORE INFORMATION

Additional information on this project may be obtained from Mr. Frank Hodi, AMMRC, AUTOVON 955-3475 or Commercial (617) 923-3475. Reference USAVRADCOM Technical Report No. RDR 1827-18, "Evaluation of Cast Titanium Alloy Compressor Components", November 1981.

Summary report was prepared by Ron Russell, 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 178 7123 titled, "In-Process Techniques for Continuous Balancing of Helicopter Shafting" was completed by the US Army Aviation Systems Command in September 1980 at a cost of \$100,000.

BACKGROUND

Today's designers are becoming more weight and vibration conscious for new aircraft designs, and the introduction of a power-transmitting shaft that runs at super critical speed becomes increasingly desirable. Past data collected on inspecting long, hollow shafts reflects that an imperfectly balanced shaft subjects the bearing support to excessive stress, and, in the case of operation at supercritical speeds, the shafts themselves are subject to severe loading when running near resonant frequencies. Balancing such high-speed shafts so that they run smoothly has long been a problem. Experience has shown that existing balancing techniques are difficult and costly requiring high speed spinning equipment and relying on unscientific trial-and-error methods.

There were no prior MMT efforts associated with this project; however, various commercial companies, e.g., Hughes Helicopter and USAAV Lab attempted to overcome the problems encountered while balancing engine shafts.

SUMMARY

The purpose of this project is to build and demonstrate an automatic machine for the balancing of long hollow helicopter shafting. The technique was developed by Hughes Helicopters and was patented by them in October 1979. This balancing method requires no trial runs to develop baseline data. All required information is virtually obtained during a one-cycle pass along the slowly rotating shaft. It is automatically processed, and the operator is given a graphic display of how much balance is to be applied along the shaft. A pictorial representation and schematic is shown in Figures 1 and 2. The instrumentation required to conduct the Hughes technique can be categorized in five basic areas:

- Ultrasonic gaging
- Preamplification
- Analog-to-digital conversion
- Shaft azimuth encoding
- Digital computation and output

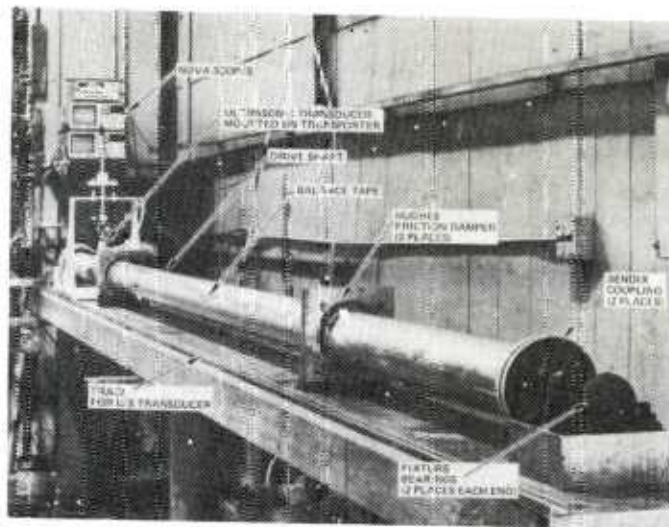


Figure 1 - Balance Machine Setup

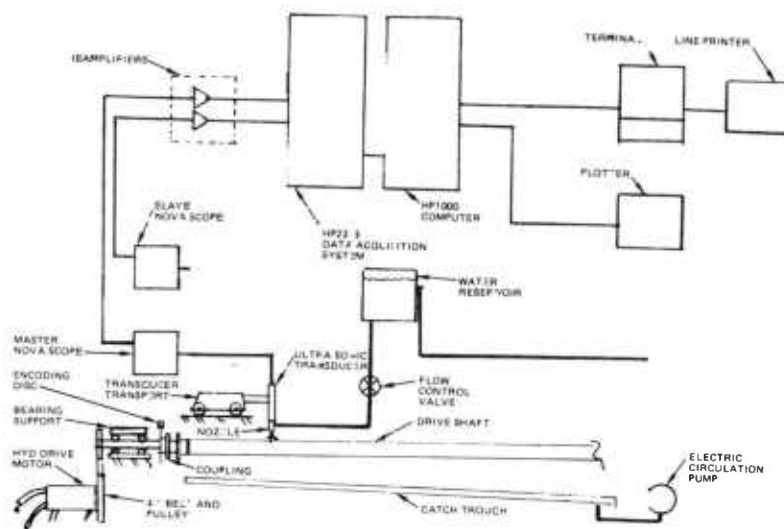


Figure 2 - Schematic of Balancing System

These areas are coordinated into the system to function in the following manner.

The ultrasonic transducer and sensors ride along a track that is parallel to the shafts centerline of rotation and measures two quantities at each of 250 azimuthal locations around the shaft for each lengthwise station along the shaft. The "slave" sensor measures the distance from the transducer to the outside surface of the shaft while the "master" measures the thickness of the wall of the shaft. The computer integrates this information around the periphery of the shaft, calculates the local center gravity, calculates the amount and location of balancing tape needed to bring the local center of gravity and center of rotation into coincidence, and displays the balance requirements in both analog and digital form. In the final step, the operator applies the adhesive-backed aluminum tape to the surface of the shaft.

BENEFITS

a. The program demonstrated the ability to place the center of gravity at all stations along the shafts within 0.001-inch of the center of rotation.

b. This procedure demonstrated a 5-hour reduction in time required to balance a YAH-64 tail rotor shaft.

c. US Patent No. 4,170,896 made on the YAH-64 (AAH) helicopter program prior to the performance of this program was reduced to practice under this contract.

IMPLEMENTATION

The process is considered available for implementation in the existing AAH helicopter program and future tail rotor drive shaft efforts.

MORE INFORMATION

Additional information on this project may be obtained by contacting Mr. Albert E. Easterling, AVRADCOM, AV 927-2971/3073/3977 or Commercial (804) 878-2771/3073/3977. In addition, technical report USA AVRADCOM-TR-8-F-15 titled, "A Computerized Balancing Technique for Supercritical Helicopter Shafting" is available from the Defense Technical Information Center as No. AD A 095-143.

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 R79 3204 titled, "Internal Shear Forging Processes for Missile Primary Structure", was completed by the US Army Missile Command in July 1981 at a cost of \$273,900.

BACKGROUND

Missile primary structures are currently fabricated from 2014 aluminum alloy sheet and plate stock by welding together the cylindrical outer skin of the structure and a series of internal stiffening rings. Cost reductions were sought for large production quantities through the use of internal shear forging to produce these structures as a monolithic construction. An additional anticipated benefit was the possibility of enhancing structural performance by incorporating thermomechanical treatments (TMT) into the internal shear forging process for these structures.

Internal shear forging consists of deforming a cylindrical ring between a rotating external die and an internal roller, resulting in a thin-walled tube with integral internal ribs. External shear forging is fairly well established as a production process for axisymmetric components and is known by a variety of names including tube spinning and roll extrusion.

SUMMARY

The object of this program was to establish the internal shear forging process for missile primary structures featuring thermomechanical treatment. For aluminum alloys, TMT typically involves introducing cold work into the precipitation-hardening cycle which results, in many cases, in improved tensile properties, fatigue strength, fracture toughness, and stress corrosion resistance.

The work performed in this program included tooling design and fabrication, an exploratory study of basic parameters, internal shear forging experiments, processing of deliverable parts with thermomechanical treatment, tensile property determination, and an economic analysis of the production requirements and costs for internal shear forging.

Using shear forging tooling in conjunction with an engine lathe, internal shear forging experiments were conducted to establish procedures for producing missile primary structures as a monolithic construction with integral ribs. The tooling which ultimately evolved is shown in Figure 1.

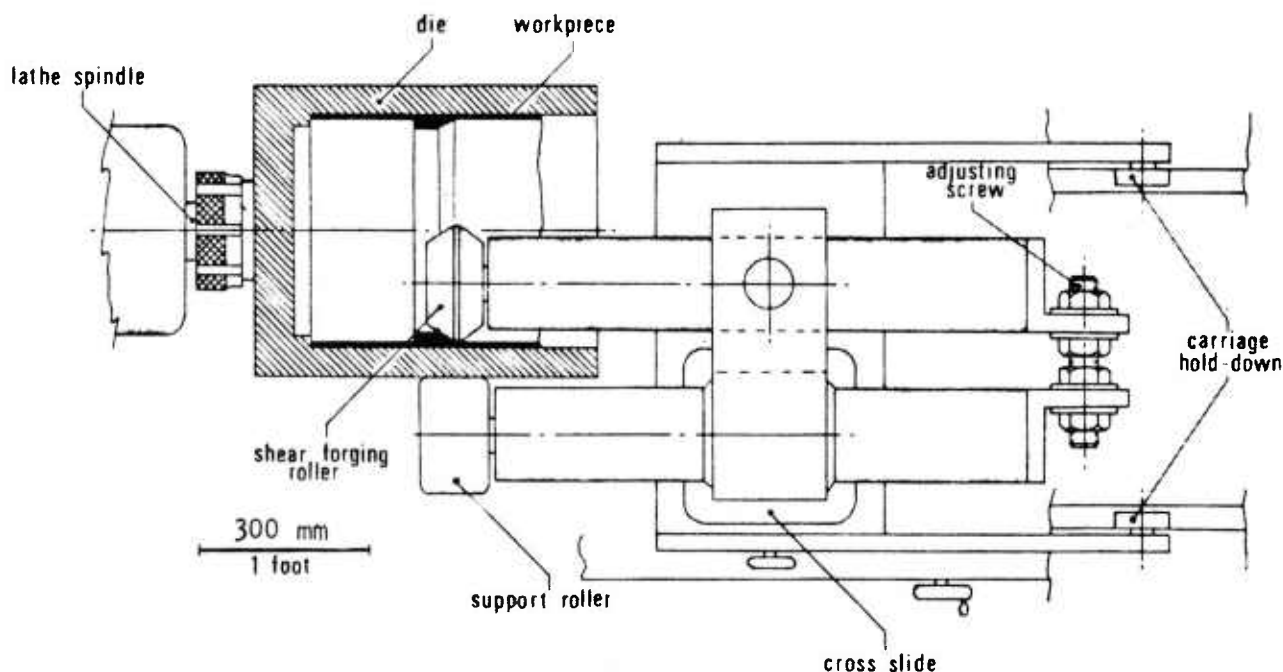


Figure 1 - Improved Tooling Design for Internal Shear Forging

The major conclusions from this program were that:

- Internal shear forging can be implemented to produce missile primary structures to near-net shape.
- The cost savings accompanying implementation of this process are substantial.
- Although the strengthening effect of thermomechanical treatment seems to be minimal for 2014 aluminum on the basis of tensile data, further testing for fatigue, fracture, and stress corrosion resistance is necessary before the effects of TMT can be confirmed.
- Dimensional stability and residual stresses resulting from TMT must be fully characterized.

BENEFITS

This Manufacturing Methods and Technology Program successfully established guidelines for large-volume production of these structures and demonstrated the potential cost savings resulting from implementation of the internal shear forging processes.

IMPLEMENTATION

Before this cost-effective, near net shape technology can be implemented, the thermomechanical aspects of the process must be carefully reviewed and evaluated, in terms of the following:

- trade-off between higher property levels (if existent) and increased processing cost due to the multiplicity of steps,
- influence of process variables on the reproducibility of end properties and product appearance,
- magnitude, polarity, and distribution of residual stresses resulting from TMT and their effect on the dimensions and mechanical properties of shear forged subshells.

MORE INFORMATION

Additional information may be obtained by contacting Mr. J. Honeycutt, MICOM, AV 746-1074 or Commercial (205) 876-1074.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Projects 476 4392 and 480 4392 titled, "Joining Dissimilar Metals", were completed in July 1981 at a cost of \$125,000 and \$23,000, respectively.

BACKGROUND

Replacement of steel armor with aluminum in certain areas such as floor panels, or the addition of steel armor in aluminum vehicles has been suggested as a means to arrive at optimum weight and protection designs. However, aluminum and steel cannot be joined directly by conventional welding techniques and mechanical fasteners introduce undesirable features. Transition strips fabricated by explosion bonding or roll bonding of dissimilar metals that cannot be joined by conventional welding have been used for several years for welding applications in electrical and fabrication industries. However, these transition strips had not been verified for heavy steel and aluminum armor manufacturing applications.

Earlier MM&T work (Project 475 4392) provided static tensile tests of 6061 aluminum and rolled steel armor welds using explosion bonded transition materials, but did not simulate production sized components or provide ballistic testing. Also, the Navy had verified the use of steel/aluminum transition strips for welding aluminum superstructures on steel ship hulls. The object of this program was to evaluate the use of commercially available steel/aluminum transition strips in the production welding of armor for military vehicles.

SUMMARY

To verify the welding of steel and aluminum armor and subsequent ballistic testing, two samples of commercially available layered aluminum/steel transition strips were selected. One was explosion bonded 5/8" aluminum 5086 or 5456 with an 1100 aluminum interlayer to 3/4" steel and the other was roll bonded 1/2" aluminum 3003 and 3/8" steel 304 stainless with an 1100 aluminum interlayer. Butt and 90° corner joints were chosen for tests to simulate potential design requirements. One-inch rolled steel armor MIL-A-12560 and one-inch aluminum MIL-A-46027 in the form of 18" x 36" flat plates were joined using the joint geometry in Figure 1.

Weldments of plates and transition strips were produced using semi-automatic gas metal arc welding and 100% argon gas shielding for the aluminum and 97% argon with 3% oxygen shielding for the steel. Twenty-four

specimens were welded, radiographically inspected, and ballistically tested at the US Army Aberdeen Proving Grounds. Ballistic tests showed that the transition strips performed at least as well as the armor plate or welds.

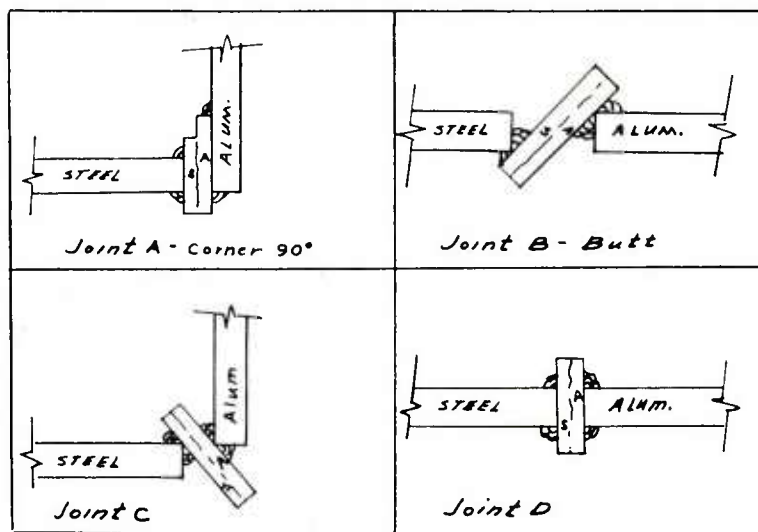


Figure 1 - Weldment Joint Geometry

BENEFITS

Dissimilar metal joining may offer the designer greater freedom for improving ballistic protection and reducing weight in armored combat vehicles. It also eliminates mechanical fasteners which are subject to failure under ballistic attack. Aluminum armored vehicles can be made less vulnerable in battle by selectively incorporating steel armor in specific areas. Steel armored vehicles can be made lighter and more mobile with aluminum-steel joints.

IMPLEMENTATION

Dissimilar metal joining technology is currently being used by shipbuilders to attach aluminum superstructures and liquified natural gas containers to steel hulls. Other applications are being made for surface transportation equipment and bridge construction. The General Motors version of the XM-1 Tank considered using this technology for the engine floor plates. The process was validated by ballistic firing and the data made available to combat vehicle designers. This project did not have a specific implementation target.

MORE INFORMATION

Additional information on these projects may be obtained for Mr. James L. Chevalier, US Army Tank Automotive Command, Warren, MI 48090, AUTOVON 786-6378 or Commercial (313) 574-6378. Reference TACOM Technical Report No. 12536, "Joining Dissimilar Metals," July 1981.

Summary report was prepared by Ron Russell, 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 5054 titled, "Laser Surface Hardened Combat Vehicle Components (Phase I)", was completed by the US Army Tank Automotive Command in December 1980 at a cost of \$175,000.

BACKGROUND

Combat vehicle track components are currently hardened by flame or induction hardening. These flame or induction hardening procedures cannot hold hardened pattern dimensions. It is difficult to control heating patterns near edges and corners which frequently results in cracking of components or produces insufficiently heat treated components. Some of these track components are subject to severe abrasive wear under the severe load conditions experienced during steering of the vehicles. Service failure of any of these components often requires the replacement of an entire set of track components. Clearly, if better methods of surface hardening could be established that would consistently produce the desired pattern, it would result in longer service life and lower surface hardening costs for these track components. Laser surface hardening is such a method.

SUMMARY

Heat treating evaluations were conducted using a continuous wave CO₂ laser rated at 5000 W of laser output power. Parametric evaluations were conducted at selected power levels of 4000 W and 5000 W on AISI 4140 steel plates using a laser beam of size 19 x 19mm. The composition of the steel plates nearly represented those of end connectors and center guides for T-142 tracks. The coated steel plates were translated under the laser beam at selected speeds ranging from 1 mm/sec to 12 mm/sec, to generate a heat treated stripe. During heat treatment, a stream of air was blown across the work surface to prevent smoke from interacting with the laser beam. The beam dwell time during laser heat treatment typically ranged between 0.5 to 10 seconds. Acceptable parameter ranges were established based upon the case depth of austenitized material and absence of surface melting. The parametric study provided guidelines for laser heat treating of end connectors and center guides.

End connectors and center guides from T-142 tracks used for the evaluations were in the finished machined condition and were not previously induction hardened. For end connectors, three heat treat stripes placed side by side were designed for each curved end. These stripes were perpendicular to the riding direction of end connectors. A gap of about 2mm between two heat treated stripes prevented back tempering of an adjacent stripe. For center guides, a total of four separate heat treat stripes were designed to

cover the wearing surfaces of both "fingers". The components were sectioned perpendicular to the heat treated stripes to note case depths. A cross-sectional view of an end connector illustrates placement of heat treat patterns as shown in Figure 1. End connectors' and center guides' wearing surfaces were heat treated to a depth of 3.1 mm and 3.65 mm respectively, with hardness ranging between R_c 50 and 54. Initial laboratory tests indicate that abrasive wear resistance of laser heat treated end connector specimen was better than that of an untreated specimen. For the center guide, the abrasive wear resistance was comparable to that of an induction hardened specimen. By adapting a broad area laser beam, shaped to cover the entire width of an end connector, it is possible to produce a continuous heat treat pattern along the curved ends during one continuous sweep of a connector under the beam.

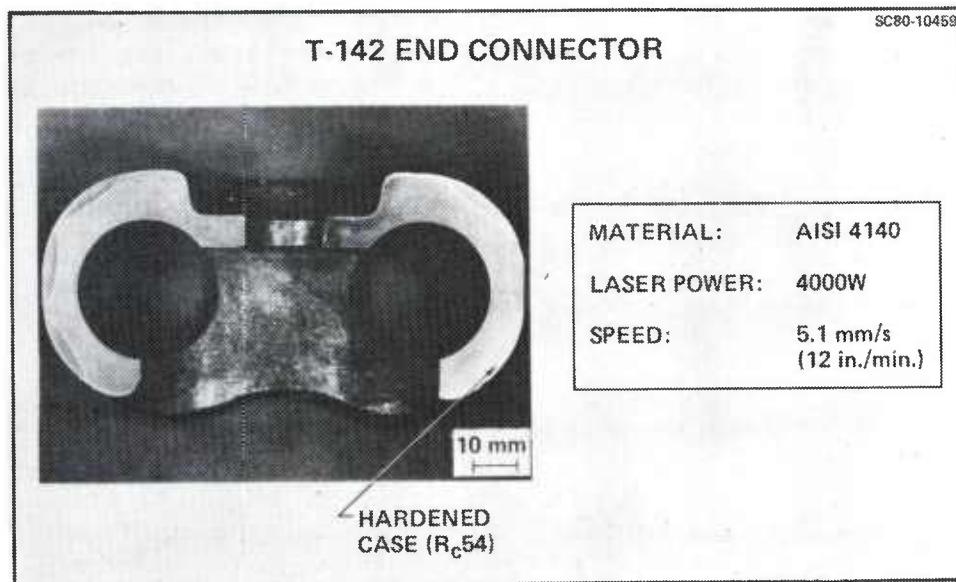


Figure 1 - Cross-Sectional View of an End Connector
Showing Placement of Heat Treat Patterns

BENEFITS

The potential result from this and follow-on projects is an alternate method for manufacturing these combat vehicle components with increased wear life. The precise controls of the proposed laser hardening technique will lower component reject rates, increase their reliability and reduce combat vehicle maintenance costs.

IMPLEMENTATION

This was the completion of Phase I of a two-phase effort; therefore, the results of this effort are not ready for implementation.

MORE INFORMATION

Further information may be obtained from Mr. Suresh Sharma, TACOM, AV 786-8711, or Commercial (313) 573-8711. The contract number is DAAK30-79-C-0136.

Summary report was prepared by Robert S. 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 579 4189 titled, "High Fragmentation Steel Production Process", was completed by the US Army Armament Research and Development Command in August 1981 at a cost of \$633,000.

BACKGROUND

The processing of Hf1 Steel under low volume production conditions had exposed many problems and the need for the refinement of economical processes to yield high quality products. This fiscal year's effort involved the purchase and metallurgical characterization of Hf1 Steel. This project is the first phase of a three-year effort, which has, as an overall objective, the optimization of high fragmentation steel production processes, using the 155mm M549 Warhead as the test vehicle. A secondary objective was to investigate fluidic temperature sensors in an attempt to provide control instrumentation that can more accurately measure mult temperature in the forge furnace.

SUMMARY

One heat of steel was purchased from each of two suppliers. The essentials of each supplier's process were also obtained. With these processes as background, each heat of steel was characterized looking at bars from the first, middle and last ingot of each heat, and assessing the uniformity relative to segregation, cleanliness, microstructure, macrostructure, hardness, chemistry and hardenability, and were found to be consistent throughout respective ingots and throughout each heat with few anomalies. However, one vendor's product, when tensile tested, gave many problems with breaks outside of the tensile specimen gage lengths. This was traced back to a lack of residual elements by chemical analysis. Apparently, this lack of residuals exaggerated the notch effect of tensile specimen imperfections. The effect that these residuals will have on subsequent processing of this steel is unknown. However, the stage is now set for the assessment of production problems with this fact in mind.

HDL had two temperature probe systems manufactured and calibrated at the National Bureau of Standards. These were installed at different locations in a forge furnace at Sunflower Army Ammunition Plant, and probe material and fluidics were assessed while measuring furnace temperature and comparing it with furnace thermocouple measurements over a one-month period. Figure 1 shows the ceramic temperature probe and metering device. Insufficient data was generated for evaluating the effectiveness of these temperature probes. Therefore, in the FY80 project, HDL will further their effort at Sunflower AAP so that the merits of fluidics versus thermocouples may be judged.

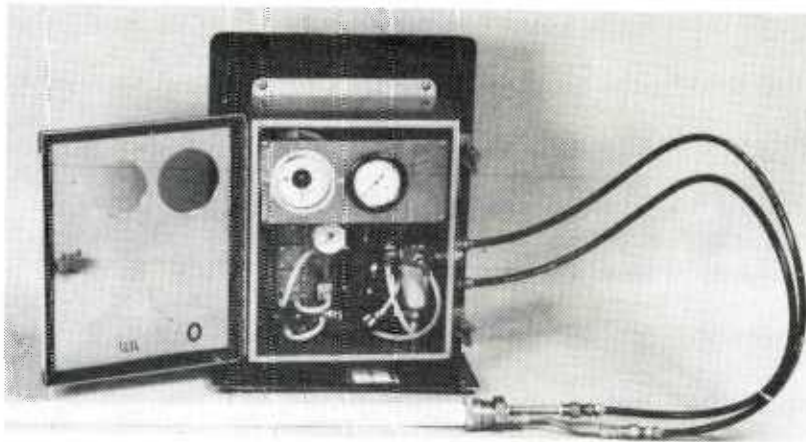


Figure 1 - Fluidic High Temperature Sensor and Probe

BENEFITS

In light of the fact that this is the first year of a three-year effort, and essentially a preparatory year for future investigations, there are no quantifiable benefits to be associated with this phase of the program. However, work performed in this phase yielded the following "building blocks" for the remaining years' efforts:

(1) Purchase and characterization of raw material to be utilized in future years' process optimizations has been accomplished. In this way, problems which are encountered during processing and are raw material related may be readily tracked.

(2) The viability of fluidics as temperature measuring devices in a forge furnace is being assessed. This may lead to more accurate control of forge furnace temperature, and thus, a more consistent forged product.

IMPLEMENTATION

Results will be utilized in analyzing process optimization problems encountered in the FY80 and 82 efforts.

MORE INFORMATION

Additional information may be obtained by contacting Mr. William R. Sharpe, ARRADCOM, Dover, NJ, AV 880-3742 or Commercial (201) 328-3742.

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 576 6642 titled, "Inertia Welded Rotating Bands for Projectile Bodies", was completed by the US Army Armament Research and Development Command (ARRADCOM) in July 1978 at a cost of \$432,000.

BACKGROUND

Prior to this program only three methods existed for assembling copper, brass, gilding metal or sintered metal rotating bands to projectiles. These methods are: pressing the band radially into a seat, continuous heliarc or plasma arc overlay welding, and swaging with special press and die equipment. Problems exist with pressing and swaging rotating bands on thin-wall projectiles like the 155mm, M483A1 Projectile and overlay welding is a very slow manufacturing process. Radial inertia welding of a gilding metal ring to the cylindrical steel projectile body was proposed to the US Army by Chamberlain Manufacturing Corporation. This proposal was based on earlier inertia welding development work on the M483A1 Projectile conducted for Frankford Arsenal.

SUMMARY

The objective of this project was to develop inertia welding as a process for assembling 90 Cu/10 Zn gilding metal rotating bands to AISI 1340 steel bodies used with the 155mm, M483A1 Projectile. Generally, in inertia welding, one component is held stationary in the tailstock of the welding machine while the other component is clamped in a spindle chuck and spun. At a predetermined angular velocity, the driving torque is removed and simultaneously the components are thrust together with a predetermined force. Friction between the components decelerates the moving part, converting the stored kinetic energy into heat. Just before motion stops, the two parts join and the remaining energy is utilized in hot working the metal interface.

The main contribution of this project was the design of tooling which makes radial inertia welding parallel to the centerline possible. Chamberlain's inertia welding machine was adapted to accept a special head stock collet which incorporated a thrust bearing that is activated by pressing the base of the projectile body mounted in the tailstock against the front race of the thrust bearing. A schematic of the tooling setup is shown in Figure 1. Activation of the thrust bearing closes the collet jaws rapidly, causing the rotating band to compress onto the projectile body and be welded.

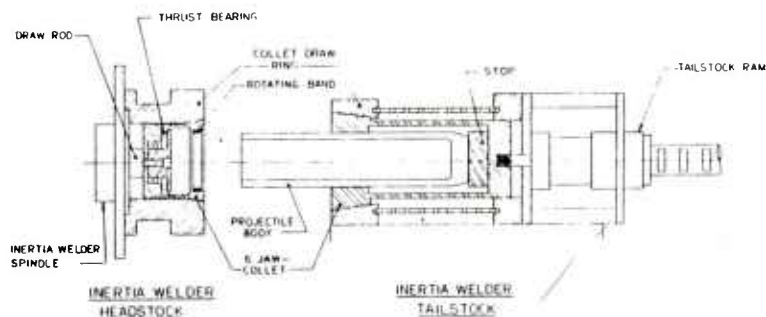


Figure 1 - Illustration of Setup for Inertia Welding Rotating Bands to Projectile Body with a Radial Headstock Collet

During this program, Chamberlain made a production run of 450 155mm, M483 and 20 8-inch, M509 Projectiles using the tooling and ultrasonic inspection procedures developed. The 70 rounds test fired at Yuma Proving Ground corroborated areas of poor bonding indicated by ultrasonic inspection and rotating band failure during test firing.

BENEFITS

The economic analysis compared current metal inert gas (MIG) overlay welding procedures with radial inertia welding. Net savings were estimated at \$.836 per projectile based on current production rates for the 155mm, M483 Projectile. The savings accrued primarily from the speed of the inertia welding process.

IMPLEMENTATION

Efforts to establish the acceptable range of welding parameters for banding projectiles was continued under Project 578 4153.

MORE INFORMATION

Additional information may be obtained from Mr. William Sharpe, ARRADCOM, AV 880-3742 or Commercial (201) 328-2522. Details of this program are contained in technical report no. C8041-PR-024, "Investigation of Inertia-Welding Process for Applying Gilding Metal Rotating Bands to Projectile, 155mm, M483A1", Chamberlain Manufacturing Corp., July 1978.

Summary report was prepared by Ron Russell, 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 680 3901 titled, "Manufacture of Fluidic Amplifiers by Cold Forming", was completed by the US Army Armament Material Readiness Command in August 1981 at a cost of \$59,000.

BACKGROUND

The fluidic amplifier manufacturing processes currently being used have not been completely successful in solving the problem of low-cost, large-quantity fluidic amplifier fabrication. The component parts are usually formed by photochemical etching of steel or aluminum laminates. The laminates are then mechanically clamped together to form a modular unit. When the laminate thickness exceeds the capability of the etching process, laminates are stacked to the desired height. This procedure is limited in dimensional accuracy, repeatability, laminate thickness, internal surface quality, and sealing that can be economically achieved.

SUMMARY

The objective of this project was to adapt the existing cold forming process of fineblanking for less costly, high quantity, higher precision production of fluidic amplifiers and other critical fluidic elements. Fineblanking can produce fluidic laminates with better dimensional repeatability and surface finish than by chemical milling and nickel electroforming. The fluidic elements chosen to be fineblanked in this project were a fluidic amplifier, a vent plate, and a dropping resistor. The active element fineblanked was a laminar proportional amplifier (LPA) design with a nozzle width of 0.5mm. All three elements were considered critical in terms of achieving repeatable performance in assembling a quantity of fluidic circuits using these components.

Drawings for the three laminates to be fineblanked were generated, reviewed, and accepted. A vendor fabricated the fineblanking tooling and produced a limited run of parts. All parts were fineblanked from 347 stainless steel.

Before the full run of LPA parts was made, an initial lot of about 100 laminates was fineblanked and null affect curves were run on a limited number of samples from this lot. The null offset curve--a measure of LPA output pressure vs. supply pressure in the absence of any control or input signal--is a sensitive indicator of small asymmetries in the LPA configuration. The initial null offsets were in the 3-5 percent range. The fineblanking die was then modified by carefully polishing one wall in the supply nozzle area and retesting subsequent parts in an iterative process until the null offset was reduced to about 1 percent. Larger quantities of LPA's were then produced.

Performance testing indicated that the LPA performance was consistent with the results obtained in Navy Manufacturing Technology Project DNA 475; i.e., the LPA gain was good and performance repeatability from laminate to laminate was also good. Performance was generally better (i.e. the LPA gain was higher) than that of the LPA's from MM&T Project 678 3901. This improvement is attributed to minor design changes from the HDL standard configuration that was incorporated into the LPA design used in 678 3901. These changes were aimed at enhancing tool life at some expected compromise in performance. No such changes had been made in DNA 475, and results suggested that they were, in fact, not necessary. Consequently, no variations from the standard LPA were made in this project.

Limited testing of vent plates and dropping resistors also showed acceptable performance and good laminate repeatability. More extensive testing was precluded by a shortage of funds.

BENEFITS

The results of this program together with those of Navy Manufacturing Technology Project DNA 475 and Army MM&T Project 678 3901 have demonstrated that fineblanking can be successfully used to manufacture high-quality fluidic laminates. The fineblanking process can lower the cost of fluidic amplifiers in quantity production. Shown in Table 1 are costs for fineblanked LPA's vs. those by the etching process. The LPA selected for comparison purposes has a power nozzle that is 0.5mm wide and 0.5mm deep. Fineblanked LPA's cost only about 60% of etched amplifiers for 10,000 parts; for 100,000 parts, the cost savings are even greater, since the major factor is the non-recurring cost of the fineblanking tooling.

<u>PROCESS</u>	<u>QUANTITY</u>	
	<u>10,000</u>	<u>100,000</u>
Chemical Etch	\$ 1.80*	\$ 1.73*
Fineblanking (hand picked)	1.14	0.24
Fineblanking (air blown)	1.03	0.13

* 4 laminates per amplifier

TABLE 1 - Comparative Unit Production Costs for Fluidic LPA's

IMPLEMENTATION

The standard fluidic LPA is being used in numerous development projects for the Army (and Navy). These development projects include gun stabilization for armored vehicles, angular rate gyros for missiles and RPV's, and dual-channel fuel controllers for gas turbine engines. Virtually any fluidic system that advances to production status would contain a quantity of these amplifiers. Technical reports summarizing the Army and Navy efforts have been prepared and distributed.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. J. W. Joyce, HDL, AV 290-3080. The following technical reports have been prepared and distributed:

a. L. S. Pecan, "Fineblanking, Diffusion Bonding, and Testing Fluidic Laminates", TriTec, Inc., Columbia, MD, Report No. HDL-CR-80-074-2, July 1980.

b. J. S. Roundy, "Manufacturing Techniques for Producing High Quality Fluidic Laminates", AiResearch Mfg Co. of AZ, PHoenix, AZ, Report No. N00019-78-C-0365, September 1980.

c. J. S. Roundy, L. E. Scheer, and J. Joyce, "Manufacturing Techniques for Producing High Quality Fluidic Laminates in Production Quantities", Fluidics Quarterly, Vol. 13, No. 2, 1981 (pp. 1-20).

Summary report was prepared by Robert 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 677 7644 titled, "Application of Integral Color Anodizing for Aluminum", was completed by the US Army Armament Research and Development Command in May 1981 at a cost of \$75,000.

BACKGROUND

The conventional impregnated color process to impart color to anodized components requires a supplemental treatment to impregnate the anodic coating pores with organic dyes or mineral pigments. Such color coatings applied to weapon components are susceptible to thermal and environmental decomposition under service. Improvement of the existing methods of conventional hardcoat processes can be obtained by the use of mixed acid electrolytes to develop more durable, colorfast coatings. The baths contain conventional sulfuric acid solutions with an organic acid additive that reacts as a modifier to reduce the rate of oxide dissolution of sulfuric acid. The end result is a faster film buildup and more rapid color development at near room temperature operating conditions. Therefore, anodizing to produce the engineering hardcoat system would be accomplished in less time than conventional sulfuric acid processes.

SUMMARY

The objective of this project was to improve the anodizing process by modifying the acid bath to produce the desired dark gray or black color on the oxide coating. This was to be a one-step process, without adversely affecting the physical properties for corrosion and abrasion resistance.

The approach was to first survey commercially available integral color anodizing (ICA) processes for application to aluminum alloy 7075-T6; then evaluate candidate coatings relative to coating thickness, color and thermal stability, abrasion and corrosion resistance, and discontinuity sites (potential corrosion sites). The most feasible treatment was then applied to actual weapon receivers.

A supply of target alloy 7075-T6 coupons, center punched to provide access to a Taber Abrader, were prepared. Coupons were sent to 12 firms that appeared to have the capability of applying their form of an ICA hardcoat. The treated coupons, representing commercially available ICA and conventional low temperature hardcoat processes, were characterized in-house, as to color and heat stability; abrasion and corrosion resistance; and coating thickness and porosity. The interested firms were requested to supply ICA treated 7075-T6 coupons that had a 0.050 ± 0.005 mm thick coating and were black in color. The submitted treated coupons were

examined for color and coating thickness. Those coupons that were unacceptable were eliminated from any further consideration in this study. Those acceptable treated coupons were then subjected to further evaluation.

Coupons were treated by various processes, i.e., Kalcolor, Duranodic, Duraelectric, and MAE. The Kalcolor processed coupons were unacceptable with respect to coating thickness, color and uniformity of color, and were dropped from further consideration. Candidate coatings were tested for corrosion, light fastness, abrasion resistance, porosity, and crazing or crack patterns. In salt spray tests, the Duranodic and Sanford-Duraelectric coatings showed the least corrosion attack when compared to coatings deposited by other processes. No changes in color were seen on test panels finished with all the various ICA processes in the light fastener test. In the Taber abrasion resistance tests, the Duranodic coating revealed less porosity, as received, and after heating at 163°C for 48 hours.

Coupons were evaluated at 163°C to simulate the thermal effects upon a weapon that has been subjected to a prolonged period of rapid firing. The Reynolds MAE finish demonstrated defined crack patterns after 4 1/2 hours of exposure. The Duranodic and Sanford finishes revealed no cracking at 56 1/2 hours. When viewed at 30X magnification, after 76 1/2 hours, the Duranodic coating showed no evidence of cracking.

Thirty upper receivers with the Duranodic finish and thirty with the standard hardcoat finish were mounted on M16A1 rifles and field tested. The results indicated that the test hardcoat process provided a greater degree of protection than the standard hardcoat.

BENEFITS

The finishing costs on the M16A1 upper receiver show a savings of \$.70 per item when the ICA process is used in lieu of the standard hardcoat process. The ICA process is conducted at room temperature; therefore, the need for refrigeration as used in the standard hardcoat application is eliminated. It will result in a 25% reduction in processing costs, and a 10-15% reduction in maintenance and supply requirements of aluminum components. Results of the laboratory and field tests showed the ICA coating has superior physical properties when compared to the standard dyed coating.

IMPLEMENTATION

A VEP has been submitted for the M16A1 rifle utilizing the ICA process on all aluminum components for that weapon, including upper and lower receiver, flip ring, charging handle, magazine release button and trigger guard. A PIP has been initiated for the M16A2 retrofit program. All aluminum parts will be coated by the ICA process.

MORE INFORMATION

Additional information may be obtained from Mr. A. P. Gigliotti, ARRADCOM, AV 880-5752 or Commercial (201) 328-5752.

Summary report was prepared by Robert 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 677 7715' titled, "Application of Controlled-Force Machining", was completed by the US Army Armament Materiel Readiness Command in May 1979 at a cost of \$64,000.

BACKGROUND

Establishment of cutting speeds and feeds for machining metal are currently based on empirical data. Machine tools are set-up for average metallurgical conditions. When the cutter is going through "soft" material the removal rate could be safely increased, however, when "hard" areas are encountered cutter breakage occurs. To overcome these problems, the uncontrolled practice of manually overriding the set machining rates is common. Ramifications are more acute when machining weapon components due to the high-strength alloys used.

SUMMARY

The objective of this project was to optimize metal removal rates by sensing and controlling cutting forces on numerical controlled machine tools (see figure 1). Various weapon components were studied, machine tool capabilities and workloads were analyzed, and various power and force sensing/control systems were compared.

An adaptive control system was selected and retrofitted to an existing milling machine at Rock Island Arsenal. NC programmers and electrical and electronic maintenance personnel were trained. The system was debugged, tested and applied in milling a 155mm Howitzer guide.

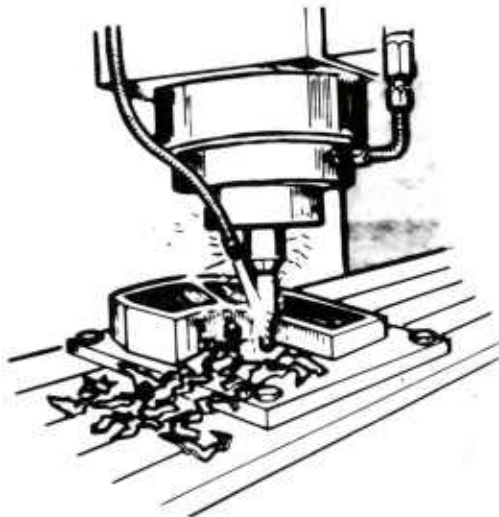


Figure 1 - The Cutter is Controlled by Monitoring Cutting Forces

BENEFITS

Adaptive control will eliminate the empirical setting of machining rates and the uncontrolled practice of manually overriding these rates. Feed rates have been related to work material and cutter geometry by computerized engineering formulae for direct application by NC programmers. Machining rates in milling have been adaptively increased without sacrifice, and often enhancement, of tool life and accuracy. Costs have been reduced accordingly. In milling a 155mm Howitzer guide, the average milling rate was increased 50% reducing the cutting time from 66 to 44 minutes for a savings of \$14.47 per workpiece. Savings for similar applications on 23 milling machines at RIA are conservatively estimated to be \$46,000 annually.

IMPLEMENTATION

Milling operations will continue to be upgraded according to the pre-processor program analyses provided by this project, and according to the feedback gained with the retrofitted control. Types of cutters, tool materials and geometries, coolants, workpiece conditions and contours will be monitored with the adaptive control; and, the improved machining parameters found possible will be applied in key RIA milling operations. New adaptive controls will be recommended in procurement, remanufacture and retrofitting of machine tools. Further work will be done specifically in use of adaptive control for close-tolerance sizing of recoil mechanism hydraulic slots, grooves and cams.

MORE INFORMATION

Contact Mr. Ray Kirschbaum, Rock Island Arsenal, AV 793-5363 or Commercial (309) 794-5363.

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

Manufacturing Methods and Technology Project 679 7965 titled, "MMT - Differential Scatterometry for Microfinish Surfaces", was completed by the US Army Armament Research and Development Command in December 1980 at a cost of \$100,000.

BACKGROUND

The in-process inspection of the surface finish for optical components is done visually by experienced and skilled workers. Prior to this effort, RDT&E Project 1T161102B11A03 and MMT Project 676 7629 developed a prototype floor model for determining lens surface roughness. The differential scatterometry techniques for the prototype were established under controlled conditions. This effort was undertaken to design and fabricate a portable surface evaluator for use on the production shop floor.

SUMMARY

The hostile operating conditions, namely vibrations encountered in the shop environment, were not overcome in the preliminary design phase. The concept developed is illustrated in Figure 1.

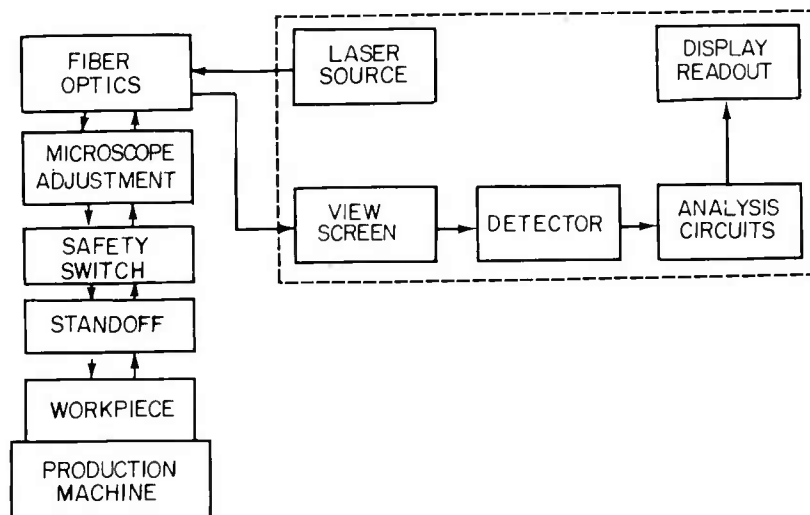


Figure 1 - Proposed Portable Surface Evaluator

IMPLEMENTATION

The project was technically unsuccessful. No additional effort is planned at this time.

MORE INFORMATION

Additional information can be obtained from the project officer. A technical report was not prepared. The project officer for this project is Mr. Stanley Kopacz, US Army Armament Research and Development Command, AUTOVON 880-2873 or Commercial (201) 328-2873.

Summary report was prepared by Stephen A. 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 680 8059 titled, "Salvage of Cannon Components by Electrodeposition", was completed by Watervliet Arsenal in December 1981 at a cost of \$152,000.

BACKGROUND

Cannon components have been rejected and scrapped due to excessive stock removal or mismachining. Many of these items could be restored to an acceptable condition if a metal deposition system could be designed to salvage the components. A portable process was needed to deposit metal on specific areas to compensate for excess stock removal.

Brush or selective plating was proven feasible through the salvage of a 175mm gas check test. This work was done prior to the initiation of this project and prompted the Operations Directorate to install their own Selective Plating System. Several large caliber tubes have been repaired through nickel plating.

SUMMARY

The objective of this project was to develop a process for depositing metal to reclaim components and gun tubes previously rejected or scrapped. The scope of application was controlled by those weapons and cannon components that have been rejected due to machining errors. Cannon tubes such as the 8" M201, 105MM M68, 155MM M185 and M199, 152MM E81, and the 106MM RR have had defects on the tubes critical exterior surface interface dimensions such as tube bearing surface and pilot diameter for muzzle brake and breech mechanism threads. Machining errors have also occurred in cannon bores. The breech face and the mating breech mechanism of the 105MM are of an unusual configuration which have also caused problems in machining.

The investigation included the use of electrodeposition of metals such as nickel, iron or chromium to reclaim previously rejected tubes and components. A prototype portable plating unit, Figure 1, was designed, built, and tested. This unit is capable of automatically controlling all of the plating parameters during the salvaging of ordnance components. With this design, the component, to be salvaged, is used as the container and the plating solution is pumped up through the area to be plated rather than immersing it in a tank. This method permits the control of solution flow, controls uniformity of deposit thickness and the temperature gradient of the electrolyte.

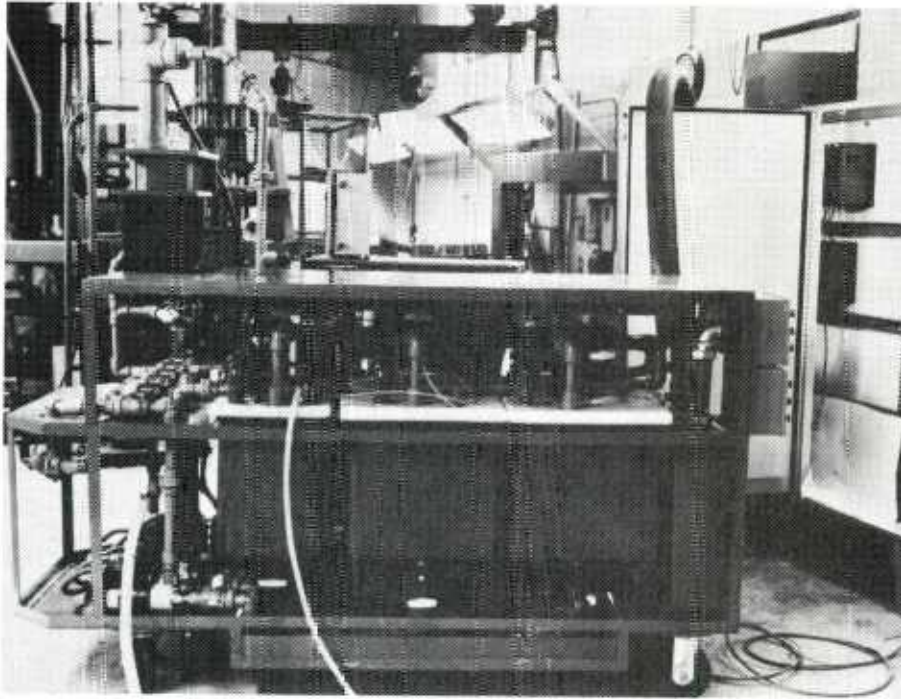


Figure 1 -

A Prototype
Portable Plating
Unit

The more difficult phase of the salvage effort, the repair of internal diameters with difficult and varying geometries, has been the major thrust of this study. Carrier housings for the 8" and 155mm weapons were mismachined internally and provided a candidate for application of the "pump thru" plating technique. This technique has been used with full length bore plating with excellent results.

BENEFITS

The use of the brush plates and the "pump thru" techniques have been established as valid procedures. The prototype plating unit permits the deposition of two improved plating materials. These are low contraction chromium which is accomplished through increased current density and corresponding increase in electrolyte flow rate and sulfamate nickel which is applied with greater assurance of acceptability. Both plating materials have been proven as satisfactory metal deposits for repair and salvage. The major advantage of the prototype system is that it can be moved to the work site rather than having to move large bulky components to the plating system.

Cost saving benefits are substantial. For example, the costs for new 155mm and 8 inch carrier housings are \$2,564 and \$1,238, respectively. The repair cost is approximately \$440 each for both the 155mm and 8 inch housing for a savings of \$2,124 and \$798, respectively. The high cost of the 155mm housing is attributed to greater amounts of machining required.

IMPLEMENTATION

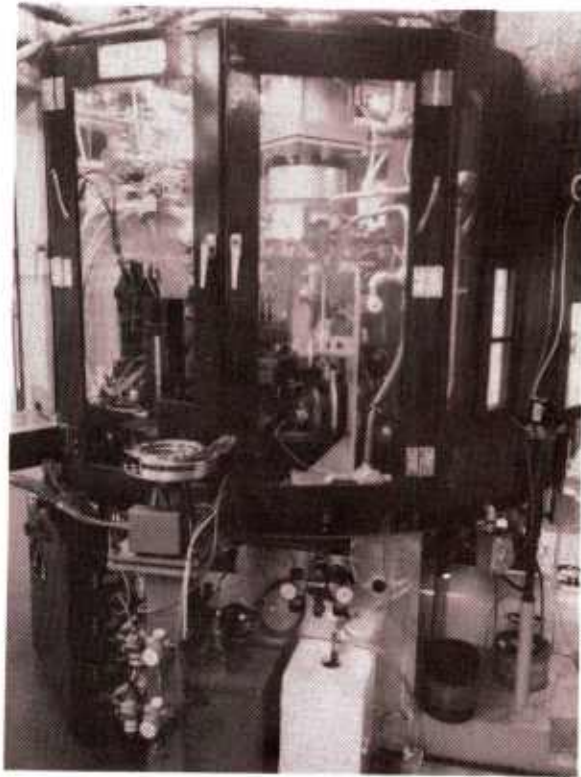
The portable salvaging facility will continue to be used by the laboratory personnel to reclaim 105mm and 155mm components. Operations personnel will be trained in the use of this unit and will be encouraged to expand its use. The unit will be utilized by operations personnel to reclaim various weapon components in approximately one year.

MORE INFORMATION

Additional information may be obtained from Mr. T. Pochily, Watervliet Arsenal, AUTOVON 974-5717 or Commercial (518) 266-5717.

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

MUNITIONS



IOWA AAP DETONATOR LOADER

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

Manufacturing Methods and Technology projects R7T 3076 and R77 3076 titled, "Mass Production Techniques for Composite Rocket Motor Components" were completed in April 1978 at a total cost of \$200,000.

BACKGROUND

Research efforts to lower the weight and reduce costs of small diameter (4-6 inches) solid fuel rocket motors have been conducted by the Army as part of an overall plan to improve future land combat rocket systems. In this effort composite motors composed of fiberglass/epoxy, graphite/epoxy and Kevlar 49/epoxy were fabricated in small batch quantities and tested. The motors exceeded all requirements; however, implementation requires the establishment of an automated manufacturing process capable of producing motors at a cost competitive with conventional metallic rocket motors.

The goal of this project was to establish a production scale process for composite rocket motors capable of producing over 10,000 units per month at a cost 20% lower than the cost of current, monolithic metallic motors. The project was accomplished by contractual effort at Hercules, Inc., Allegany Ballistics Laboratory, Cumberland, Maryland 21502.

SUMMARY

This project completes the effort initiated with project R75 3076 (Phase 1) and continued with project R76 3076 (Phase 2). The objective of this project is to refine the process established in Phase 2 and to explore and establish test methods to predict strength levels of units after hydrotest. Refinement of this process included: reduction of winding time by 30%; improvement of resin delivery rate and quantity applied; improvement of cleanability; establishment of a method for recycling excess resin; improvement of adapter holding during winding; and testing of the units. All of these were achieved and implemented in the following manufacturing process in which 300 units were fabricated.

The metallic mandrels were prepared by cleaning, applying a liquid mold release and attaching the motor head closure adapter. They were then installed two at a time (two motors per mandrel) on a modified EN-TEC winding machine. Four spools of 12 end S2 glass rovings were fed through the resin impregnation system and delivery head and tied on the mandrel by the operator. The automated winding pattern is shown in Figure 1. The fill was controlled from a constant horizontal feed with a revolution counter. After the 90° fill was completed the machine was changed from a level wind to a helix mode which took

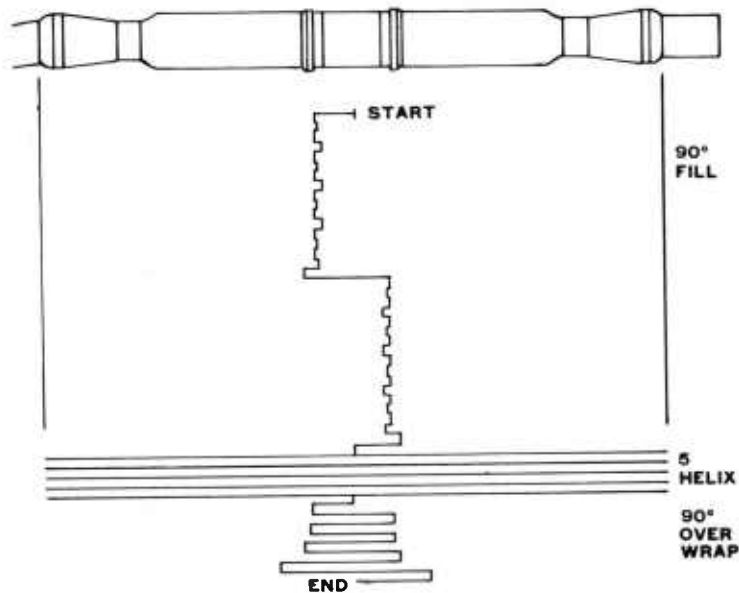


Figure 1 - Winding Pattern

2035 revolutions at 350 rpm (5.8 minutes). After the over wrap was completed, the wrapped mandrels were placed on a rotating fixture and cured. The parting cuts to remove the units from the mandrels were also the final cuts. After mandrel removal, the motor units were hydrotested to 7,000 psi and examined for dimensional and structural reproducibility.

Examination before hydrotest showed that all units met inside diameter tolerances and four units failed T I R. After hydrotest, two distinct populations were identified which related to differences in winding pattern. Head stock units displayed an 87% out of ID tolerance and 71% out of T I R. Tail stock units displayed a 71% out of ID tolerance and 34% out of T I R. This difference was caused by the fact that the delivery heads are mounted on a vertically cantilevered member with the result that the lower head is farther away from the mounting. At the higher winding speeds used in this phase, the slight differences noted in the Phase 2 project were accentuated. In addition to dimensional superiority, the results of the burst test also showed that the tail stock units were stronger than the head stock units, although all exceeded the 11,400 psi minimum burst pressure. A significant difference in weight of the two populations was also noted.

The evaluation of the units showed that the winding pattern is very critical in determining dimensional stability, strength, and weight. These differences can be eliminated with a machine specifically designed for this type of component. Such a machine would feature adequate controls and dynamic response.

An attempt was made to develop a mechanical and material evaluation test for the purpose of predicting strength levels of units after hydrotest. Two approaches, ultrasonic and acoustic impact testing, were explored. The results of this test program were inconclusive.

Production manhour requirements and costs are presented in Figures 2 and 3. Figure 2 presents the number of manhours required for producing 500 units, and Figure 3 presents the cost breakdown in 1978 dollars. These values are competitive with the values for current monolithic metallic motors.

<u>OPERATION</u>	<u>MANHOUR REQUIREMENT</u>		
Winding	8	Labor	\$ 2.77
Storage	2	Supervision	0.72
Machining & Mandrel Removal	4	Production	0.40
Mandrel Cleaning	3.5	Roving	1.92
Mandrel Assembly	4	Resin	0.21
Mold Release	4	Adapter	2.07
Liner Application	4	Closure	2.67
Hydrotest and QC	10	Snap Ring	0.64
Materials Handling	8	Liner	0.04
Fill-In Man	8	Packing Crates	0.13
		Tool Bits	0.08
		Shipping	0.07
		Special Tooling	0.48
	55.5 Manhours		\$12.20

Figure 2 - Manhours Per 500 Motors

Figure 3 - Cost Per Unit

BENEFITS

This project successfully completed the three phase effort to establish an economical production process for manufacturing small, high performance rocket motors. The process can be applied to motor case sizes up to 6 inches in diameter and 7 feet in length.

IMPLEMENTATION

The results of this effort have been incorporated in the manufacturing process for the Viper rocket motor case. Direct implementation was not possible, however, due to a design change in the adapter region of the case which required additional, extensive work to establish a manufacturing process.

MORE INFORMATION

Additional information on this project is available from Mr. William Crownover, MICOM, AV 746-5821.

Summary Report was prepared by Ferrel 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 Project 378 3396 titled, "Injection Molding of Low Cost-One Piece Nozzles," was completed by the US Army Missile Command in June 1980 at a cost of \$180,000.

BACKGROUND

The General Support Rocket System (GSRS) provides the Army with an alternative to the howitzer's role in the area saturation mission. The GSRS launcher is lightweight, compact, readily transportable, and low in cost when compared to the towed artillery piece; however, the rocket itself costs more than the conventional artillery round.

Solid propellant motor nozzles are currently being fabricated by joining dissimilar materials and components by various techniques. The multi-component construction involves substantial production time and cost. Production costs continue to be dictated by performance driven designs and by the conventional manufacturing methods employed by aerospace vendors.

Previous R&D efforts have demonstrated the feasibility of injection molding advanced thermosetting or thermoplastic materials into temperature and erosion resistant one-piece nozzles. This MMT project, the first year of a two-year program to establish the production process, was conducted at MICOM and under contract with the Boeing Aerospace Company, Seattle, WA.

SUMMARY

The overall objectives of the two-year program were to establish processing techniques and tool design parameters, to optimize materials characteristics and to fabricate parts for test firing.

As a first step, the materials selection phase included a survey of material suppliers for candidate plastics having good potentials for withstanding a rocket motor environment. This preliminary survey focused on materials that had compositions similar to those that had survived earlier motor firings. More than thirty different materials were provided by suppliers in the form of test specimens. The specimens were subjected to simulated motor environment tests (oxy-acetylene flame) and mechanical properties tests. All materials were rated, taking vendors' prices into consideration. See Figure 1.

Ten materials judged best were selected for further study. Each of these ten possessed impact strengths greater than Durez 124, a material that had been successfully molded into a nozzle but lacked strength when subjected

MATERIAL I.D.	THERMAL CONDUCTIVITY	CHAR DEPTH	MATERIAL COST \$/10 20,000 TL	I Z O D	REMARKS
321	172 ⁰	0.08"	.69	.55	
DUREZ 29237	172 ⁰	0.08"	.66	.55	
308	174 ⁰	0.08"	.51	.30	
602	177 ⁰	0.10"	.58	.50	
DUREZ 123 *	175 ⁰	0.10"	.64	.37	TEST STANDARD LOOSE CHAR
FM - 1132P	175 ⁰	0.08"	1.10	1.1	
DUREZ 22257	180 ⁰	0.08"	.64	.43	
RC 125450	180 ⁰	0.065"	.65	.65	
RCI 25406	185 ⁰	0.08"	.64	.50	
RX 448	185 ⁰	0.06"	.97	.7	
DUREZ 152	185 ⁰	0.10"	.57	.30	LOOSE CHAR
RX 950	190 ⁰	0.09"	.87	.5	
PLASCON 52-40-40 (DAP)	190 ⁰		1.99	3.9	EXCESSIVE SMOKE
29186	190 ⁰			.35	
RCI 25000	195 ⁰	0.06"	.54	.27	
RCI 25346	195 ⁰	0.10"	.54	.33	LOOSE CHAR
DUREZ 156	212 ⁰	0.09"	.57	.34	LOOSE CHAR
GE 12983	215 ⁰	0.08"	.45	.32	LOOSE CHAR
DUREZ 30645	215 ⁰	0.085"	.97	.65	
1533	218 ⁰	0.10"	.89		
DUREZ 30614	225 ⁰	0.115"	.665	.34	LOOSE CHAR
PLASCON 8000	228 ⁰	0.055"	1.45	.68	
DUREZ 23570	232 ⁰	0.07"	1.30	.30	
RX 625	232 ⁰	0.10"	1.01	.50	
FM - 4005 *	235 ⁰	0.04"	1.50	.50	
FM 4017	235 ⁰	0.04"	--	.60	
PLASCON 8010	240 ⁰	0.07"	1.65	.60	
DUREZ 29053	242 ⁰	0.06"	.92	.35	
AX 862 *	255 ⁰	0.08"	1.03	1.2	
GF 7021	255 ⁰	0.06"	--	.45	
RX 462	255 ⁰	0.05"	.99	1.4	
PLASCON 1961A	255 ⁰	0.06"	1.67	.55	
FM 21288	265 ⁰	0.06"	1.41	9.0	
PLASCON 1906	270 ⁰	0.06"	1.65	.40	

* KNOWN ROCKET MOTOR MATERIALS

Figure 1 - Candidate Nozzle Materials

to a drop test. Also, the flame test performance of these materials compared favorably with asbestos filled phenolic (RX 462) and the Roland rocket motor insulator material (FM-4005). Additional test specimens were prepared by the contractor using injection and compression molds. This work established the critical design parameters for the injection molds as well as the processing procedures for each material. All processing records were compared. The injection and compression molded specimens were subjected to another round of flame and mechanical tests and compared to each other. Two materials, Reichold 25450 cellulose/mineral filled phenolic and Durez 29237 wood filled phenolic, were chosen for the next phase, nozzle molding.

Tooling for injection molding the nozzle was designed and fabricated. The design was based partly on the techniques and experiences gained during the supplier survey and material selection phases. The nozzles were molded in a 500-ton injection molding machine having a 60-ounce capacity. The nozzle configuration is illustrated by Figure 2. The nozzle weight was nearly twice the machine capacity; thus, manual multi-shop operation was necessary. Twenty nozzles were forwarded to MICOM for laboratory analysis and exposure to simulated rocket motor environments.

BENEFITS

As a result of the nozzle molding phase, various tooling and equipment improvements have evolved. The contractor recommended several measures that would improve part reliability and fabrication rate for a production program.

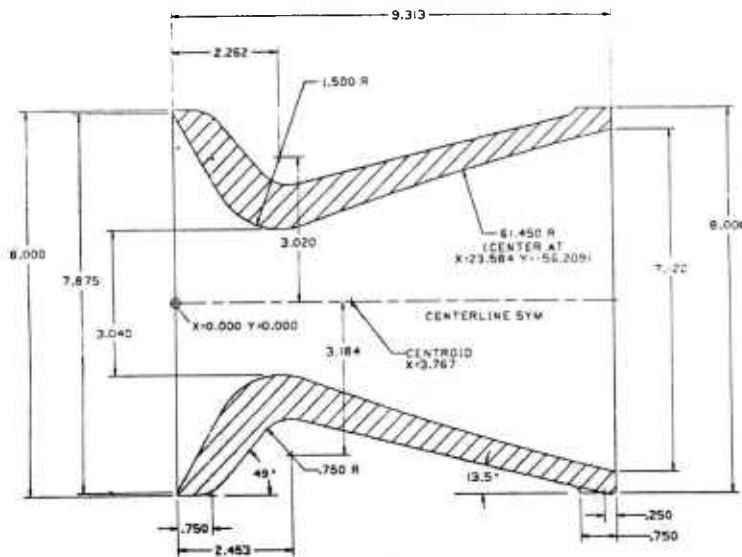


Figure 2 - 8" Nozzle

IMPLEMENTATION

Implementation of this project awaits the results of the follow-on MMT Project 380 3396.

MORE INFORMATION

Additional information on this project is available from Mr. William Crownover, MICOM, AUTOVON 746-5821 or Commercial (205) 876-5821. The interim technical report from the contractor is TR-RK-CR-80-13, "Injection Molding of Low-Cost, One-Piece Nozzles".

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

PROJECT SUMMARY REPORT

Manufacturing Methods and Technology Project 576 1274 titled "White Phosphorous Dry Filling Line", was completed by the US Army Armament Research and Development Command in December 1978 at a cost of \$1,200,000.

BACKGROUND

This project was the second phase of an effort to install a prototype white phosphorus (WP) dry filling line at Pine Bluff Arsenal (PBA). The current wet filling process poses a hazard to operating personnel and is the cause of a significant amount of water and air pollution. The installation of a dry fill process would eliminate the disadvantages of the wet fill process and improve productivity by including several automated stations. In the first phase, project 575 1274 provided an operable line with an automated dry filling station using the volumetric filling concept supported by manual operations for most other required stations. This line was designed to load 105MM M60 Projectiles with white phosphorus (WP).

SUMMARY

The purpose of this project was to prove out the volumetric filling concept, upgrade the filling from 5,000 to 8,000 rounds per shift, automate other stations, and provide a line for four WP (105MM, 81MM, 60MM, and 2.75") munitions.

This work was performed in-house at PBA. The existing line at PBA developed under MMT Project 575 1274 was modified, improved and automated to increase productivity. The relative location of equipment and stations is shown in Figure 1. The work performed in this project was confined to stations shown within the shaded area. The conveyor systems, WP tanks, inert gas generator, and WP supply systems were utilized as they existed except for minor modifications to make them operational. The following stations were designed and fabricated with computer control.

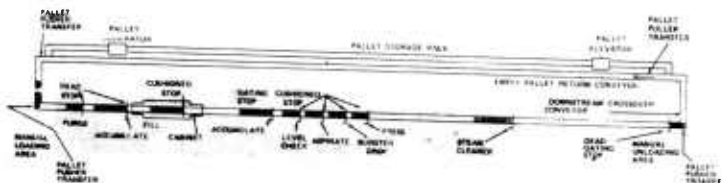


Figure 1 - WP Dry Filling Line Layout

Vacuum-Purge Station

The munitions were evacuated and then pressurized (15 psig) with an inert gas (CO_2 , N_2). A nozzle was used to evacuate and pressurize the munition and was retracted before the munitions left the station.

WP Filling Station

Eight munitions were hydraulically lifted and filling nozzles were lowered into each munition cavity. The volumetric dispenser automatically released a premeasured volume of WP into the munition. The filling valve closed and the volumetric dispenser was recharged. The lift mechanism lowered the filled munitions, and the eight munitions were moved to the next station.

Height-of-Fill Preaccumulator and Gating Station

This station consisted of a cushioned gating stop system which prevented WP from spilling out of the filled munitions and released trains of four munitions and pallets out of the station to the height-of-fill operation. This station has a capacity of 12 munitions and pallets and dispensed four munition units to the height-of-fill station upon demand by that station.

Height-of-Fill Check

Munitions were checked at this station for acceptable height-of-fill. After four munitions were in place, height-of-fill check nozzles were pushed down into the filled munitions until a nozzle flange contacted the top of the shell which stopped further movement of the nozzle. After the height-of-fill nozzle retracted, the munitions were released and the data for the filled condition of the munition were temporarily stored in the line computer. This information was transferred to the aspiration station for correction of high fills and to the burster drop station for removal of underfilled munitions.

Munition Aspiration Station

A train of four munitions released from the height-of-fill station entered the aspirator station and was stopped (provided one or more of the filled munitions are overfilled or if the burster drop station is occupied). If munitions were overfilled, the computer directed the aspiration station to stop the train and aspirate the excess WP from the munition(s). If no correction was indicated and the burster drop station was not occupied, the munitions passed through the aspirator station.

Burster Casing Press Station

The press station stopped all trains of four munitions and raised the munitions 1/4-inch off the slat conveyor, and the press rams pushed down inside the nose of the shell and pressed (metal interference displacement) the burster casing into the munition burster housing. After a 2-second dwell time, the munitions were released to the steam-dry air cleaner.

Steam-Dry Air Munitions Cleaning Station

The munitions-pallets were stopped in the station and raised 4 inches above the slat-type conveyor into munition alignment devices. The cleaning nozzle penetrated into the threaded portion of the munition. Steam valves then opened for a timed interval, blowing live steam through the nozzle into the threaded mouth end of the munition. The steam valve closed and a dry-air valve opened for a timed interval forcing air into the nose of the munition. After the air valve closed, the lift mechanism dropped the munitions-pallets to the slat conveyor, the station stop opened, and the munitions traveled out of the station to the munition removal station.

The line was successfully operated for the 105MM M60 and the 2.75 inch M156. Tests were not conducted with the 60MM and 81MM munitions because components were not available. Although the line was successfully operated, there were a number of problems, especially with the WP supply system and the conveyor system. Modifications were made later to correct these deficiencies and the line was then determined to be acceptable for production operations. The completed WP dry fill line provided a safer, more accurate system and reduced air and water pollution by more than 97% over the original wet fill system.

BENEFITS

A prototype production facility was designed, built and successfully operated to load WP munitions using this dry fill concept, resulting in a cost savings of \$15,000 per shift. In addition, the new line was safer and reduced air and water pollution by 97% over the original wet fill system.

IMPLEMENTATION

The automatic multi-munition WP dry fill line has been fabricated and installed at Pine Bluff Arsenal. It has the capability of 8,000 WP rounds per shift.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. M. Erickson, AV 584-2390 or Commercial (301) 671-2390.

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 580 1339 titled, "Manufacturing Technology for Chemical Agent Detector Production Waste Disposal", was completed by the US Army Armament Research and Development Command in December 1981 at a cost of \$240,000.

BACKGROUND

Detector papers utilize dyes that react with chemical agents giving a color change on a leaflet containing the dye to indicate the presence of lethal chemical agents. Toxicological tests performed on the three dyes used in the M-8 Chemical Agent Detector (CAD) paper and B-1 dye used in the XM-9 Liquid Agent Detector (LAD) indicated that these dyes have mutagenic potential. TRADOC has a continuing requirement for detector paper kits even if the dyes were classified as mutagenic and/or carcinogenic. The dyes and paper are currently produced by commercial manufacturers; however, effluent waste disposal methods for both dye or detector paper containing the dyes were not available, thus the requirement for this project.

SUMMARY

The purpose of this project was to establish a method for the disposal of all hazardous materials resulting from the production of detector kits including dye paper, waste, and end items. The technology established provided a data base for disposal of waste during manufacture of current and future dye and detector papers.

The incineration process for complete destruction of the dye wastes was determined as the most feasible method based on earlier bench scale tests. The residence time and temperature were determined as the critical operating parameters. Two methods of incineration were investigated; the fluid bed and the chain grate. Pine Bluff Arsenal (PBA) was selected as the site for the pilot incineration studies. Four materials were selected for evaluation: B-1 dye slurry; XM-9 LAD paper; M-8 CAD dye mixture; and M-8 CAD paper booklets.

The pilot fluid bed was used for B-1 dye slurry and M-8 CAD paper dye slurry evaluations. A scrubber water treatment system was used in conjunction with the fluid bed. For the B-1 dye slurry evaluations, the maximum pumpable concentration was determined to be 20% (WT/WT) B-1 dye/water. Tests were conducted at 1500, 1600, 1700 and 1800°F for the dye slurry. Results indicated that complete destruction was obtained at a temperature of 1800°F with a retention time of three seconds.

For the M-8 CAD paper dyes (red, yellow and green), the optimum slurry concentration was determined to be 1.9% red, 1.85% yellow, and 2.0% green. The three test temperatures were 1200, 1400 and 1600°F. Chemical and biological tests indicated no toxicity at 1400°F and 1600°F. Therefore, the recommended fluid bed incineration temperature for the M-8 CAD dye was 1400°F with a retention time of three seconds.

The chain grate incinerator was selected for destruction of the XM-9 LAD and M-8 LAD papers. A schematic diagram of the chain grate incinerator located at PBA is shown in Figure 1. The materials to be destroyed passed through the furnace at temperatures up to 1500°F on a conveyor chain belt with resulting gases removed to an afterburner for further destruction.

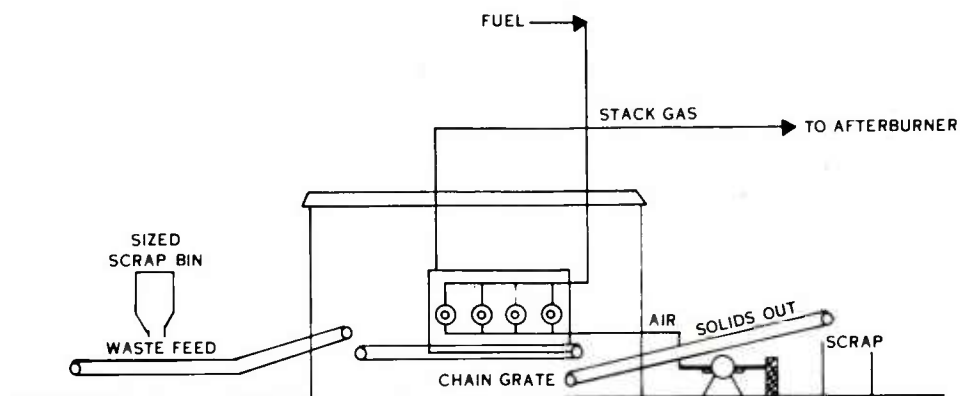


Figure 1 - Schematic Diagram of the Chain Grate Incinerator

A shredder was used to reduce large XM-9 LAD paper rolls prior to incineration in the chain grate. The recommended incineration temperature for shredded XM-9 LAD paper was 1500°F in a chain grate incinerator with the incinerator gases passing through an afterburner at 1800°F. The retention time for the chain grate was one hour for capacities up to 1260 lbs. The retention time for the gases in the afterburner was five seconds at 1800°F. The gases were scrubbed using a caustic Venturi scrubber and released to the atmosphere. All stack gas analyses met State and Federal air quality standards.

The M-8 CAD booklets are individually sealed in plastic when issued. Preliminary tests indicated no difference between sealed and unsealed booklets for retention time, air quality or amount of ash remaining. Therefore, all M-8 CAD incineration tests were conducted using sealed M-8 CAD booklets. Tests were conducted using 100 booklets (4 lbs) at 1475°F and 300 booklets (12 lbs) at 1500°F in the chain grate incinerator with the incinerator gases passing through an afterburner which was maintained at 1500°F and had a retention time of seven seconds. The chain grate incinerator residence time was ten minutes for 100 booklets and 18 minutes for 300 booklets. The stack gas values after passing through a caustic Venturi scrubber, met both State and Federal air quality standards. The scrubber water met all water quality standards after treatment by the PBA Central Waste Treatment

Facility (carbon, alum, lime and polyflox process). Biological test results indicated an aquatic toxicity before treatment and no aquatic toxicity after treatment by PBA's Central Waste Treatment Facility. The data indicated that all non-serviceable M-8 CAD booklets and/or paper waste from production of the M-8 paper can be destroyed in an environmentally safe manner using a chain grate incinerator at 1500°F which is equipped with an afterburner operating at 1500°F and seven seconds retention time, and a scrubber water treatment.

BENEFITS

A safe environmental procedure utilizing incineration was developed for the disposal of dye, waste, and end items resulting from the production of M8 and M9 CAD papers.

IMPLEMENTATION

A process description of the incineration procedures has been incorporated into the technical data package for the M8 and M9 CAD papers.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. D. Lee, AV 584-3912 or Commercial (301) 671-3912.

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 578 1345 titled, "Manufacturing Technology for Bio-Detection and Warning System (BDWS)", was completed by the US Army Armament Research and Development Command in December 1981 at a cost of \$480,000.

BACKGROUND

The Chemical Systems Laboratory (CSL) at Edgewood, MD, has been developing a detector for biological agents called the Automatic Biological Agent Alarm. The alarm is composed of two major subsystems, the chemiluminescent XM19 and the XM2 sampler. The XM19/XM2 refill kit contains several critical components for which manufacturing specifications, tolerances, and methods are not currently available. An essential component of the alarm system is an impaction tape for collection of the aerosols. The tape is composed of a natural rubber adhesive on a polyester film substrate. To date, Southern Research Institute (SRI) was the major source of tapes produced on a laboratory scale. Therefore, efforts were necessary to confirm that this component is producible by standard production techniques and establish a manufacturing process for the component.

SUMMARY

The main objective of this project was to establish a pilot facility, investigate process parameters, establish quality control procedures, and develop a Description of Manufacture (DOM) for the tape for the XM19 refill kit.

Initially, SRI conducted studies to identify certain measurable physical properties of the tapes, to correlate those measurable properties with actual XM19 performance, and to identify process parameters which affected those physical properties. This data was to provide input into the design of the pilot-scale coating unit at CSL. As correlations to XM19 performance could not be made due to the unavailability of an operational XM19 breadboard unit, the data generated was used primarily as a guide to enable CSL personnel to duplicate on the larger pilot-scale coating unit tapes originally prepared by the SRI on a laboratory scale.

The basic operations in the preparation of the impaction tapes involve (1) application of a coating of a solution of natural rubber to a polyester film, (2) evaporation of the solvent from the coating, (3) irradiation of the coating with ultraviolet light to bond the rubber to the film, (4) slitting of the tapes to the desired width, and (5) winding of the tapes onto selected spindles. Each of these operations was evaluated to identify important processing parameters.

The following parameters were investigated to define the optimum process parameters: (a) coating solution composition and mixing methods, (b) physical characteristics of the tape (tack, peel, coating thickness), (c) effects of ultraviolet (UV) and corona discharge, and (d) winding and package alignment.

For preparation of coating solutions, it was found that a 4.8% by weight solution of natural rubber in Rule 66 mineral spirits with a viscosity range of 250-350 cps, was the most desirable. This was prepared by milling the rubber under slow roll milling conditions (24.8rpm) for 15 minutes with a nip setting of 3 (55 mils) with an initial roll temperature of 139°C. The solution viscosity could be used as a quality control method for coating solutions.

Several tack test methods were investigated to obtain a suitable method to quantify the relative adhesive value of the coating. The peel-from-mylar method was the most sensitive and reliable of the methods evaluated. Using this method, the adhesive tack of a natural rubber coating (5 to 10 micrometers) on polyester film (0.001 to 0.002 inch thick) was measured. In addition, the effects of addition of tackifier was evaluated. The apparatus used was a tensile-testing machine capable of applying a constant crosshead movement while recording the tensile load. The specimens were gripped as shown in Figure 1. The results indicated that with a constant coating thickness, the tack increases and begins to maximize at approximately a 4:1 rubber-to-tackifier ratio. The data suggested that controlling coating thickness was important when determining tack and equally important was a process-control parameter.



Figure 1 - Position of Specimen During Tack Test

The effects of UV exposure on peel strength was evaluated at different wavelengths, dosage, and exposure time. The data obtained show that optimum peel strength was attained at 250-nm wavelength, 2000 uw/cm² dosage, and 4 seconds exposure. The use of corona discharge was less effective in promoting adhesion of the rubber to the polyester film than the UV exposure.

A method was developed for quality control testing of the alignment of a package of tape. The method used an aluminum gage block that was machined to the outer dimensions of the spool along the edge of the spool onto which the tape was wound. The gage was oversized along the inner spool dimensions to allow easy passage of that portion of the spool through the gage block. The coated film would be passed through the gage block only if the film was properly aligned on the package. Any misalignment of the film prevented passage of the package through the gage block, and the roll would be rejected.

The results of the project show that certain physical properties of the tape coating can be measured. These properties could be effectively varied or controlled in the coating process by the manipulation of various processing parameters. The coating process was scaled up by CSL on the pilot-scale coating unit by monitoring the physical properties of the tapes and correlating these properties to various process parameters. The tapes prepared on the pilot unit had physical properties very similar to those obtained on tapes prepared on the laboratory coater at SRI. Tentative specifications for the physical properties of the tape were established. These specifications were (1) coating thickness 4 to 12 um, (2) tack 1 to 4 gm/cm, and (3) peel strength 4-12 gm/mm.

BENEFITS

Methods and physical properties of tape coating for use in the XM19 detector were developed. The process variables and process parameters were established to assist CSL in the scale-up of the coating operation.

IMPLEMENTATION

The physical properties and specifications developed by SRI were used as a guide by CSL to successfully produce tapes on a larger pilot scale unit.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. T. Gervasoni, AUTOVON 584-4250 or Commercial (301) 671-4250.

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 1403 titled, "Improved Process/Substitution of Nontoxic Dyes in Smoke Grenades", was completed by the US Army Armament Research and Development Command in March 1982 at a cost of \$315,000.

BACKGROUND

The current green and yellow colored smoke hand grenades use component dyes benzanthrone and Vat Yellow 4. Research studies conducted indicated that the organic dyes in these colored-smoke pyrotechnic formulations pose serious potential health hazards to exposed personnel. Reports concluded that benzanthrone causes dermatitis in man and affects the liver and autonomic nervous system. In 1979 the National Cancer Institute reported that Vat Yellow 4 was proven carcinogenic to mice. In 1980 the Oak Ridge National Laboratory revealed that both the green and yellow dye mixes exhibited mutagenic activity. These health hazards were of concern as they could have resulted in a potential ban on production and use of colored-smoke munitions. The preferred solution to the problem was the substitution of dyes which are noncarcinogenic, nonmutagenic, and of minimal (reversible, nonincapacitating) toxicity to industrial personnel and the environment.

SUMMARY

This project was conducted to identify "safer" dyes or dye mixes which could be substituted into the yellow and green M18 grenades without changing the item configuration or performance. The standard M18 smoke grenade is a burning-type munition used for signaling or marking. A drawing of the grenades with appropriate data is shown in Figure 1. The green-smoke grenade has four smoke emission holes in the top (fuze end) in addition to a hole in the bottom. The colored-smoke grenades produce smoke by volatilization of organic dyes. The dyes are intimately combined with a pyrotechnic mixture of fuel, an oxidizer, and a coolant (burning-rate modifier).

Initially, a literature search was performed to find substitute dyes. A substitute yellow dye was identified with the trade name Solvent Yellow 33. The dye was previously identified as having been successfully used in smoke munitions and has been used in combination with Solvent Green to produce a green smoke. It was assumed to be less of a human health hazard, based on certification by the FDA for use in externally applied drugs and cosmetics.



ITEM:	M18 GRENADE
TYPE:	CORE BURNING
COLORS:	RED, VIOLET, GREEN, YELLOW
SIZE:	2.5-INCH DIAMETER, 4.5 INCHES LONG
WEIGHT : (TOTAL)	1.07 LB
(MIX)	.73 LB
FUZE:	M201A1 PYROTECHNIC FUZE
BURNING TIME:	50-90 SECONDS

Figure 1 - M18 Colored-Smoke Grenade

Preliminary formulation studies were conducted to evaluate the new dye Solvent Yellow 33 in combination with various pyrotechnic ingredients. The formulations for both the yellow- and green-smoke mixes were varied in an attempt to produce smoke clouds with persistence, good volume, and highly visible color for 50-90 seconds. The standard (original) smoke mix formulations contained Vat Yellow 4, benzanthrone, potassium chlorate, sodium carbonate and sulfur. The new smoke mixes contained Solvent Yellow 33, Solvent Green 3, potassium chlorate, magnesium carbonate and powdered sugar. The sulfur and sodium bicarbonate were unacceptable as fuel and coolant since they burned unevenly and the smoke color was faded.

The optimum grenade performance was obtained with the magnesium carbonate and sugar in the oxidizer-fuel ratio of 1:5:1. Bright yellow smoke was produced using Solvent Yellow 33 alone. A bright green smoke which was superior to the standard green smoke grenade was produced by a 70 to 30 (by weight) mixture of Solvent Green 3 and Solvent Yellow 33.

A preliminary surveillance study was performed to determine the effect of accelerated storage on the improved grenades. Yellow- and green-smoke grenades were placed in ambient, hot (160°F), and cold (-65°F) environments for 12 weeks. Standard yellow- and green-smoke grenades were included for comparison. Grenades were withdrawn after 3, 6, 9, and 12 weeks, and the burn times were compared to the burn times of a control group which had been tested immediately after being made. Only a minimal number of grenades were placed in this test as the intent was only to determine gross changes indicative of chemical instability. The results indicated that the improved yellow- and green-smoke grenades were comparable in performance to the standard grenades after accelerated storage, and no deterioration had occurred to the smoke mixture.

At the conclusion of preliminary testing, optimum yellow- and green-smoke mixes were selected and evaluated by rough handling, simulated environmental, and design efficiency tests. The improved grenades were to be evaluated against the yellow and green standard grenades and against the

requirements of the M18 grenade item specification, MIL-G-12326. The grenades to support the test programs were manufactured at Pine Bluff Arsenal, Arkansas, in the M18 grenade production facility. The smoke mixes were blended using the acetone granulation method. Grenades were loaded and packaged in accordance with standard operating procedures. These grenades were then shipped to Chemical Systems Laboratory (CSL) where they were repackaged, serialized, and made ready for testing.

The performance and hazards classification testing of the improved yellow- and green-smoke formulations indicated that the formulations were safe and effective. The improved grenades performed as required in MIL-G-12326H(MU) and produced smoke colors which were slightly different in hue than the grenades they replaced. The reliability of the improved grenades can only be properly assessed after more items are tested. As there are other design improvement tests scheduled for the M18 grenade in the immediate future, additional test data will be forthcoming before the improved items are first produced.

BENEFITS

The most important benefit derived from the substitution of Solvent Yellow 33 into the M18 yellow- and green-smoke grenades was the reduction in the health hazards to exposed personnel. Although available information indicates that the improved yellow- and green-smoke formulations are much safer than the standard formulations, the medical evaluation program will fully assess the health effects. An additional benefit gained from this dye substitution is a significant cost savings. The Solvent Yellow 33 dye costs less than the Vat Yellow 4 and benzanthrone dyes it replaced, so there is an estimated savings of \$1.42 per yellow-smoke grenade and \$.35 per green-smoke grenade. The average annual savings based on projected grenade requirements for 1982-1987 is \$293,680.

IMPLEMENTATION

The information obtained from this project was utilized to update the technical data package for the M18 grenade. New dye specifications were also prepared. An engineering change proposal (ECP) recommending that the technical data package be changed to allow the use of the improved yellow- and green-smoke formulations was prepared. This ECP was approved by the CSL Configuration Control Board (CCB) and by the US Army Armament Materiel Readiness Command CCB on 27 July 1981. This decision will allow the production of the improved grenade as early as 1982.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. M. Smith, AV 584-3223 or Commercial (301) 671-3223..

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 1905 titled, "PBX Continuous Casting for Munitions Loading", was completed by the US Army Armament Research and Development Command in January 1982 at a cost of \$248,700.

BACKGROUND

The increased use of castable plastic-bonded explosives (PBX) in support of Navy, Air Force and Army ammunition has created a potentially serious production short-fall. This project was to identify equipment and processes which would improve productivity thru continuous processing rather than the current batch processing.

SUMMARY

The objective of this project was to provide a basic design for a PBX pilot plant which would have a high potential for successful continuous mixing and casting of PBX. A second major objective was to determine the economic advantage such equipment and processes over current methods.

The continuous process design consisted of commercially available equipment and systems judged to be technically feasible based on the present composition of PBX. To provide a basis for comparison of the continuous equipment, processes and systems with the existing batch PBX production methods, an economic analysis was conducted (see Table 1). The cost projections were based on the conceptual schematic flow diagram shown in Figure 1.

Specifically included in the analysis was production-scale cost relationship for direct comparison with the existing batch process.

	Continuous Mixing		Batch Mixing	
	10^7 lb/yr	25×10^6 lb/yr	10^7 lb/yr	25×10^6 lb/yr
Operating Labor (\$/lb)	0.21	0.11	0.33	0.21
Capitalization (\$MM)	8.40	13.40	12.00	29.00
(\$/lb PBX)*	0.17	0.11	0.24	0.23
Total Cost (\$/lb)	0.38	0.22	0.57	0.44
Annual Savings (\$MM)	1.90	5.50	--	--

* Based on five-year plant amortization without considering the time value of money.

Table 1 - Summary of Significant Economic Results (PBXN-106)

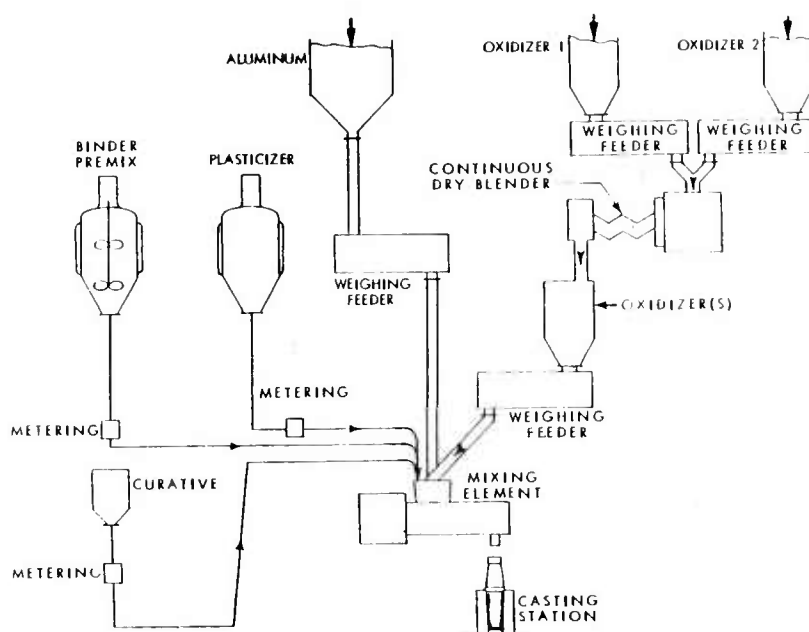


Figure 1 - Schematic of Continuous PBX Process

BENEFITS

This study provided a feasible pilot plant design which would increase productivity and significantly reduce costs.

IMPLEMENTATION

The results of this study were satisfactorily completed. The follow-on project will not be funded unless there are definite requirements for large volumes of PBX.

MORE INFORMATION

Additional information on this project is available from the Project Manager, Mr. John A. Zehmer, ARRADCOM, AUTOVON 953-4764.

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 Projects 574 4009, 575 4009, and 576 4009 titled, "Automation of Equipment for A/P of Small Shaped Charge Rockets" were completed by the US Army Armament Research and Development Command in July 1980 at costs of \$1,009,900, \$641,500, and \$763,000, respectively.

BACKGROUND

Currently packaging of rockets being done at load plants is a manual operation. If the load plant were required to produce at MOB rates, the labor and space requirements would become prohibitive. The major objective of this project was to develop a prototype packaging system suitable for installation at the load plants.

SUMMARY

The method of packaging currently used in loading facilities is comprised of a number of labor-intensive functions. This project established the LAW Packout System. It was designed to provide the appropriate degree of mechanization that would provide the greatest economic return. The system used commercially available components and custom designed only those components which could not be readily obtained.

The system was designed as a group of discrete, functional modules, each totally capable of performing one or more related functions now being performed by hand. The system layout is illustrated schematically in Figure 1 with six modules identified according to their principal functions. This arrangement permits maximum flexibility in the layout of the packaging line.

As the rockets enter the conveyor system, they are checked automatically for proper orientation. When five rockets are accumulated in the proper position, the conveyor moves them to the cluster assembly area where they receive the saddles. At this point, the five rockets and two end saddles are ready to insert into corrugated cartons. The open carton is moved to a loading position while a ram pushes a cluster of five rockets and two saddles into the carton. The carton is closed and sealed with pressure sensitive tape. The carton is then placed automatically in a multi-wall laminated bag and heat sealed. After heat sealing, the bagged carton is stamped with a lot number and date. The bag ends are glue sealed to form a neat package. The first carton into the box loading station is manually fitted with a carrying strap. After the carrying strap

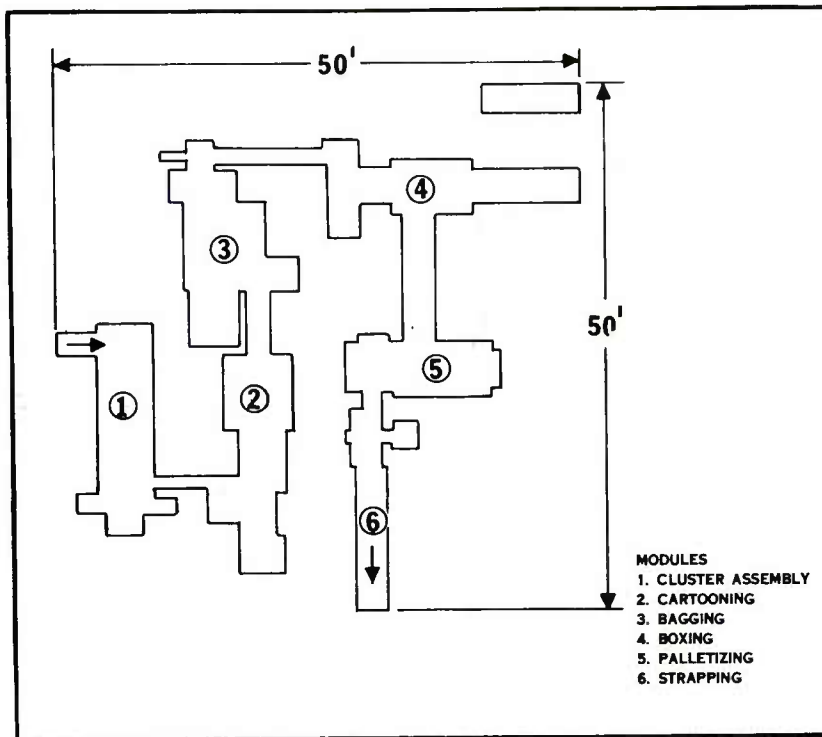


Figure 1 - LAW Packout System Layout

is installed, two more cartons are placed side by side in the automatic boxing machine which wraps a wire bond box around the three cartons. The closed wire bound box then moves to the palletizing module where it is placed on a pallet. When three boxes have been so placed, the pallet moves to the strapping module where two steel straps are automatically placed around the pallet load. After the pallet load is tightened and secured, the pallet rolls onto a gravity conveyor to await removal by a forklift truck. This completes the Packout System.

BENEFITS

The results of this project provide an automated packout system capable of packing the LAW Rocket in groups of 45 on a pallet. This Packout System is capable of packaging various size munitions of similar configuration with very little modification. This system greatly reduces the number of personnel required when compared to the labor intensive hand line system.

IMPLEMENTATION

Production of the LAW has been discontinued. At present, the equipment is in storage at Lone Star AAP until it can be relocated to a facility that can use it for a similar item.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Warren W. Burger, ARRADCOM, AUTOVON 880-6278 or Commercial (201) 328-6278.

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 575 4041, 576 4041 and 578 4041 titled, "Automated Equipment for Assembly of Mortar Components", were completed in January 1982 by the US Army Armament Research and Development Command at costs of \$426,000, \$423,200 and \$811,800, respectively.

BACKGROUND

The objective of this project was to develop, build and test the necessary equipment to automatically load, assemble and inspect 60mm and 81mm Mortar Propelling Charge increments. This equipment is required to perform the above operations more safely, reliably and economically than hand line, as well as to provide for mobilization.

SUMMARY

The prototype system for loading and assembling of M204 (60mm) Mortar Propelling charges was designed, built, debugged and successfully tested. This prototype system is capable of assembling five increments per minute with the limiting operation being the propellant fill station with a cycle time of 11 seconds. The line is a non-synchronous or power and free production system, and is composed of six separate and different station designs and work areas.

1. The empty weigh station automatically receives the empty increment or container, inspects, weighs and places it in a pallet for subsequent operations.
2. The powder or propellant weigh and fill station automatically weighs and checkweighs the propellant and assures its complete disposition into the container.
3. The tab seal station automatically cuts the tab, applies acetone and seals the container pouring hole.
4. The tab check station automatically stops the pallet for tab placement and automatically releases the pallet.
5. The reject removal station automatically stops a pallet with a rejected increment, removes the increment and deposits it in the reject bin.
6. The final weigh station automatically weighs the propellant of each sealed increment (container weight rated), checks increment height again, and stamps the container assembly nomenclature and lot number.

The system represents a significant advancement in the state-of-the-art of automated propelling charge increment production. The following are some of the important features of the system:

- a. The incorporation of an accurate, stable, beamless force restoration scale in the empty and final weigh stations.
- b. The use of a programmable logic controller (PLC) to control operation of the line and each station and to effect 100 percent check weighing of the propellant (when in the sealed container) in the final weigh station.
- c. The use of independent stations integrated with a non-synchronous transport system permits optimum pallet floats between operations of manufacture.
- d. The use of in-process inspection as a part of the process control to assure production of an acceptable item, to eliminate any unsafe conditions or unnecessary maintenance, and to accommodate product dimensional and physical deviations wherever possible.

BENEFITS

The benefits of this system include dollar savings through line personnel reduction, improved safety of all operations thru reduced exposure of line personnel to explosive components, and increased reliability of the item.

In the final acceptance test conducted with inert propellant, the individual stations reached 88 to 93% of the critical values set forth by the PMO. The overall system reached 87% of these critical values. (See Table 1).

Station	Parts Per Minute		Length of Test (Min.)	Critical Value* Obtained	Critical Value* Required	Requirement Obtained (%)
	Machine Rate	Test Rate				
Empty-Weigh	26.3	28.3	30	0.660	0.713	92
Powder-Weigh- and-Fill	4.3	4.8	30	0.686	0.713	96
Tab-Seal	8.0	4.8	30	0.631	0.713	88
Final-Weigh	26.3	7.5	30	0.662	0.713	93
Overall System	4.3	4.8	240	0.376	0.429	87

*Critical value (CV) is defined as the total number of acceptable (N) items divided by the product of the production rate (R) of the station or system and the length of time (T) of test run, or $CV = N/RT$.

Table 1 - Test Critical Values

The line also permits initiation of production in a very short time, and production of either the 60mm or 81mm propelling charge by a tooling change. This design could accommodate possible changes in charge increment weight, and configuration, if required.

IMPLEMENTATION

Action has been taken to have this prototype equipment shipped and installed at Milan AAP. After installation, debugging and acceptance testing; it will be used to load and assemble production orders of mortar increments.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Olavi F. Anderson, ARRADCOM, AV 880-6279 or Commercial (201) 328-6279.

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 574 4054 titled, "Process Imp Eng for the Modifications and Automation of Artillery Prop Chg Manufacture", was completed by the US Army Armament Research and Development Command in July 1980 at a cost of \$686,000.

BACKGROUND

The manufacture and inspection of propelling bags for the 155mm and 8-inch is labor intensive. The present method utilizes individual sewing machine operators to manufacture, print, and inspect propellant bags.

This project will provide prototype equipment to automatically manufacture propellant bags and to inspect bag cloth and printing. The advantages will be reduced cost and increased quality of cloth and printing on bags.

SUMMARY

This project resulted in two major pieces of equipment being designed and built. One was an automated bag sewing system for fabricating three-dimensional propelling charge bags and was designed and built by the IIT Research Institute. The other, a combined propelling charge bag cloth defect detection, print, and print inspection system designed and built by Zia Associates, Inc. Following are descriptions of the equipment:

A. Bag Sewing System - The three-dimensional bag sewing system is an eight-station rotary machine designed solely for the purpose of producing 155mm and 8-inch cloth propelling charge bags. The center of the system is an automatic barrel cam indexing drive unit upon which a dial plate carrying eight horn assemblies is mounted. The horn assemblies are used for fixturing the fabric utilized in the charge bag assembly. Feeding and orienting of raw material (rolls of cloth and end discs of cloth) into the horn assemblies are accomplished on the first three stations of the system. The other remaining stations perform the sewing operations. These are located radially about the dial plate. The machine is equipped with automatic controls to monitor the function of each station of the system and will alert the operator should a malfunction occur during any phase of the bag manufacture.

B. Cloth Defect Detection, Print Inspection System - The cloth defect detection portion of the system (see Figure 1) functions by continuously scanning a roll of unprinted cloth for defects such as holes 1/16-inch in diameter or larger; taped or stitched splices; rust; dark oil or dark dirt spots. The system is capable of inspecting cloth at speeds up to 600 feet per minute and cloth width from 1-inch to 14-inches. Defects are marked with a colored marker for automatic discarding of the piece.

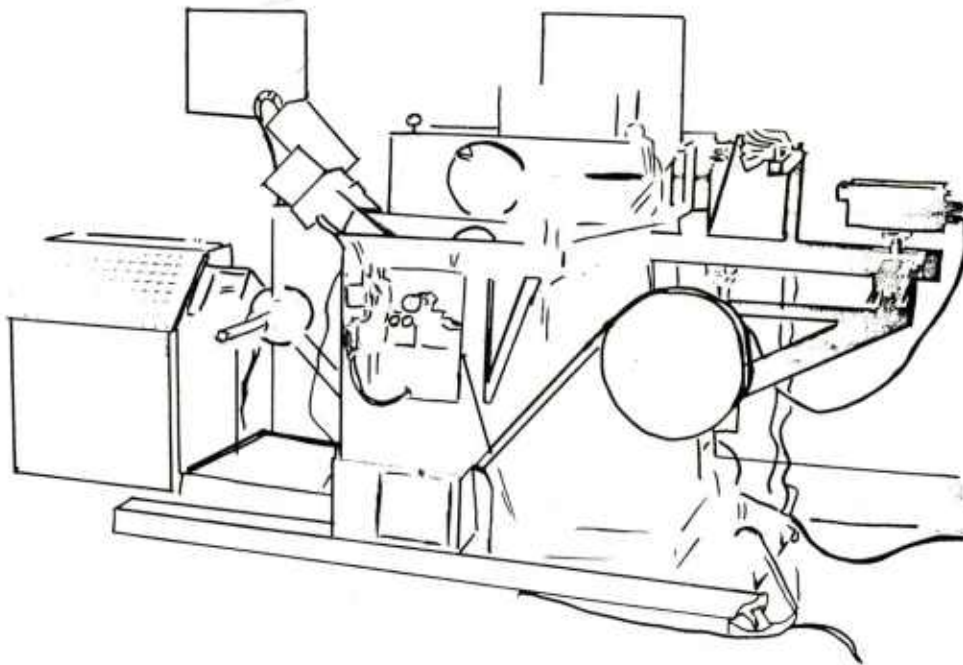


Figure 1 - Overall System

The print and inspection portion of the overall system was developed to print and inspect cloth panels on a continuous roll of cloth. The width varies from 2-inches to 9-inches and the diameter can vary up to 36-inches. As the cloth moves through the machine, a roller prints a size description and increment number on the sidewall of the material. By electronic means, the printed area is then inspected for proper legend and index markings. The inspection operation determines if these are clearly imprinted without smudges, ink spots, etc. If the piece of cloth is rejected, it is automatically marked and later discarded during the bag manufacturing operation.

The equipment has not been released for production due to the following problems: the bag sewing machine is only 50% effective because of breaking thread and the cloth inspection machine will not detect oil or rust spots or tears in the cloth running in the direction of travel.

BENEFITS

Quantifiable benefits have not been achieved as the equipment has not been released for use in production of propelling charge bags because of problems with thread breakage and with failure of the cloth inspection machine to adequately screen defects.

IMPLEMENTATION

The automated bag sewing system has been delivered to ARRADCOM for additional fine tuning to improve the operating efficiency of the equipment. The cloth defect detection, print and print inspection system has been delivered to the Indiana Army Ammunition Plant (INAAP) for implementation.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Cedric E. Reeves, ARRADCOM, AUTOVON 880-4162 or Commercial (201) 328-4162.

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 579 4137 and 580 4137 titled, "Automated Loading of Center Core Igniters", was completed by the US Army Armament Research and Development Command in January 1981 at a cost of \$189,700 and \$64,800, respectively.

BACKGROUND

The purpose of this project was to design a feasible system to automate the loading operations of the 155MM and 8-inch propellant charge center core igniters. The center core igniters consist of a flat circular cloth bag attached to a long slender cloth bag. Both of these bags are loaded with black powder. These igniters are presently manually loaded resulting in high labor costs as well as exposing the human element to hazardous operations and conditions. The project includes some of the design and technology developed by MMT Project 4050, Automated Flash Reducer Loading Module.

SUMMARY

This project examined the four methods and concepts for automating the loading of center-core igniters for 155MM M203 and 8-inch M188A1 propelling charges. These igniters consist of a flat, circular, cloth bag (the pad) to the center of which is attached a long tube-like cloth bag (the core) with a length-to-diameter ratio of approximately 40 to 1. Both the pad and core are firmly packed with black powder. The core is subsequently inserted and fastened, by tying, into a capped nitrocellulose tube to complete the igniter assembly. The following four methods were chosen for study:

1. Funnel with inclosed screw.
2. Funnel with piston or plunger.
3. Funnel with peristaltic squeezer.
4. Funnel with vacuum (Figure 1).

The above methods were subjected to a paper study to determine if dimensional requirements of the proposed methods were compatible with the firmly fixed bag and the filler (black powder) particle dimensions.

Method #1 and #2 were discarded for clearance and safety reasons. Method #3 was tested and indicated the reproducibility of loading compaction density was poor. Method #4, vacuum loading, was tested extensively and favorably.

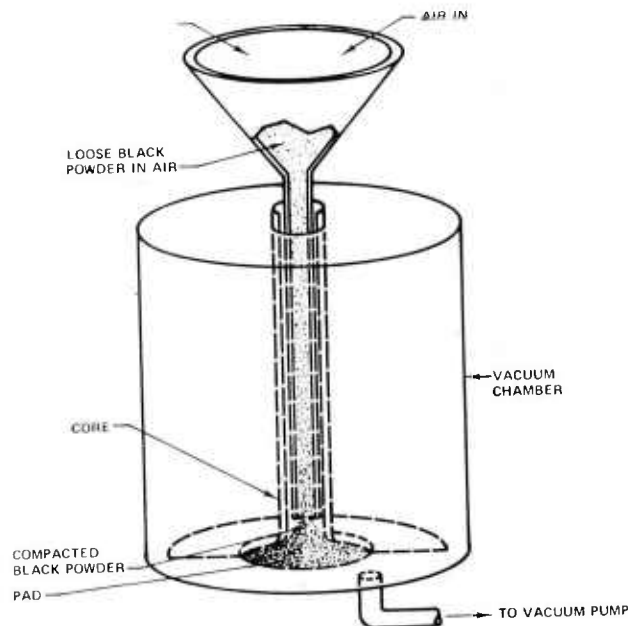


Figure 1 - Vacuum Fill Method

The vacuum loading method used a 28-inch spout funnel inserted into the igniter core bag with the bag encased in a full length vacuum chamber and the funnel's cone open to the air. A circular plastic spacer resting on a shoulder within the vacuum chamber supported the igniter pad during loading of the core. At times, the spacer was used as a weight (approximately 6 oz) on the unsupported pad. Results of tests conducted on a mockup vacuum loading fixture showed that both the center-core and base pad portions of the center core igniter could be loaded with the use of appropriately designed vacuum fixtures.

Economic analysis of possible alternatives to manual loading of center-core igniters indicated return on investment as great as 13.157%

BENEFITS

This project provided for future effort toward automation of loading of center core igniters. ROI of 13% has been calculated on peacetime production based on the current igniter design.

IMPLEMENTATION

Follow on effort is required to design, build, test, and install the automated equipment for loading center core igniters based on the evaluated results of the feasibility study effort. PBM has indicated that funding for the equipment will not be provided due to the probability that the center core igniter will become obsolete.

MORE INFORMATION

Additional information on this project can be obtained from Mr. N. D. Baron, ARRADCOM, AUTOVON 880-3269 or Commercial (201) 328-3269.

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 578 4143 titled, "Advanced Technology for Manufacturing Canisters and Components (M259/XM264 Rocket Warhead)", was completed by the US Army Armament Research and Development Command in June 1981 at a cost of \$160,000.

BACKGROUND

The original wick body was manufactured from pre-perforated low carbon steel formed into the truncated triangular shape. The overlapped seam down the length of the body was secured with seven spot-welds. The wick, a fiberglass strip, was pulled into the body, which was then closed by two separate end caps, also of perforated metal. These end caps were secured to the main body with two spot welds on each.

SUMMARY

The objective of this project was to develop a method of manufacturing wick bodies that was more efficient and cost effective.

The project was conducted in three phases. During the first phase, the current wick design was reviewed and three alternate concepts were developed. In the second phase, samples of the conceptual designs were manufactured and tested. After testing, the best features of all three designs were merged into a fourth design which was also manufactured and tested. In the third and final phase, 500 samples were manufactured in accordance with the fourth conceptual design and tested.

All samples were produced using standard sheet metalworking equipment, including shear and pressbrake, for the wick body, and a simple punch and die set mounted in a punch press to blank out the end caps.

The design configuration and manufacturing methods employed were:

a. Die formed body with integral end caps would use a progressive die fed with pre-perforated coil stock to form the wick body, including the end tabs, in a five or six station die.

b. Roll formed body with separate end caps. This concept would use a group of approximately 14 sets of forming rolls to form the pre-perforated coil stock into the wick body shape. This roll forming method would also include the rolling of a lockseam down the length of the wick body, eliminating the need for subsequent welding. By pre-notching and shearing the strip,

pieces would be produced to the required finished length at the roll former. To close the ends of the wick tube, stamped end caps would be pressed into each end. These caps, manufactured from spring steel, would be formed in such a way that the bent ears would be an interference fit into the wick tube and would provide a self-retaining fit.

c. Die formed body with separate end caps. This concept would use a progressive die formed body, similar to paragraph a above, but without the end tabs. The ends of the wick body would be closed with separate end caps.

Examples of each of these three concepts are shown in Figure 1.

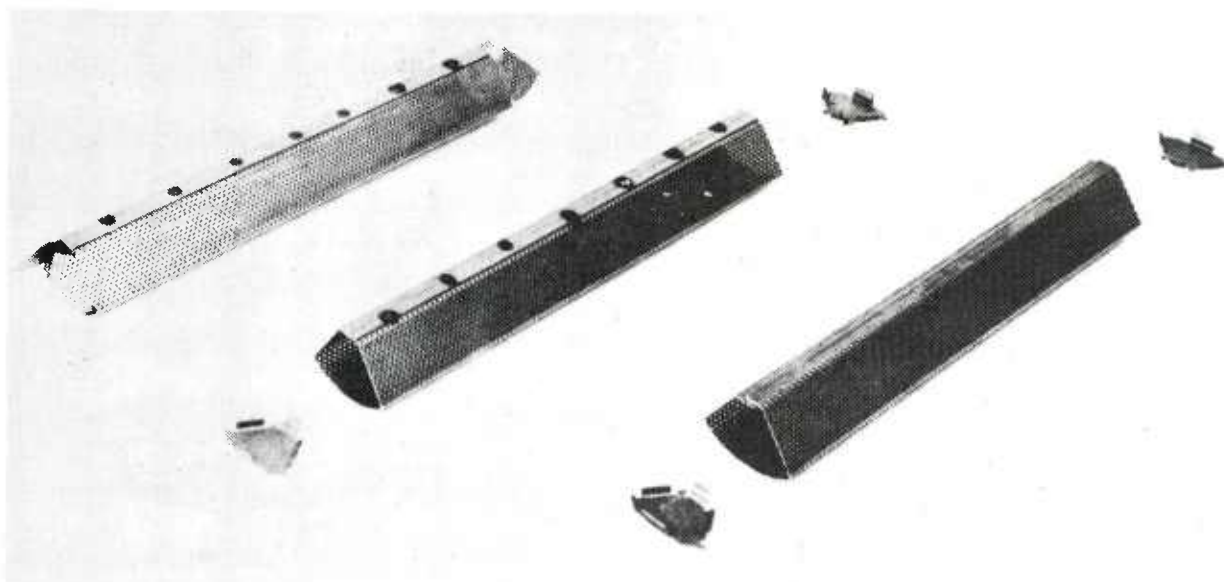


Figure 1 - Three Different Prototype Bodies Prior to Filling

Testing each of the designs showed that both types of body seams, the overlap with spot welds and the lockseam, were able to withstand the deformation forces caused by a burster charge. However, the end caps failed to withstand the burst pressures. The loss of end caps allowed the fiberglass strip to partially extrude from the wick body. If this happened in a live round, a burn time shorter than specified would result. This failure dictated a change in the design and manufacturing procedure of the wick tube.

The new design consisted of a lockseamed wick tube with integral end caps, but the production method used for the lockseam tube did not lend itself to the production of integral end caps at a reasonable cost. The idea of crimp closing the wick tube was conceived and developed into reality. A

crimping tool was developed to make a satisfactory, repeatable end crimp without distorting the wick body profile. The tools were designed to be used in a small press brake. A 90-degree notcher was used to shear off the excess tubing from each end of the wick body after the crimping operation.

For volume production, the use of roll forming equipment was recommended. The crimping and shearing of the wick tubes would be accomplished by a combination tool. All tooling costs could be amortized over a production quantity of 300,000 wick bodies. It was estimated that the unit cost of a complete wick body would be \$.59.

BENEFITS

The cost of producing the wicks prior to this MMT project was \$1.50 each. This project developed a method which could produce wicks for a unit cost of \$.59, resulting in a cost savings of approximately \$273,000 for a production run of 300,000 units.

IMPLEMENTATION

An engineering change proposal was processed and implemented into the technical data package.

MORE INFORMATION

Additional information can be obtained from Mr. Charles Ferret at ARRADCOM, AV 584-3223 or Commercial (301) 671-4424. A report was prepared under Contract No. DAAK11-79-C-0014 by R. C. Schoon, 1980, "Reduced Cost Production 2.75-Inch Rocket Warhead". Gard, Inc. (ARCSL-CR-80055).

Summary report was prepared by A. 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 Project 579 4163 titled, "Controlled Production Loading System for 105MM HEAT-T M456AL" was completed in January 1981 by the US Army Armament Research and Development Command at a cost of \$491,000.

BACKGROUND

The 105MM HEAT-T projectile M456Al contains a shaped charge that is CAST loaded with Composition B explosive. Loaded projectiles were failing to meet inspection specifications with reject rates of 30 to 50 percent due to casting defects in Composition B. There was a need to develop an effective cast loading system to minimize defects and reduce rejects to a level of five percent or less.

SUMMARY

ARRADCOM proposed a two year program, the first year was to develop the process and supporting technical data for the process technique. During the second year, ARRADCOM improved the process and control procedures. They also developed a suitable production method at Milan AAP. The method at Milan AAP is described as follows:

Eight projectiles were placed upon metal trays with pouring funnels installed, these trays were then placed on a conveyor and fed to an oven which preheated the projectile to a temperature of 64-68°C. After the projectiles were up to temperature, they were removed from the discharge end of the oven and placed on another conveyor leading to the fill station as shown in Figure 1.

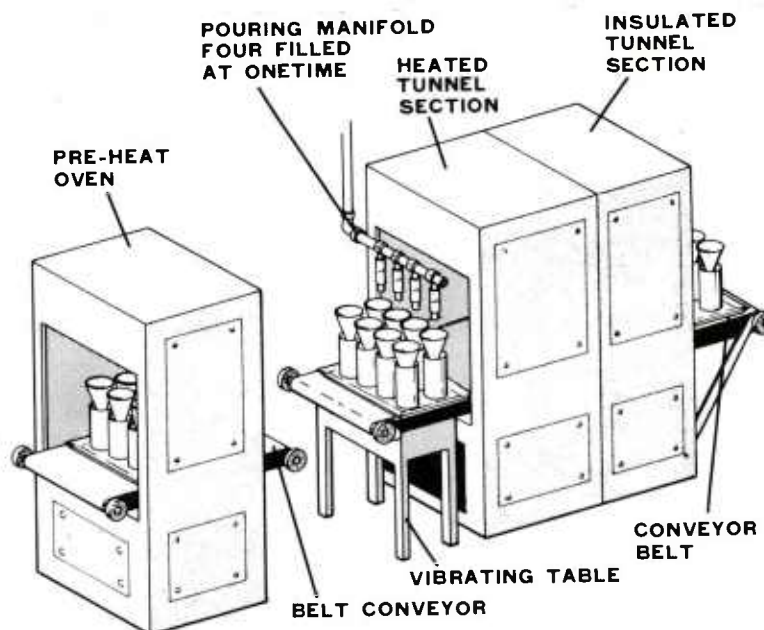


Figure 1 - Skematic of Milan AAP Production Line for 105mm Projectile Loading

Four projectiles were filled from a pouring manifold with Composition B at a pouring temperature of 88°C. During fill, the projectiles and tray were vibrated to reduce voids.

After filling, the tray and projectiles were conveyed through a heated tunnel section for 20 feet and continued for another 20 feet through an insulated section of tunnel, to control the cooling rate after fill.

After emerging from the tunnel, the tray and projectiles were allowed to cool still further at ambient temperature. This process handles eight projectiles per tray and produces the desired results of production capabilities and low scrap rate.

BENEFITS

The technology developed established a method and equipment design for use at Milan AAP with an acceptance rate of over 95 percent.

IMPLEMENTATION

ARRADCOM furnished the project results to Milan AAP for production applications and a satisfactory production loading line has been built. Milan AAP has implemented the process and equipped the production load line in accordance with the parameters developed at ARRADCOM.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Peter Skerchock, ARRADCOM, AV 880-4252 or Commercial (201) 328-4252.

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 Projects 574 4223 and 577 4223 titled, "Application of Ultrasonic Energy to Double-Base Propellant Extrusion Processes", were completed by the US Army Armament Research and Development Command in February 1981 at costs of \$397,000 and \$330,000, respectively.

BACKGROUND

Solventless double-base rocket propellant grains are manufactured by extrusion in 15-inch hydraulic presses. These are large expensive presses. When the plant is at full capacity, extrusion is the bottleneck unit operation because of quality and safety limitations. Also, propellant compositions with high solids loading are difficult or impossible to extrude due to the stiffness (viscosity) constrictions.

Reduced operating costs and increased capacity for these presses might be realized if they could be adapted to ultrasonic die activation techniques. An earlier project demonstrated the feasibility of ultrasonic die activation on a 2-inch press in which extrusion rate increases of up to 500% were realized. Analysis of the extruded propellant showed that the density, tensile strength, and strand burning rate were not affected by ultrasonic excitation. In fact, photomicrographs showed an even finer material texture.

SUMMARY

The objective of these two projects were, in essence, to scale up the earlier studies, install and evaluate an ultrasonic prototype on a 15-inch press at ARRADCOM. The ultrasonic array is attached to the extrusion press as shown in Figure 1.

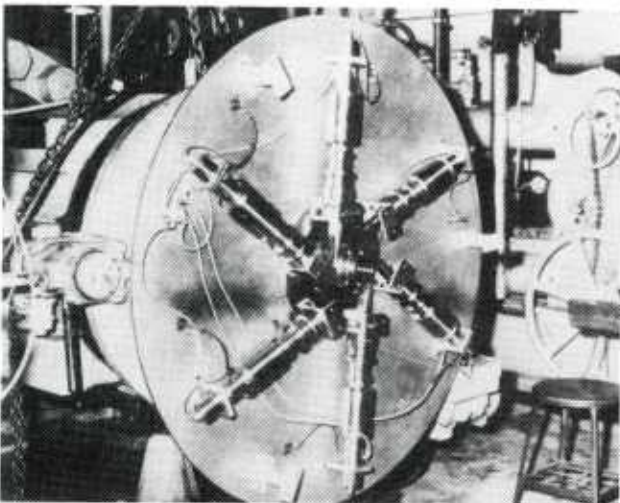


Figure 1 - Ultrasonic assembly mounted on 38 cm (15 in.) press prior to installation of housing front plate

A number of problems were encountered. First, performance difficulties were encountered in the prototype die design. The electronic power supply and control system necessitated a redesign of the die holder from an Elmore mount to a mass terminated type. Further, the control system limited maximum power input to 5 KW rather than 18 KW called for in the design.

During initial ultrasonic extrusion runs using inert propellant simulant, no extrusion run pressure decrease was observed. However, a noticeable improvement in extrusion breakthrough characteristics was obtained at lower press temperatures. When live N-5 propellant was used, extrusion parameters showed no significant differences between conventional and ultrasonic excitation extrusion. This lack of improvement appears to be due to too low a power level or too soft a composition.

On March 25, 1980, during attempts to balance the transducer array between extrusion runs, a fire occurred in the extruder. The ram had been retracted and a heel of N-5 propellant was present in the press basket. The cause of the fire was traced to a loose joint between the die approach and the die body which heated up due to frictional vibration from ultrasonic excitation. The die system was redesigned to avoid this problem in the future.

It was also recommended that before any future program activities using live propellants, the thermal characteristics of the assembly stud area be closely monitored using either an empty press or inert propellant. At this point, it was decided to terminate the program and prepare a Final Technical Report covering all efforts to date.

BENEFITS

There are no benefits at this time. However, the potential exists if power levels are successfully increased. A reasonable goal for increasing capacity of the existing 15-inch presses is 25%. Also, successful application would enhance potential use of the more economical solventless process to manufacture RAP propellant grains.

IMPLEMENTATION

The final report recommends that the system be evaluated with a stiffer composition, e.g., AA2, and high energy filled compositions. Also, it recommends that the power level of the system be increased to its 18 KW design maximum.

MORE INFORMATION

Further information may be obtained from Mr. E. P. Huselton, ARRADCOM, AV 880-4243 or Commercial (201) 328-4243. Also Technical Report ARLCD-TR-80057 titled, "Application of Ultrasonic Energy to Double-Base Propellant Extrusion Process", was published in July 1981.

Summary report was prepared by Wayne R. 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 Projects 572 4228, 573 4228, 574 4228, 576 4228, 577 4228, and 578 4228 titled "Automated Bag Loading, Charge Assembly and Packout for the 155MM and 8-Inch Propelling Charges" were completed by the US Army Armament Research and Development Command in July 1980 at costs of \$999,000, \$430,000, \$238,000, \$1,260,000, \$1,324,000 and \$137,400, respectively.

BACKGROUND

The purpose of these projects was to automate the bag loading, charge assembly, and packing of 155MM M3A1 and M4A2 and 8-Inch M1 and M2 propelling charges in support of load plant mobilization rates. The secondary purpose of the projects was to support mobilization rates with a reduction of personnel and thus effect a cost savings.

SUMMARY

The complete automated load and pack system is comprised of the following major sub-systems:

1. Bag loading carousel.
2. Conveyor system.
3. Charge assembly machine.
4. Packout line.
5. Bulk-fill scale.
6. Control console.

The sub-systems were received and installed. Debugging was initiated throughout the system. The system works as follows: empty increment bags are tare weighed and positioned on fixtures for filling with propellant. During the rotations of the carousel, acceptable propellant weights from the scale are delivered to the bag-fill operation and the bags are filled. The increment bag closure opening is sewn, and the bag is put on a scale where the increment is either accepted or rejected if any propellant was spilled during the bag-fill cycle.

Completed increments are transplanted on conveyors through a buffer which supplies the assembly machine. The base bag is positioned into a fixture by hand and the successive increments are automatically placed on this increment.

A subsequent operation includes the bag tie. When completed, the propelling charge assembly is transported to the packout line.

The initial operation on the pack line, see Figure 1, is automatic inspection and checking of total weight, length, and diameter. Rejected charges are diverted and acceptable charges continue to the igniter protective cap insertion station. The charge is then pushed into a shipping canister. Subsequent operations include the placing of coupons on the charge as dunnage, cover placing, torquing, leak testing, closure washer and plug inserting, wire seal, and inspection. The completed canister is then removed and transported to shipping or storage area to await shipment.

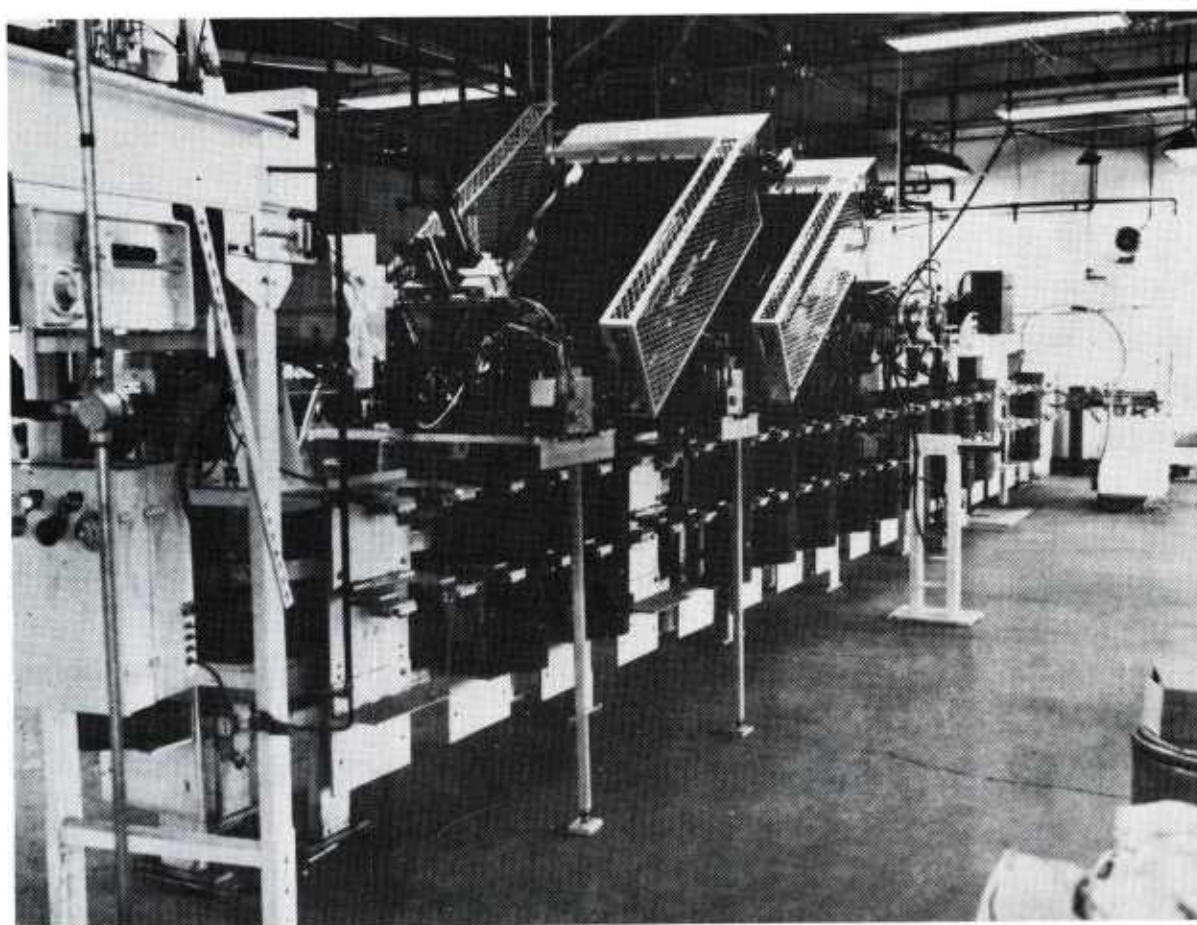


Figure 1 - Packout Line Stations

BENEFITS

PBM tasked an engineering consultant to review the project. Based on the consultant's findings, the work was terminated.

The project was technically unsuccessful and there were no benefits derived.

IMPLEMENTATION

Based upon an independent consultant's evaluation of the performance of the bag loader and scales, PBM (Jan 78) directed that work be terminated on the bag loading carousel and scale system. The system, less the bag loader and scales, were subsequently shipped to Indiana AAP.

MORE INFORMATION

Additional information on this project can be obtained from Mr. John Smarz, ARRADCOM, AV 880-4162 or Commercial (201) 328-4162.

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 Projects 574 4263, 575 4263, 576 4263, 577 4263, 578 4263 and 579 4263 titled, "Automated Pilot Line for Controlled Cooling and Processing of High Explosive Loaded Projectiles" were completed by the US Army Armament Research and Development Command in January 1981 at costs of \$713,500, \$1,300,000, \$1,145,000, \$900,000, \$257,000 and \$329,000, respectively.

BACKGROUND

Current production processes for high explosive loaded projectiles are inefficient, characterized by manual operations, high personnel exposure, large explosive allowances and poor quality control.

Consequently, a need existed to demonstrate the design, installation and operation of a continuous, automated melt pour pilot facility for loading, controlled cooling and processing medium and large caliber projectiles. Information obtained during the operation of the pilot plant would be used to modernize GOCO loading facilities.

SUMMARY

The purpose of this effort was to develop a prototype plant production line in which the thread protector and funnel were inserted and removed by automated machines. These machines were designed and built by Midwest Research Institute. The machines underwent "debugging" and were interfaced with the system. See Figure 1.

Also included were metal part pre-heat, automated melt-pour, and controlled cooling; interfaced to a complete projectile material handling system which included station transfer subsystems. As a result of this effort, this pilot line provided a means of evaluating system designs and processing procedures prior to procurement of full scale equipment for the modernization of GOCO facilities.

BENEFITS

The operation of the pilot line provided a means of evaluating state-of-the-art in system designs and processing procedures prior to procurement of full-scale equipment. The data generated by this program was used to develop design criteria and technical data packages (drawings, specifications and costs) for mass production GOCO facilities. The project also provided a melt pour facility with a high degree of safety, less personnel exposure, and lower explosive allowance per bay. The application of safety design

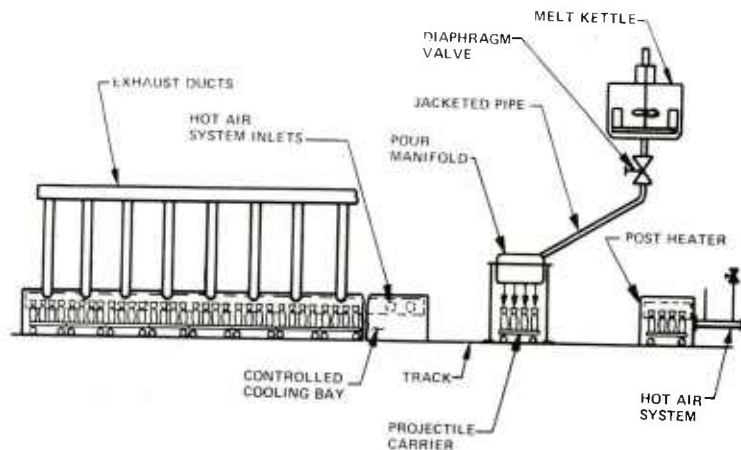


Figure 1 - Melt Pour Process Flow Sheet

criteria reduced hazards to neighboring areas and equipment. In addition, there was a considerable reduction in the cost to produce finished munition items due to the decrease of 18 operators per load line, or \$491,000 per year per line on a 3-shift 5-day operation.

IMPLEMENTATION

Data obtained from this study was used to support the design and development of mass production loading at the following GOCO plants: Iowa AAP, Milan AAP, Louisiana AAP, Ravenna AAP, Kansas AAP.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Curtis Anderson, ARRADCOM, AV 880-3162 or Commercial (201) 328-3162.

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 577 4267 titled, "Continuous Process for Granular Composition B", was completed by the US Army Armament Research and Development Command in January 1982 at a cost of \$500,000.

BACKGROUND

This effort is the continuation of the development of a continuous method for producing granular Composition B. The granular Composition B will be used as an alternate fill for Composition A-5 in munitions. In an FY75 project, laboratory studies were accomplished on various methods for producing granular Composition B. The prilling process was selected as a candidate for further evaluation.

SUMMARY

The objective of this project was to design, procure, install and check out the equipment for producing approximately 500 lbs/hr (226.8 kg/hr) of granular Composition B. A continuous process for prilling molten Composition B to granular Composition B was to be investigated. It was anticipated that a more efficient method of controlling process parameters, product granulation, and bulk density in the manufacture of granular Composition B would result. The continuous process should improve throughput, lower operating costs, and increase the capacity for producing granular Composition B.

Niro Atomizer Inc. was sub-contracted by Holston Army Ammunition Plant (HAAP) to determine if a cascading hydraulic nozzle could be utilized to form simulated granular Composition B. A product with a Bechtel bulk density of 0.94 g/ml was formed at equilibrium conditions. A design for the process was also prepared by Niro Atomizer as part of this contract. Upon examination of the design, it was determined that some components in this design would not be acceptable for use with explosives, i.e., metal to metal contact and air conveying systems.

Therefore, the scope of work was revised by ARRADCOM to allow HAAP to perform an additional three month bench scale evaluation of some alternatives to the dry prilling of granular Composition B. HAAP evaluated processes such as conventional wet prilling, wet prilling with an eductor, ultrasonic dispersion, centrifugal pump, mechanical grinding, and mechanical graining. Results of the study indicated that granular Composition B produced by the wet prilling process would not meet the particle size specifications required for this product and that the red water pollution problem with the water

slurry process was severe. Also, the mechanical granulation processes proved unsuccessful. A better process for dry prilling Composition B could not be found by HAAP. It was recommended that the design criteria for manufacturing granular Composition B be based on the dry prilling process, utilizing the two-fluid nozzle as the prilling device.

While the bench scale study was being conducted by HAAP, an additional study was underway by Niro Atomizer, Inc. to evaluate their two-fluid nozzle for granulation of simulated (inert) Composition B. The final product had a bulk density of approximately 1 gm/cc as required for granular Composition B.

ARRADCOM prepared a detailed SOW encompassing the design, construction, and operation of a prototype facility for prilling granular Composition B. After detailed evaluations of proposals from various GOCO plants, Lone Star AAP was selected as the site for the granular Composition B pilot plant facility.

The FY77 Scope of Work was rewritten to encompass the design and procurement of the pilot facility by Lone Star AAP, assisted by Niro Atomizer, Inc. Installation and operation of the pilot plant were deferred to future funding (FY78). A specification package for the design of the pilot plant for granular Composition B manufacture was prepared by Lone Star AAP and forwarded to Niro Atomizer, Inc. for proposal and bid. The pilot plant was to be designed for a rate of 500 lbs/hr with the capability of being upgraded to 1500-2000 lbs/hr.

In November 80, Niro, for legal considerations of indemnification, terminated all negotiations with Lone Star AAP. Consequently, the FY77 Scope of Work was revised striking all reference to Niro Atomizer, Inc. and calling for renewed solicitation of design bids.

Several spray drying companies were contacted which had expressed interest in the design of the prilling tower and system to manufacture granular Composition B. These companies also had the technical capability and test facilities for experimentation with the inert simulant. Two companies, Vali-met, Inc. and Southwest Research Institute, had the capability to do live explosive testing, as well. Vali-met recommended the use of a rotating cup instead of the two-fluid nozzle to granulate Composition B. A diagram of the use of the rotating cup mechanism is shown in Figure 1. The molten Composition B is fed into a cup which is rotating at about 400-500 rpm. The particles then spin out from the cup, congeal and fall to the bottom of the tank for removal.

In March 1981, inert and live prilling tests using Composition B were performed at Southwest Research Institute, San Antonio, TX with a two-fluid nozzle and a rotating cup. The results of the testing were not conclusive as to the type of atomizing device to be used in the pilot plant. However, no safety problems were encountered with either device.

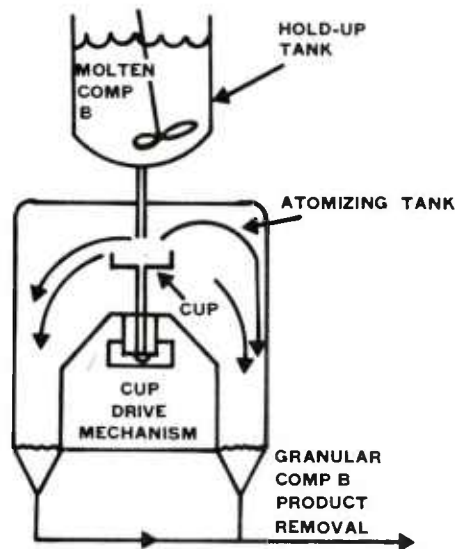


Figure 1 - Rotating Cup

On the basis of the above developments, the FY77 Scope of Work was revised replacing the two-fluid nozzle as the basis for design of a pilot plant with the term "atomizing device" in order to include other techniques of atomization as candidate systems. A preliminary design for the pilot plant based on the use of a rotating cup but adaptable to the two-fluid nozzle technology was prepared by Lone Star AAP.

In June 1981, all design activity at Lone Star AAP was terminated. This was done because it was determined that most of the process technology such as melting and conveying were proven technologies. Therefore, a pilot plant effort was not required. The project was then closed out and a late start FY81 program prepared. The FY81 project would involve setting up a "bread-board" prilling tower with a rotating cup for testing inert simulant.

BENEFITS

The rotating cup technology was selected for the prilling of granular Composition B.

IMPLEMENTATION

The best atomizing process was established for the production of granular Composition B. Tests are planned on the rotating cup technique to determine the parametric data and utilize the information to prepare design criteria for an IPF.

MORE INFORMATION

Additional information on this project is available from Mr. I. Weissman, ARRADCOM, AV 880-3859, or Commercial (201) 328-3859.

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 578 4267 titled, "Continuous Process for Granular Composition B", was completed by the US Army Armament Research and Development Command in January 1982 at a cost of \$254,000.

BACKGROUND

This project is a continuation of the effort to develop a continuous method for the production of granular Composition B. It was planned to use granular Composition B as an alternate fill for Composition A-5. Since there is less RDX in Composition B, than in Composition A-5, the cost of manufacture will be reduced. The FY77 project established the rotating cup as the best technique for the prilling of Composition B. In addition, decisions were made that a pilot plant design study was unnecessary and the project was restructured. An FY81 project was programmed to further evaluate the rotating disc technology testing inert simulant for granular Composition B.

SUMMARY

The original objective of this project was to operate and evaluate a pilot plant for producing granular Composition B by the dry prilling process. However, decisions made on the FY77 project resulted in restructuring and termination of some of the tasks planned in this project.

The only task completed under this project was a contract awarded to determine the charge generating characteristics of falling granular Composition B. The main purpose of this task was to investigate the safety of the prilling process. In the prilling process the molten Composition B is atomized into droplets at the top of a tower into which heated, filtered air is introduced. The droplets, solidify in contact with the air and are in a dry spherical condition when they reach the base of the tower. The potential safety hazards are the impact of the Composition B on the tower base, generation of electrostatic charges and dusting of the product.

Drop and impact tests were conducted to determine the effect of cast Composition B charges falling freely and impacting against a steel plate. These tests simulated the impact of a mass of Composition B with the base of the prilling tower. The test apparatus consisted of a stationary carbon steel plate which could be positioned at both 60° and 0° angles to the horizontal. A helicopter hook was used as the drop mechanism for the Composition B. The cast Composition B charges were manufactured with the

use of mold fabricated by segmenting an 8 inch shell. The charges weighed about 2 kg, a high speed camera was used to record the results. The results obtained at a drop height of 10.7 m from the steel plate indicated that 31 drops were made without an explosive incident.

A second experimental program was conducted to establish the electrostatic charge generating characteristics of free-falling granular Composition B. All experiments performed during this program were conducted with the experimental apparatus shown in Figure 1. The apparatus consisted of a stainless-steel granular Composition B feed hopper suspended over a vibratory feeder. A stainless steel funnel placed directly beneath the exit of the feeder trough acted as a flow director and spray dryer nozzle simulator. The granular Composition B receiver vessel was a Faraday cup connected to an electrometer and x-y recorder. The electrometer was operated in the coulomb mode, and the recorder plotted the coulombs generated per second of granular Composition B flow.

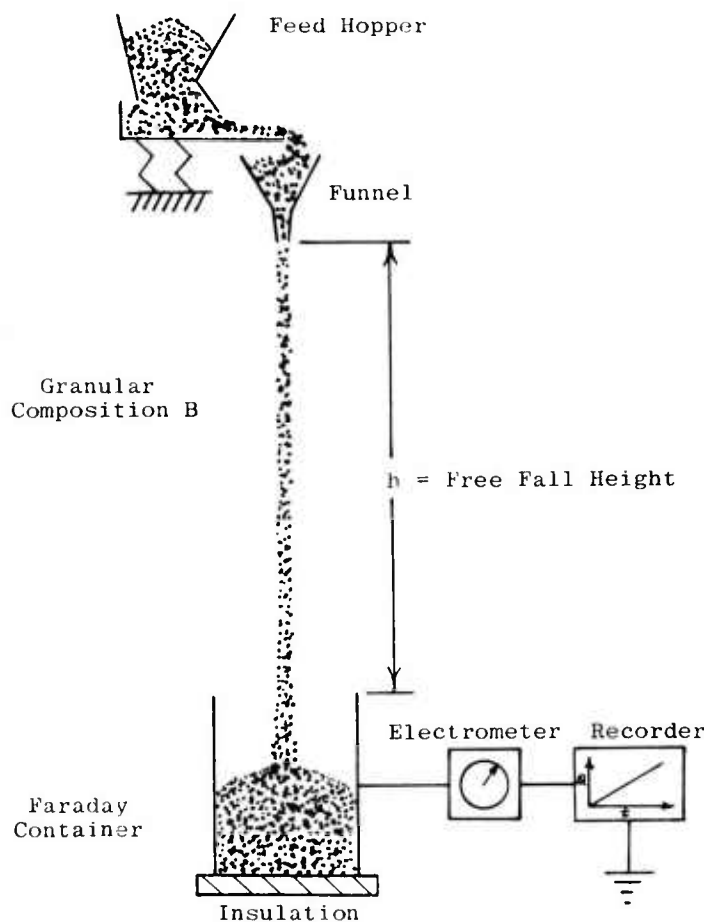


Figure 1 - Design of Experimental Setup

The effects of free fall height and weight flow rate were studied independently. Drop heights of 0.30 m to 3.96 m were investigated at a constant granular Composition B flow rate of 0.48 kg/s. Flow rate effects were measured by maintaining a constant 2.90 m drop height and by varying weight flow from 0.06 kg/s to 0.38 kg/s. Results indicate that the charge density is constant for all drop heights above 0.61 m. In addition, charge density decreased as the flow rate increased from 0.06 kg/s to 0.22 kg/s. The maximum charge density measured was 9×10^{-7} coulombs/kg at a flow rate of 0.09 kg/s, a drop height of 0.30 m, and a corrected relative humidity of 16%.

Since the threshold ignition for 200 mesh (worst case) Composition B is 2.0×10^{-6} coulombs/kg, the safety factors for the constant flow rate and constant drop height are 3.32 (332%) and 2.65 (265%), respectively. With proper grounding the safety factors would be significantly increased and there would be no significant hazard in operation of a prilling tower due to electrostatic charge buildup.

BENEFITS

This study demonstrated that there was no impact hazard when dropping granular Composition B from a maximum height of 35 ft in a prilling tower and that proper grounding should be incorporated to minimize the potential buildup of electrostatic charges.

IMPLEMENTATION

The results of this study will be implemented into the design and installation of the prilling tower. The purchase, installation, operation and evaluation of the prilling process will be programmed for FY82 and FY83 projects.

MORE INFORMATION

Additional information on this project is available from Mr. I. Weisman, ARRADCOM, AV 880-3859 or Commercial (201) 328-3859.

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 (MMT) Project 579 4305 titled, "Production Technology for Improved WP 155MM Smoke Munitions (XM825)," was completed by the US Army Armament Research and Development Command in August 1981 at a cost of \$265,000.

BACKGROUND

In 1977, a Letter of Agreement (LOA) was approved for the development of an improved white phosphorous (WP) 155mm smoke munition. The felt wedge WP (FWWP) concept was developed as shown in Figure 1. The concept was to deliver a ground screening smoke by burning wedge-shaped pieces of felt which have been saturated with WP. The system consisted of two major components, the projectile carrier and the payload. The chief concern of this project was the canister containing the felt wedges. Under this project, it was necessary to determine the most feasible production method for filling, closing, inspecting, and leak testing the WP canister.

In a related effort, MMT Project 576 1336, pilot equipment was acquired to fill a 2.75-inch rocket warhead with WP and close the munition with an inertial weldment. The engineering data obtained from the MMT studies were used in the design of a limited production capability for the M259, 2.75-inch rocket, at Pine Bluff Arsenal.

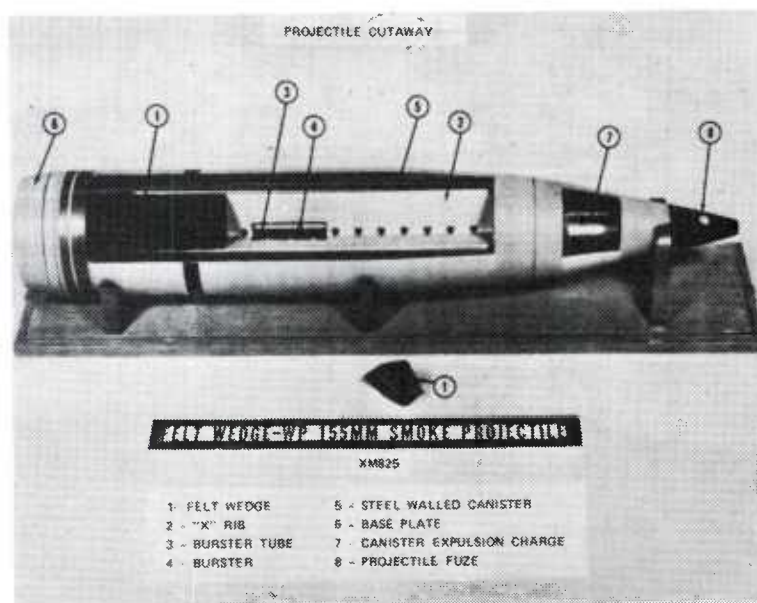


Figure 1 - Projectile Cutaway

SUMMARY

The major objective of this project was to conduct process studies to determine the most feasible method for preheating, purging, filling, closing, inspecting, and leak testing for production of the XM825, 155mm WP projectile. This was accomplished by modification of the equipment developed in a prior year, MMT Project 576 1336, to conduct the studies.

Preheating studies were performed to determine the effects on filling capacity of the canister. Filling tests were conducted on both unheated and heated hardware. In the unheated condition, (75°) 1-3 pounds less than the normal or specified amount of 13 pounds could be loaded into the canister. Preheating tests at 140°F and 160°F were conducted to determine the affect on filling capacity. Based on the tests, canisters preheated to 160°F could be filled to the required weight.

The next series of tests involved filling studies to establish the filling conditions and procedures for the XM825 canister. The studies were conducted on a prototype volumetric filling machine which was designed and fabricated under an earlier MMT Project 576 1319. The filling machine was redesigned to provide, mainly, a new filling head and volumetric cylinder and other minor changes. A diagram of the volumetric cylinder is shown in Figure 2. A series of tests were conducted with both the actual canisters and reusable plastic canisters. Based on these tests, the following filling cycle was established:

- (a) Preheat canister to 160°F.
- (b) Open vacuum valve for 26-inches, then open WP fill valve.
- (c) Leave vacuum on for 1 minute 20 seconds, then close valve.
- (d) Close fill valve after 1 minute 40 seconds.

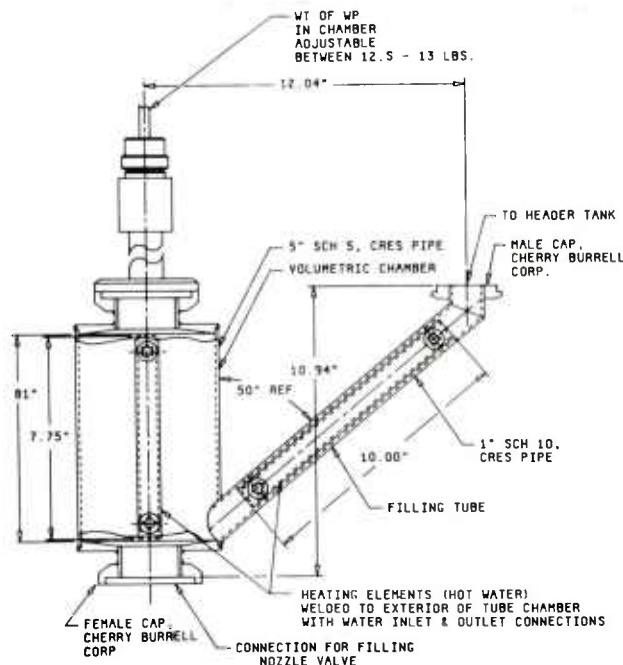


Figure 2 - Diagram of the Volumetric Cylinder

In order to close and seal the WP in the canister, inertia welding was selected for welding the closure plug. A parametric study of weld parameters, including pressures and spin rates, was conducted. The optimum conditions were established at 4200 rpm for the welding speed and 800 psi for the set-down pressure. This combination provided good weld strength and a very low probability of leakage.

Leakage tests were performed next to determine whether the sealing technique used on the canisters was successful. For this test, four WP filled and instrumented canisters were placed in an oven. Two canisters were filled with a minimum void (maximum fill) and two with a minimum fill (maximum void). The pressure and temperature of the canisters were monitored while the temperature was increased from ambient (77°F) to 230°F. Based on test results, it was recommended that filled canisters be tested at 160°F for 8 hours in an oven followed by a visual inspection.

After completion of the various studies, an operator training and debugging period followed. During the prove-out period, water was used for filling. Several deficiencies were noted and corrected. An SOP and hazards analysis were prepared prior to startup of the line. A total of 200 canisters were then filled with WP successfully. Leak tests were performed and visual inspection of all canisters revealed no leakage.

Based on the studies performed under this project, the following base-line WP filling conditions were developed: (1) The canister should be preheated to 160°F and soaked for four hours, (2) a 26-28 inch vacuum be maintained for 1 minute and 0 seconds, and (3) the filling cabinet should be maintained at 160°F and the WP at 145°F. The above parameters will give a properly filled round in 3 minutes. The prototype station developed provided a nominal loading rate of 10 rounds per hour.

BENEFITS

The equipment, methods and operating parameters were developed for the preheating, WP filling, closing, and leak testing of the canister for the XM825 155mm projectile.

IMPLEMENTATION

The information developed in the project was used for the plant design of the initial production facility at Pine Bluff Arsenal for the XM825 155mm projectile.

MORE INFORMATION

Additional information is available from Mr. F. Stewart, US Army Armament Research and Development Command, Chemical Systems Laboratory, AV 584-2863 or Commercial (301) 671-2863.

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 4460 titled, "Continuous Mixer-Illuminant Composition Analysis and Control System," was completed by the US Army Armament Research and Development Command in November 1981 at a cost of \$236,000.

BACKGROUND

Longhorn AAP's new modernized automated process for illuminant manufacture for flares includes the use of a Mix Muller Continuous Mixer. It provides a continuous stream of illuminant composition consisting of magnesium, sodium nitrate, and organic polymer binder. Should any one of the automatic feeders malfunction or deviate from its set mass feed ratio, a considerable quantity of material can be mixed before the deviation or malfunction can be detected and corrective action taken. Feasibility studies conducted in the past have indicated that physicochemical instrumentation can be designed and constructed to serve as composition analyzers for on-line process control.

SUMMARY

The objective of this project was to design and evaluate a prototype analysis and control system to measure illuminant composition at Longhorn AAP. Literature studies and vendor testing were conducted on three potential concepts as follows:

(1) Nuclear Activation - This technique subjects a sample to radiation from a shielded isotope source. The source is selected so that radioactive isotopes of the element of interest are produced. A suitable detection system can then be used to determine the concentration of the element. No off-the-shelf equipment, however, is available for this method.

(2) X-Ray Diffraction - This method is based on the fact that when an x-ray beam strikes a sample, a cone of secondary rays is produced, the intensity of which varies with atomic structure at different angles of detection. Some success in analyzing for sodium nitrate was observed, but not for magnesium. Additional testing is needed to establish this method.

(3) X-Ray Fluorescence - This technique subjects a prepared sample to a beam of primary x-radiation which causes the elements present to emit characteristic secondary x-radiation. The secondary x-radiation for each element is unique in Bragg angle and energy level and can be detected and analyzed for quantitative information.

The latter approach was selected for test and the prototype system used consisted of the following components:

1. Bulk vacuum chamber for sample evacuation.
2. Iron-55 radioactive source.
3. Silicon detector.
4. Vertical dipstick (cooled by liquid nitrogen).
5. Integrated analyzer system.
6. Control console.
7. Teleprinter.

The samples were pressed into tablet form, primarily because a vacuum chamber was necessary to reduce background interference. Accordingly, several small mixes having several levels of magnesium were prepared and pressed into tablets. These samples were used to perform test runs at the vendor's laboratory. The steps necessary to perform each test on this instrument are outlined as follows:

<u>STEP</u>	<u>TIME REQUIRED (MINUTES)</u>
Obtain sample	1
Weigh and press sample	3
Place sample in chamber and evacuate	2
Excite/count	10
Computer analysis	3

A new sample could be introduced into the chamber during the last step, thereby reducing the sample analysis time for repetitive tests. Using an x-ray source in place of the Iron-55 would provide a hundred-fold increase in count rate, dropping the Step 4 time to 4 minutes. Therefore, the effective total analysis time could be around 12 minutes.

Results of the samples sent for evaluation were as follows:

<u>Sample No.</u>	<u>% Magnesium</u>		<u>% Sodium</u>	
	<u>Mixed</u>	<u>Tested</u>	<u>Mixed</u>	<u>Tested</u>
1	0.27	0.76	26.25	24.65
2	44.14	44.52	12.86	12.10
3	50.12	51.01	9.63	11.25
4	56.10	54.71	9.64	9.82
5	45.00	41.46	12.59	12.54
6	49.00	52.71	11.52	11.50
7	52.04	52.00	10.72	10.93

The actual counting is done over a 3/8" diameter surface. The large difference in particle size between the magnesium and sodium nitrate presents a non-homogeneous surface. Moreover, in order to reduce the sample and analysis time to a minimum, the other elements (i.e., everything except magnesium and sodium) present are assumed to be constant. As the sodium nitrate content varied in the samples, some differences in the percentages of the other elements would take place. To gain further information, sample No. 2 above was repeatedly analyzed. It showed a standard deviation of 0.39% for magnesium and 0.56% for sodium.

This data approximates the reproducibility obtainable with the system on a given sample. Estimated cost for this system varied from about \$55,000 for the unit with the Iron-55 source to \$80,000 for the x-ray unit.

The X-Ray Fluorescence analysis has been recommended for procurement based on the test evaluation and minimal off-line installation requirements. This equipment, like other equipment tested, will not furnish automatic feedback control. However, it will serve as a useful and rapid quality verification tool.

BENEFITS

This project will benefit modernized illuminant manufacture at the continuous blend facility at Longhorn AAP by reducing the amount of reject material, with incorrect composition, to be reworked. An X-Ray Fluorescence analysis system will measure the composition of an illuminant consisting of magnesium metal, sodium nitrate and binder satisfactorily in less than 15 minutes. The existing laboratory analytical methods require at least two hours.

IMPLEMENTATION

The core of the system to be implemented is a commercially available tested unit for which a procurement scope has been prepared. The equipment would be utilized on the modernized illuminant facility at Longhorn AAP, i.e., Project 576 2679, "Modernization of Illuminant Mix & Consolidation Facilities". It was thought that the proposed procurement package would be executed with PS&ER (Production Support and Equipment Replacement) funds but this appears less certain now. The reason is low current production rates and lack of a strong economic incentive until production increases.

MORE INFORMATION

Additional information can be obtained from Mr. Robert O. Wolff, ARRADCOM, at AV 880-4122 or Commercial (201) 328-4122. Also, Technical Report ARLCD-CR-81026 titled "Continuous Mixer Illuminant Composition Analysis and Control System" was published in November 1981.

Summary report was prepared by Wayne R. 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 578 4472 titled, "Development of Equipment for Automatic/Mechanized Fabrication of Center Core Propellant Bags" was completed in June 1980 by the US Army Armament Research and Development Command at a cost of \$208,100.

BACKGROUND

The present manual method of loading the center core propellant bags is costly for 155mm M119A1, 155mm M203, and 8 Inch M188. There was a need to develop a method to reduce cost.

SUMMARY

The purpose of this project was to improve on the present method of manufacture of center core propelling charge bags. An evaluation was conducted on the following propelling charges; 155mm M119A1, 155mm M203 and 8-inch M188. The evaluation was conducted by ARRADCOM and Novatronics of Pompano, FL in two areas: (1) Fixtures and, (2) Mechanization. A third area, Automation, which would require changes in product materials and assembly techniques, was not recommended for implementation at this time due to high technical risk. The first approach was to improve fixtures. Basically this approach examined the present work station, equipment and methods and suggested improvements that would result in an annual labor savings of 9%.

The second approach was to mechanize the fabrication of the bag, web, body and liner assembly. It would be produced in the following manner:

1. Automatically cut off a length of web material.
2. Place a length of lead liner on the web material.
3. Sew two seams simultaneously along the edges of the liner through the web material.
4. Fold the assembly and sew the edges together.
5. Pass on to a handline for completion.

Figure 1, Body and Liner Assembly Station, shows the layout for the above work stations as proposed by Novatronics Inc. An economic analysis was completed which considered the costs to design, build and operate this unit. A Return on Investment (ROI) of 54% was determined using peacetime production requirements.

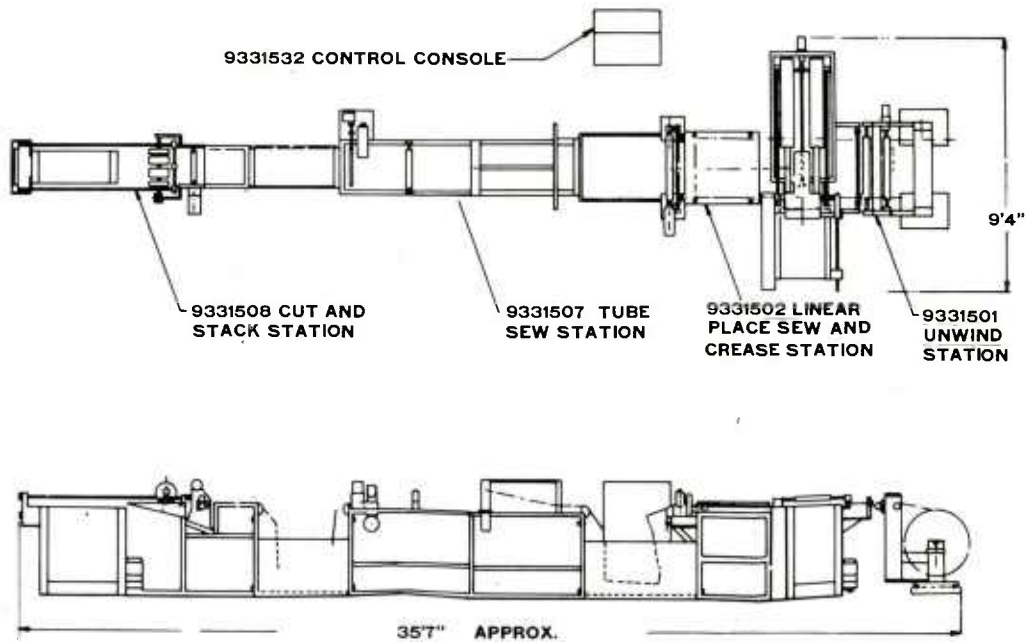


Figure 1 - Body and Liner Assembly Station

BENEFITS

The mechanization approach has been found feasible and would produce a ROI of 54% when implemented.

IMPLEMENTATION

A recommendation was made to PBM to design and build a machine to mechanize the fabrication of web, body and liner assembly. The cost for this was estimated to be \$652,000. No further implementation is expected at this time.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Cedric Reeves, ARRADCOM, AV 880-4162 or Commercial (201) 328-4162

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 6557 titled, "Continuous Propellant Drying, Salt Coating and Glazing", was completed by the US Army Armament Research and Development Command in June 1981 at a cost of \$862,000.

BACKGROUND

The dry processing line at Badger AAP includes batch tray dryers in which total moisture and volatiles (M&V) content is reduced from approximately 8% to the specified 1%. The dried propellant is then coated with potassium nitrate (KNO_3) and tin dioxide (SnO_2), polished, and glazed with graphite in Sweetie barrels. This processing is required to enhance ignition, reduce muzzle flash, and minimize static charge. Both drying and salt coating require high manpower, prolonged cycle times, considerable material handling, and excessive personnel exposure to dry ball propellant. An explosion several years ago destroyed one of the tray dry houses at Badger AAP and sufficient drying capacity does not exist for Mobilization conditions.

An earlier MMT project established that a continuous dryer would be safer and more efficient than the existing batch operation. However, insufficient data was generated to make a final selection. It was concluded that in order to obtain the information required for the design of a production facility, a continuous operating pilot plant for the dry processing of ball propellants should be built and evaluated.

SUMMARY

The objectives of this effort were: (1) to select, assemble and demonstrate a continuous, pilot-scale, ball propellant dry processing prototype system; and, (2) to develop accurate design data necessary for construction of a safer, more modern ball propellant drying and surface salt coating facility.

The first year project (FY74) resulted in a preliminary design and a hazards analysis. Also, it defined the configuration of the feed system. Tests confirmed the reliability of gravity feed of a propellant-water slurry. A schematic of the ball propellant drying system is shown in Figure 1.

The major emphasis of the FY75 program centered on the procurement of process equipment. The Niro Atomizer Dryer was selected because it represented the least costly and intrinsically the safest design. It is an upflow fluid bed dryer with vibrating bed. Since a review of the literature indicated no equipment better than the continuous drum coater in operation at Olin's St. Marks facility, the plan to construct a pilot plant surface coater was cancelled.

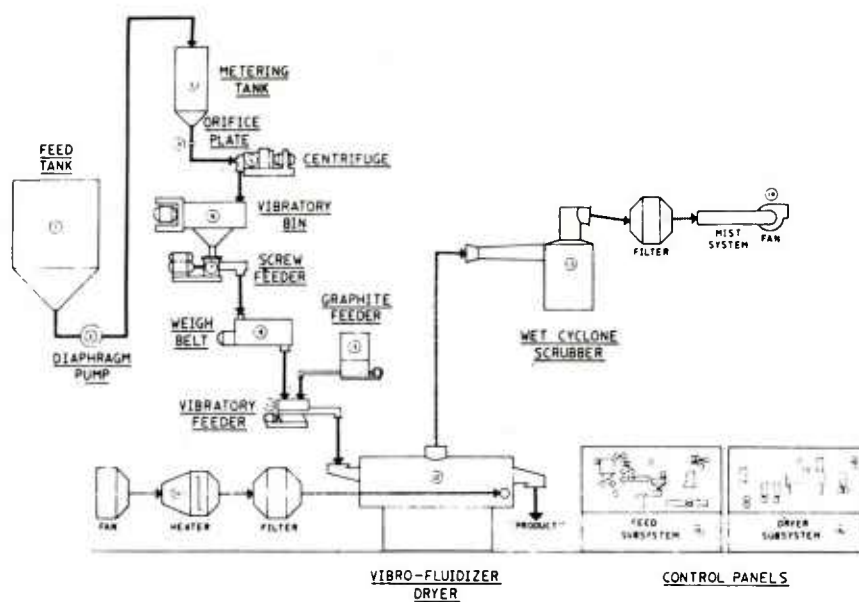


Figure 1 - Ball Propellant Drying System Schematic

In the final FY76 phase, the components of the continuously operating pilot plant were installed and evaluated in order to provide a data base for the modernization of the ball propellant drying lines at Badger AAP. The pilot plant consisted of feeding equipment, a vibratory, fluid bed dryer, process control hardware, and a high speed, fire protection system.

A 32-hour continuous test of the pilot plant demonstrated the ability to produce ball propellant within specifications. The dryer feeding equipment group proved to be able to dewater a slurry of double base ball propellant to a M&V content of $7.56 \pm 0.31\%$ at rates ranging from 50 to 357 lb/hr. The dryer then further reduced the propellant M&V content to $1.06 \pm 0.14\%$ at a continuous running rate averaging 52 lb/hr. The average response time of the fire protection system was determined in tests to be 72 milliseconds.

A continuous process was also designed for the application of KNO_3 and SnO_2 to the surface of propellants used in 20mm ammunition and a preliminary design of a through-circulation belt dryer was prepared. Hazards analyses of all the systems designed or tested were conducted.

The major thrust of this effort was to develop a drying system which could be operated with significant improvement in safety. The pilot plant did not require the presence of personnel in the hazardous area. Operations were monitored and automatically controlled from a separate control room and the drying complex was monitored and protected by an ultraviolet-based quick response sprinkler system. This effort also demonstrated that the product moisture is more controllable which should, therefore, allow for a reduction in the amount of blending required to meet specifications.

BENEFITS

The major benefit of this project is the establishment of a continuous drying process with significantly improved safety. Sufficient data was gathered and organized upon which the development of functional design criteria for a modernized drying plant can be based.

Another beneficial aspect of the continuous design concept is reduced in-process inventory of dry propellants. The batch process results in a product that M&V varies over a broad range. To meet specifications, it is usually necessary to blend propellant from several batches. Due to the more controllable nature of the continuous process, a substantial reduction of blending stocks should be achieved.

IMPLEMENTATION

The results of this project were to have been implemented under Facilities Project 2879 titled, "Ball Powder Line." This project has been deferred to the 1990's time frame. Consequently, no immediate implementation action will be taken. However, the design data accumulated will be invaluable at a later time.

MORE INFORMATION

Additional information can be obtained from Mr. Joel M. Goldman at ARRADCOM, AUTOVON 880-2693 or Commercial (201) 328-2693. The following reports were prepared for these projects:

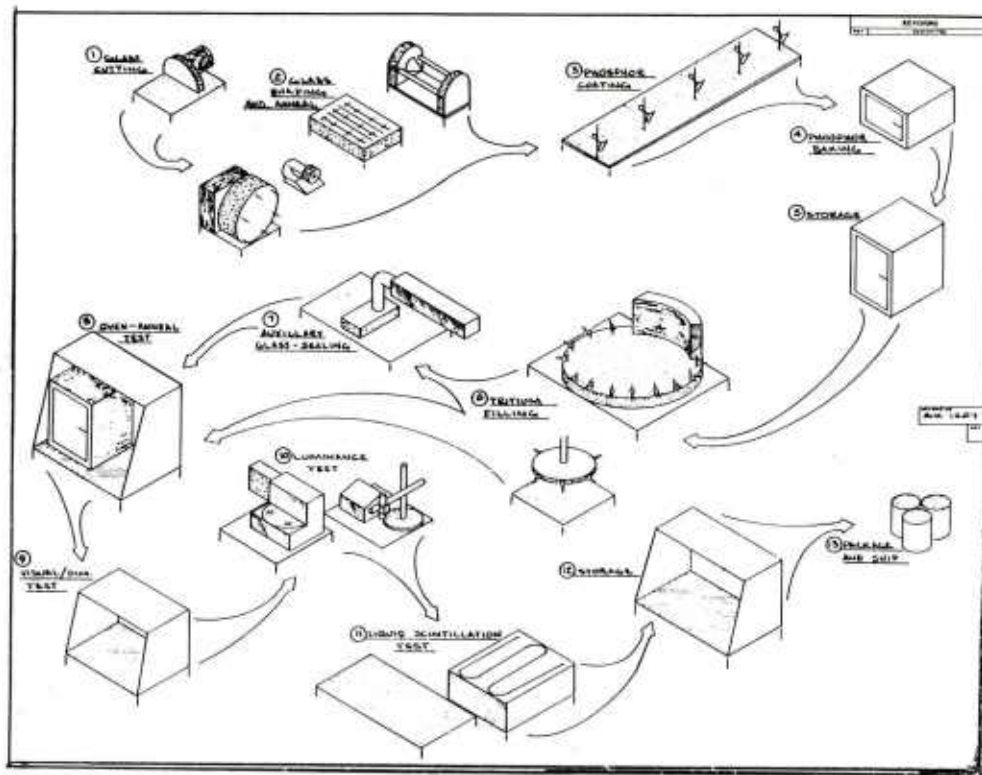
"Pilot-Scale Evaluation of a Ball Propellant Fluid Bed Drying System,"
ARSCD-CR-80024, February 1981.

"Engineering Hazards Analysis of the Wolverine Belt Dryer Design,"
ARSCD-CR-80023, February 1981.

"Selection of a Ball Propellant Dryer for Pilot Plant Evaluation - An Economic Analysis," ARSCD-MR-78001, November 1978.

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

NON-METALS



SELF-LUMINOUS LIGHT SOURCE PROCESS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 175 7042 titled, "Microwave Curing of Epoxy Resins", was completed by the US Army Aviation Research and Development Command on September 1978 at a cost of \$250,000.

BACKGROUND

Conventional techniques for curing epoxy resin and fiberglass composite laminates involve the promotion of polymerization reactions by heating in an autoclave or integrally heated mold. These methods result in temperature gradients and non-uniform heating in thick sections of the material due to the low thermal conductivity of the glass and epoxy. As a result, the core of the structure may not always reach a sufficient temperature for complete cure of the epoxy. A potential solution to this problem is the use of the microwave heating technique. This technique results in uniform heating throughout a dielectric (epoxy) volume exposed to a time dependent electric field; however, in contrast to heating in a constant temperature environment, the temperature of the material increases continuously in microwave heating. Application of microwave heating, therefore, must be closely controlled. Although the temperature of the epoxy can be monitored during heating, the ability to predict the heating behavior, based on an understanding of material and field dependent parameters, is desirable for process control.

SUMMARY

The purpose of this project was to determine the mechanics involved in microwave heating of epoxy systems in order to optimize the cure of thick epoxy fiberglass laminates. Two epoxy systems were evaluated. They were Epon 828, a diglycidyl ether of bisphenol A, manufactured by Shell Chemical Corporation; and 3M Corporation 1009, a 2 to 1 mixture of Dow Chemical epoxy novalac, DEN 438, and Epon 828. The dielectric constant and the loss tangent for these systems were determined as functions of both microwave frequency and sample temperature since the rate of microwave heating is dependent on these constants. These measurements were made on gelled samples of the epoxy systems. A technique for modeling the microwave heating of the epoxy systems was developed from the measurements.

Tests using high power heating were conducted using a conventional microwave oven operated at 2.45 GHz with two available power settings of 245 and 700 watts. The oven was modified by the introduction of a shielded thermocouple into the cavity. The thermocouple entered the cavity via a waveguide, which was of such a length that the cut-off frequency was large

enough to prevent radiation leakage. The thermocouple was placed in a glass tube and inserted into the sample. Thermocouple voltage was monitored with a chart recorder during heating. Results of the heating runs are shown in Figure 1 and 2. The curves show better agreement with a model based on the assumption that the curing epoxies exhibit a bulk loss tangent closer to that of pure water rather than the value measured for the gelled epoxy, and a dielectric constant in the same range as that of the gelled material. The thermal runaway, exhibited after external heating had ceased, resulted from the extremely rapid promotion of exothermic curing reactions. This is another factor that must be considered in microwave curing.

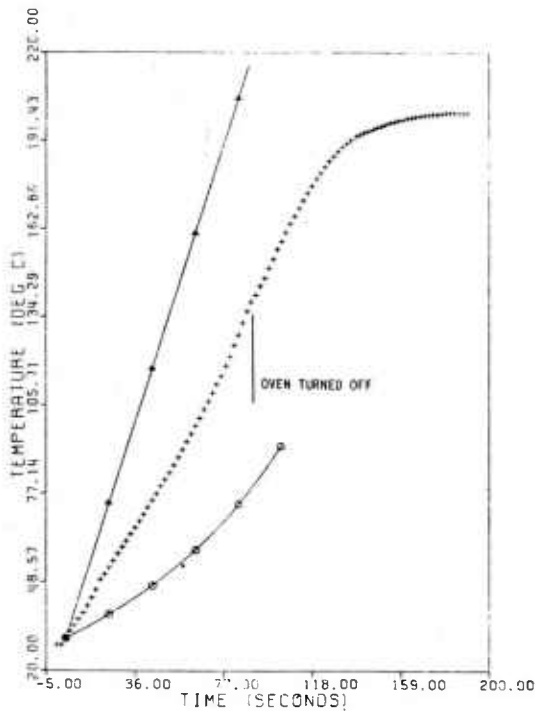
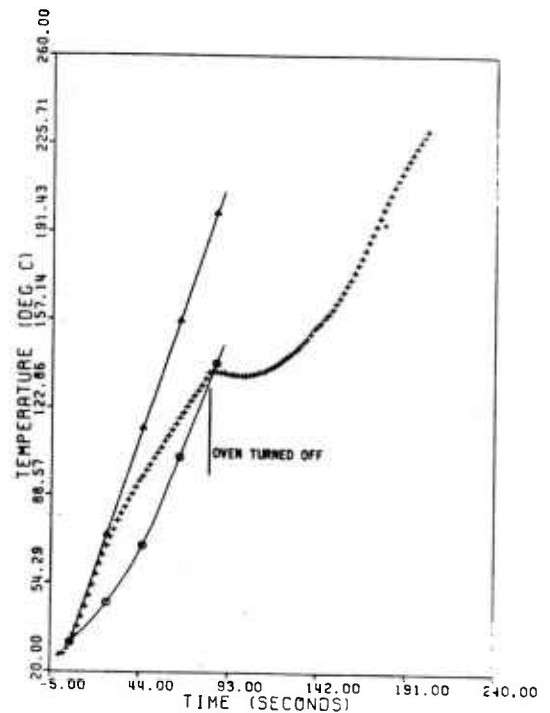


Figure 1 - Experimental Microwave Heating in 30 ml 828-T403 at 245W and 2.45 GHz. Solid Lines Show Models Based on the Loss Tangent of Gelled Samples (θ) and Pure Water (Δ).

Figure 2 - Experimental Microwave Heating in 30 ml 828-Z at 245W and 2.45 GHz. Solid Lines Show Models Based on the Loss Tangent of Gelled Samples (θ) and Pure Water (Δ).



The reasons for the significant difference between the measured values of the loss tangent and the values observed in the high power heating runs are not clear. The most plausible explanation is that the gelled samples used for the measurements exhibited dielectric properties of cured rather than uncured epoxy. Based on the results of this project, it is suggested that microwave curing of uncured epoxies is due to energy absorption by dipolar hydroxyls. It was also determined that the minimum value for the depth of penetration in epoxies is 4 cm.

From these tests, it was concluded that the use of microwave heating to promote the cure of thick fiberglass/epoxy laminate structures is a viable alternative to conventional methods.

BENEFITS

The viability of microwave curing of epoxy based composite systems was demonstrated, and factors relating to control of the heating cycle were identified.

IMPLEMENTATION

A Technical Report, AVRADCOM Report No. 78-46, was issued September 1978. The work accomplished in this project will be continued in a follow-on project (177 7042).

MORE INFORMATION

Additional information can be obtained by contacting Dr. Bernard Halpin, AMMRC, AV 955-3100 or Commercial (617) 923-3100.

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 Project 176 7042 titled, "Microwave Cure of Epoxy Glass Composites", was completed by the US Army Aviation Research and Development Command in May 1980 at a cost of \$250,000.

BACKGROUND

Current manufacturing technology for curing epoxy/fiber composite structures involves the use of large energy consuming facilities such as ovens, autoclaves, and resistant or radiant heaters. These facilities entail costly flow times. An alternative is the use of direct dielectric heating. Cost savings of 75 percent have been realized by the use of this method over conventional conductive curing. Dielectric heating acts throughout the total volume of a dielectric material with substantially greater speed and uniformity than conventional methods. The purpose of this project was to establish a dielectric heating capability for curing fiber reinforced composite structures. Specific objectives were to develop optimum radio frequency (rf) cure cycles for resin/fiber composites, and to establish process parameters relative to feed rate, rf power levels, electrode spacing, and material thickness variations.

SUMMARY

The dielectric curing process established in this project consisted of cycling a self-contained, pressurized tool containing the uncured epoxy/fiberglass part on a conveyor belt between flat-plate electrodes. This approach was adopted since it is compatible with the curing of parts of complex geometry and varying thicknesses, and allows the use of inexpensive nonmetallic tooling. The 90-100 megahertz frequency range was selected. The advantage of this frequency range as opposed to the microwave frequency range is that virtually all of the heating field is located between the electrodes. The equipment used in this project was a 20-kilowatt conveyorized dielectric heater (Model 20/CV/90) designed and manufactured by LaRose Associates, Cohoes, New York. The specifications for this heater are presented in Table 1.

TABLE 1
Dielectric Model 20/CV/90 Specifications

Power Output	20 Kilowatts
Electrode Area	22 x 35 inches
Electrode Spacing	4 x 16 inches
Frequency Range	72 x 108 megahertz
Belt Speed	0.5 to 5 feet/minute

Two simulated component laminate configurations were used to demonstrate the process. One was wedge shaped, illustrated in Figure 1, and the other was a constant thickness shape. Each laminate was made up of 10 sections separated by peel plys. The prepreg material was Scotchply Type 5P-250-E-33-W-456, Jumbo 50, Unidirectional, supplied in 72 yard rolls 6 1/2 inches wide manufactured by the Minnesota Mining and Manufacturing (3M) Company.

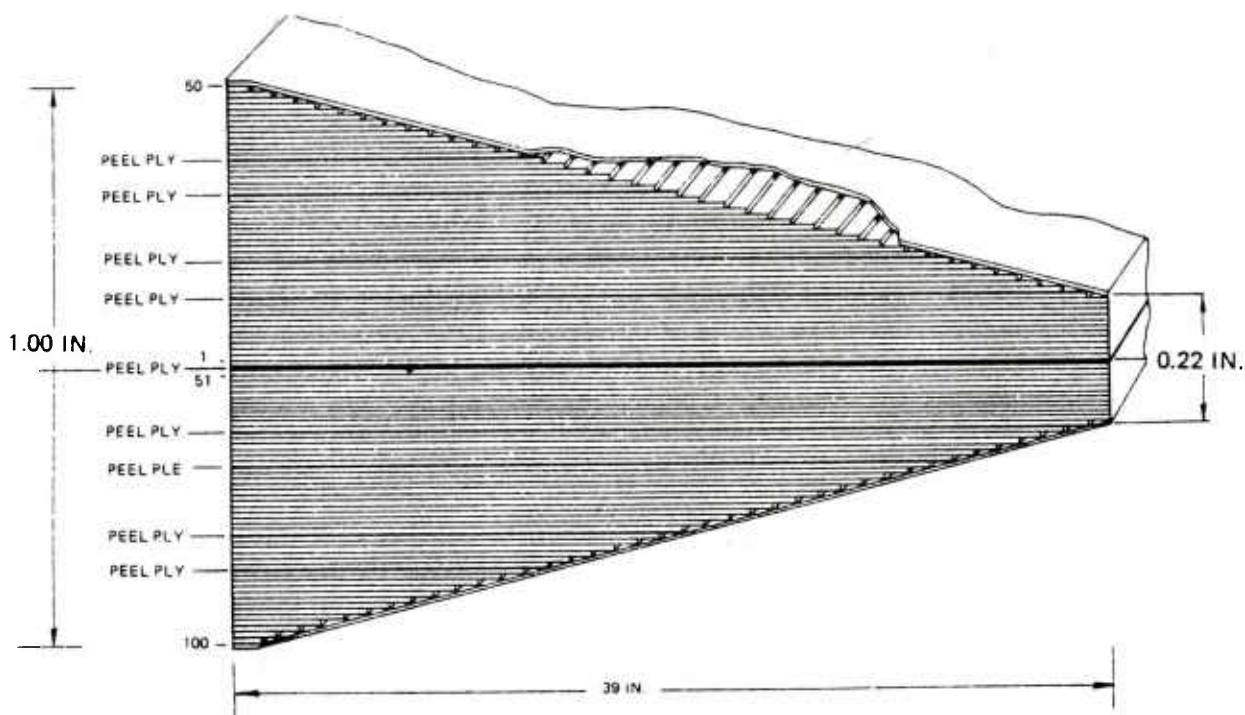


Figure 1 - Epoxy/Fiberglass Laminated Wedge Section

Tooling consisted of matched polypropylene mold dies in four sections: bottom contained the laminate to be cured; midsection floating pressure plate; midsection spacer plate; and top containing a pressure bag. Six sighting ports for IR temperature monitoring were located at six-inch centers along the side of the bottom section. Several nonmetallic tooling materials transparent to rf with appropriate electrical, mechanical and thermal properties were considered. Polypropylene and silicone rubber were selected. Polypropylene was selected because of its low dissipation factor and 2.2 dielectric constant. Its upper temperature limit of 270-300°F and its creep and deflection properties at the cure pressures were of some concern, but consideration of the cure conditions and creep tests eliminated these concerns. Silicon rubber was selected as the material for the pressure bag and edge spacers. The laminate was sandwiched in bleeder cloth, sealed in a nylon bag, placed in the lower tool, and positioned with edge spacers. The midsection spacer plate was then placed on the lower tool and was followed with a floating pressure plate. The top plate, which contained the pressure bag, was then positioned, and the assembly was bolted together at 10 psi with polypropylene bolts. The containment bag was then pierced through the six ports to facilitate resin squeeze-out and fiber optic, IR thermal monitoring.

The laminates were cured by cycling the assembly through the rf field between properly spaced electrodes at a controlled speed. For constant thickness sections, a heatup period of 70 minutes was necessary. For the wedge sections, 120 minutes was necessary since the thinner half of the wedge required additional heating. Thirty to 40 psig pressure was applied during the temperature range 170°F to 200°F, and cure time was one hour at 250°F. Processing parameters reduced themselves to essentially electrode spacing and application of the rf field.

The specimens were tested against a Boeing Material Specification (BMS-8-196A) for Beam Shear, Flexural Strength Modulus, and Tension/Modulus and were measured at -65°F, 74°F and 180°F after oil, boiling water, and temperature exposure. Fatigue, hardness and resin content were also determined. Values for the rf cured sections were slightly below those of the press cured control. Hardness tests and a retest on specimens which were post-cured at 250°F for 16 hours demonstrated that curing was complete in the original run; however, resin content varied from 20-28%. The lower properties were attributed to the inability to apply sufficient pressure because of the creep limitations of the polypropylene tooling material, and to possible damage to the test specimens caused by their physical separation from the parent laminate. It was recommended that polysulfone be used in the future as a tooling material because of its better temperature and pressure performance.

BENEFITS

The applicability of curing epoxy/fiberglass composite laminates by radio frequency heating was demonstrated. It was recommended that additional work be conducted to apply the process to a structural helicopter component. In this way, full applicability and an economic analysis would be accomplished.

IMPLEMENTATION

Implementation of this process will require additional work to demonstrate the full applicability of the process to helicopter components and to determine the extent of cost savings.

MORE INFORMATION

Additional information is available from Mr. P. Dehmer, AMMRC, AV 955-5172 or Commercial (617) 923-5172.

Summary report was prepared by Ferrel 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 Project 178 7121 titled, "Integrally Heated and Pressurized Tooling for UTTAS Rotor Blades", was completed by the US Army Aviation Research and Development Command in July 1981 at a cost of \$229,784.

BACKGROUND

Significant costs are associated with autoclave curing and bonding of helicopter rotor blades. This method is relatively slow, energy intensive, requires the use of vacuum bagging and costly tooling, and is susceptible to scrapage due to vacuum leaks and quality problem. In addition, increasing quantity requirements for composite rotor blades are further exposing the limitations of the autoclave process. These limitations have led to new fabrication concepts for bonding and curing such as cocuring and the use of processes other than autoclave.

SUMMARY

The objective of this program was to establish a new, lower cost process by reducing tooling complexity and cure cycle time. The process selected was to be based on a mold system incorporating integral heating and pressurization.

The project consisted of five tasks: article selection, mold design and manufacture, fabrication of demonstration blades, qualification testing, and cost analysis. The candidate demonstration articles were the Bell 214 and 412 main rotor blades and the Bell 599-318-103 bearingless tail rotor. The tail rotor was selected due to its smaller size (74 inches). This would allow the fabrication of a full sized blade within the cost restraints of the project, and the technology would then be scalable to any size blade. In addition, this design had been successfully test flown and has the potential for retrofit on the OH-58 Helicopters in service.

Mold design and manufacture consisted of the evaluation of heat mediums, mold closing mechanisms, mold configuration analysis and design and fabrication of the mold. Heating mediums evaluated were steam, oil, electricity and pressurized water. Mold closing mechanisms evaluated were mechanical devices, hydraulic cylinders, pneumatic cylinders, and pneumatic inflatable tubes (fire hoses). The mold configuration evaluation considered the following options:

1. Electrically heated and water cooled sculptured steel mold.
2. Water heated and water cooled sculptured steel mold.
3. Electrically heated and water cooled steel platens with removable sculptured inserts.

4. Water heated and cooled steel platens with removable sculptured inserts, and

5. Panel coils with removable sculptured inserts.

A mold energy requirement analysis conducted on these configurations resulted in the selection of option five as the most energy efficient. The design of the mold system is shown in Figure 1. Pneumatic inflatable tubes (fire hoses) were selected to pressurize the tool. The retaining structure is composed of steel plate, and the insulation material is transite. The face plates, which provide point load protection and a thermal conduction medium, are composed of 3/8" aluminum.

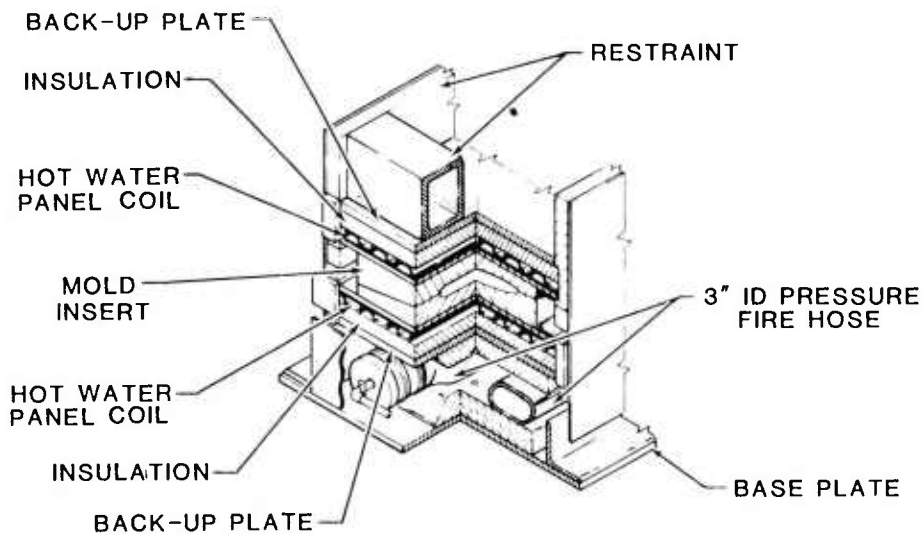


Figure 1 - Mold Structure

The inserts are composed of 6061-T6 aluminum. The bottom platten floats within the mold and transfers pressure to the mold inserts from the expanded fire hoses. The panel coils are composed of stainless steel, and are available commercially.

The completed mold assembly and water and pressure supplies were tested with a solid aluminum block in place of the mold inserts. The test results were:

- o water flow rate: 10.2 gallons/min.
- o temperature rise: 90°F to 270°F in 24 minutes.
- o heat up rate: 7.5°F/minute.
- o total time of test from 90°F: 83 minutes.

Maximum temperature and pressure achievable with this system are 400°F and 400 psi, respectively.

Blade fabrication was the same as that followed in the R&D blade development program, which differed from the proposed production procedure in that the skins and spar were precured rather than the spar only. The blade consisted of glass/epoxy composite with aluminum honeycomb core and doublers, and NARMCO 1113

Epoxy supported film adhesive. Cure temperature was 240-280°F and the time required was 60 minutes (90 min. total cycle time). Three blades were fabricated. One blade is to be tested to the same qualification tests as the R&D blade. The other blades underwent shear, resin content and bond line qualitative evaluation. Non-destructive tests consisted of visual inspection, tapping, and ultrasonic/radiographic techniques. The blades were acceptable.

The cost analysis included tooling, manufacturing labor, materials and energy. Comparison was made with the R&D program blades and autoclave curing methods for a set of 1000 blades. At production rates of less than twenty blades per month, the MMT mold conserves up to 83% of the energy consumed by the smaller autoclave if a single tool is utilized. If production rates in excess of 100 blades/month are required, five autoclave tools would be necessary versus one MMT mold. At this point, energy costs are equivalent but the use of the MMT mold provides a 45% reduction in tooling costs. Other cost savings are realized by the elimination of autoclave bagging and sealing. Also, fewer tools are required to meet production rates. The MMT process can also stack mold inserts to allow curing of two blades per mold assembly that would result in a 25% cost savings on the second blade.

BENEFITS

This curing approach can result in cost savings for any size helicopter rotor blade at production rates typical for military helicopters. A projected minimum savings of \$257,000 is estimated for a production run of 1000 blades at 5 blades a day in comparison to autoclave curing. This estimate does not include capital equipment costs outside of tooling.

IMPLEMENTATION

Tooling technology gained from this program will be implemented for the bearingless tail rotors for OH-58 type aircraft with further application to postforming of pultruded broadgoods and postforming of filament wound broadgoods with/without inserts.

MORE INFORMATION

For additional information contact Mr. Dana Granville, AMMRC, AV 955-3172 or Commercial (617) 923-3172.

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

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology Project 176 7164 titled, "Filament Winding Resin Impregnation System," was completed by the US Army Aviation Research and Development Command in July 1979 at a cost of \$89,200.

BACKGROUND

Precision winding of aircraft components requires precise impregnation control to achieve optimum strength-to-weight ratios. Existing methods of impregnation, including funnel-type baths, orifice-type impregnators, dipping-type baths, and roller/bath impregnators yield a resin to fiber ratio variation of ± 4 percent. Additional difficulties include reduced pot life if resin is heated to reduce viscosity and reduced physical properties of the resin system due to the use of diluents.

An impregnator is needed which will provide control on the order of ± 2 percent. Further, the system has to be effective with a wide range of fibers, including S-2 glass, Kevlar, and graphite roving.

SUMMARY

The non-bath roller impregnation process was chosen to be developed into controllable production hardware. Since it does not require catalyzed resin to be held at high temperature, premature gel or set-up of a large mass of resin is minimized.

A roller impregnator capable of dispensing resin and hardener to the rollers by means of dispensing pumps was constructed. A schematic diagram of the impregnator is shown in Figure 1. The impregnator operates as follows: dry fiber is passed as multiple rovings through a spreader bar at the rear of the impregnator. They then pass through a quartz-element oven where they can be heated to a predetermined temperature. The roving then passes over a dual chamber manifold which delivers the resin and hardener directly onto the roving through separate orifices. The wetted roving then moves over a series of four rollers which work the resin/hardener combination into the roving. At the impregnator output, a second spacer bar maintains roving separation for delivery to winding equipment. Resin and hardener ratios and temperatures and fiber temperatures are controlled from outside the system.

Before attempting actual resin impregnation, the fiber heating unit, resin heating system, metering pumps, and resin delivery system were evaluated to determine operational nature. The feasibility of applying beta gage measurement for determination of roving mass was explored.

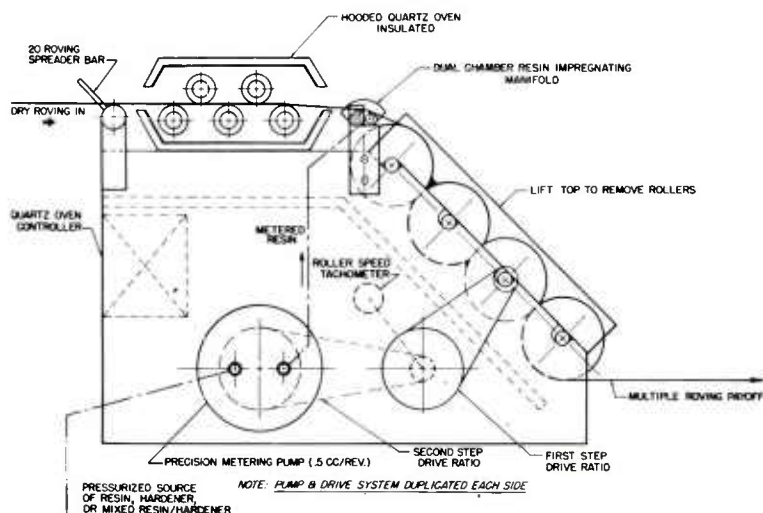


Figure 1 - Roller Impregnator Schematic

Fibers, resins, and a hardener were chosen for testing of the impregnator. The fiber materials included S-2 fiberglass, Kevlar 49, and graphite roving. The resins selected were high and low viscosity bisphenol-A and a solid epoxy-novalac resin. The hardener used was a high viscosity aromatic amine type, chosen due to its reduced hygroscopic characteristics.

A test matrix was devised to yield the optimum resin type, impregnation speed, and resin and fiber temperature combination. Tests included a resin-to-fiber ratio, short-beam shear testing to measure wetness consistency, and microscopic evaluation using the scanning electron microscope to determine resin/fiber distribution. The basic test philosophy was to conduct a general evaluation of process parameters using the less expensive S-2 fiberglass roving to determine the most suitable resin type and temperature for use with Kevlar and graphite.

Test results showed that the impregnator achieved ± 2 percent resin to fiber ratio. They also indicated that direct impregnation is not effected by either roving speed or resin temperature, although industry experience indicates otherwise. The reason for this discrepancy is unknown. The direct effect of fiber temperature was significant, with optimum conditions at 200°F resin and 250°F glass. The resin system chosen for further evaluation was Epon 828 (a high viscosity resin) and APCO 2330 hardener applied at 200°F.

The resulting S-2 glass, Kevlar, and graphite impregnated fibers were subjected to tubular compression, unidirectional tension, and short-beam shear tests. The unidirectional tension results were generally satisfactory. However, the tubular compression and short-beam shear values were lower than expected, indicating that the optimum properties were not achieved. Further development will be required to obtain better matrix properties.

Various additional tests indicated that premixing of resin and hardener is required to obtain thorough mixing, and that beta ray measurement is not feasible for use in determining roving mass.

BENEFITS

This project successfully developed a roller resin impregnator capable of applying resin and hardener to fibers within 2 percent by weight for a given fiber yield. This accuracy is attained by using metered pumps and pressure balance control. The increased accuracy allows reduction of the current 4-1 margin of safety which will in turn reduce the weight and cost of fabricating composite structures. Improvements have also been devised and incorporated into existing machinery designs. These include electronic ratio control of metering pumps, pump pressure balancing, and static premixing of resin/hardener.

IMPLEMENTATION

The contractor on the project will continue to use the impregnator for his wet filament winding (laboratory) work. At the present time, the contractor does not have any wet filament wound components in production. A consultant to the prime project contractor has incorporated project developed equipment improvements into the systems he is selling to industry.

MORE INFORMATION

Additional information concerning this project can be obtained from Mr. Daniel Haugan, AVRADCOM, AV 693-1625 or Commercial (314) 693-1625.

Summary report was prepared by Ferrel 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 174 8035 and 175 8035 titled, "Production of Transparent Forms of Polyolefins for Lightweight Armor Applications" were completed by the US Army Aviation Research and Development Command in April 1980 and January 1981 at costs of \$125,000 and \$125,000, respectively.

BACKGROUND

Sheet acrylic materials used in windows for aircraft or armored vehicles will shatter when impacted by stones, munition fragments, or small arms fire. The best fragment protective lightweight armor material available today is XP, a proprietary opaque or slightly translucent polyolefin material. Other polyolefins, similar to XP materials can be produced in transparent forms. These materials offer significant safety advantages over other available transparent materials. They should be able to give twice the protection at the same weight or the same protection at half the weight. To produce this material, additional effort was required to fully develop the process, optimize operating parameters, and scale up specific applications.

SUMMARY

The general objective of this project was to provide the production technology to produce oriented polypropylene film. The film must then be converted into fragment resistant transparent armor suitable for Army aircraft glazing applications. The manufacturing process must produce a laminate with sufficient adhesion to resist debonding during thermal cycling and yet react as a laminar structure during ballistic impact.

Accomplishment of the objectives required the completion of the following six major tasks:

- Preparation of reference film and sheet to which all other film and sheet could be compared.
- Effect of film characteristics including evaluation of additional films compared with the reference film and the selection of film for optimization.
- Molding of flat sheet to optimize the molding process.
- Protective covers evaluation and selection.

- Process specifications that describe the selected materials and the procedure for converting the film into molded sheet having the desired properties.
- Production of film and bonded sheet in accordance with the process specifications.

These tasks were accomplished in consecutive order so that a film material or processing condition from one task found to improve transparency and ballistic performance could be used in the next task.

The fixed triangular window of the UH-1 Helicopter crew door shown in Figure 1 was used as a demonstration project. Twenty windows (10 each of two thickness) have been molded and coated on each side with an abrasion resistant coating. Also, the primer used before the coating was treated with UV absorbers to impart a degree of resistance to surface degradation by the ultraviolet component of sunlight. These last two items were not lab tested since it was felt that their effectiveness could best be checked by actual flight testing.

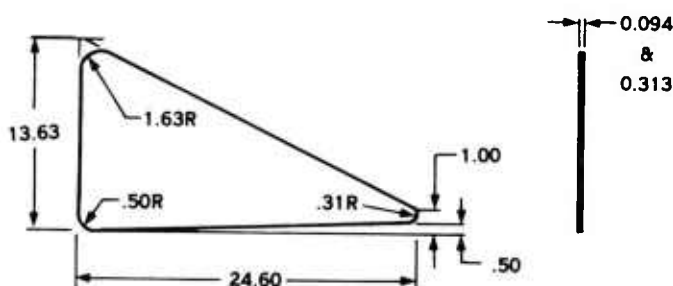


Figure 1 - Fixed Triangular Window of the UH-1 Helicopter Crew Door

BENEFITS

These windows can provide a degree of resistance to penetration by munition fragments greater than can be achieved with acrylic or polycarbonate windows. These windows are completely non-shattering and have good multiple-hit capability. The project has made possible an improved alternate to present commercial transparent materials for aircraft windows. It has been determined that it will cost more to produce transparent armor window than the current window. Therefore, no cost savings from this project are anticipated.

No patent rights are involved.

IMPLEMENTATION

The final report was distributed to Army laboratories, commodity commands, TRADOC, and schools concerned with aircraft and ground vehicles.

If arrangements can be made, flight testing will be conducted to determine whether these windows are visually acceptable to pilots and to assess their durability and resistance to abrasion and ultraviolet light.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. Anthony L. Alesi, AV 955-5103 or Commercial (617) 923-5103. Reference AMMRC Technical Report TR 81-41 titled, "Transparent Polyolefin Film Armor", dated August 1981.

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 277 9827 titled, "Processing of Armor for Radar Antenna Hardening", was completed by the US Army Electronics Research and Development Command in January 1981 at a cost of \$583,100.

BACKGROUND

Current radar systems employ no protective armor. The forward exposed location and large upright area of an artillery locating radar system is highly vulnerable to enemy artillery fire.

Polypropylene film armor consists of multiple plies of highly unidirectionally oriented film. An assembly of such cross-plyed films possess exceptional resistance to penetration by munition fragments. This capability is essentially retained when the assembly is carefully molded into a rigid sheet with the right amount of heat and pressure. Tests determined the electrical characteristics of rigid armor panels and concluded that they had applicability for protecting radar systems without serious degradation of radar performance.

SUMMARY

The general objective of this project was to establish a production capability for rigid armor panels molded from cross-plyed, unidirectionally oriented polypropylene film. The film starts out as a blown tube extruded from polypropylene homopolymer. The collapsed tube is subsequently stretched uniaxially in an oven equipped with radiant heaters. The resulting oriented film is much reduced in width and has a double layer thickness of about 1.5 mils. Winding on a mandrel at ± 45 degrees is then performed and the product cut off the mandrel when an appropriate quantity of film has been wound. This procedure accomplishes cross-plying and assembly into pads. Pads can be stacked to achieve desired armor weight and cut to the desired size and shape. The flexible pads are further processed into rigid sheets by molding.

At the start of work, oriented film was obtained from a company that produced oriented ribbon from polypropylene film. This company had worked with AMMRC in developing its procedures and equipment to produce suitable film. However, the film supplied split so easily in the machine direction that it was not considered suitable for mandrel winding. Also it had been drawn to a lesser extent than optimum. It was decided to use film that would be supplied and oriented by AMMRC on its equipment. The contract work was delayed until mandrel wound film pads were delivered. Upon receipt of this new material, numerous process trials were made while attempting to achieve technically acceptable panels.

Delamination of plies, usually surface plies, was the most severe problem encountered and proved to be the most difficult to resolve. It persisted until an experiment using a rubber surface sheet between the film stack and the rigid caul plate was tried. This resulted in a well bonded sheet which, as shown in Figure 1, had excellent appearance, i.e., no whitening, striation or milky appearance. The rubber pressure pad allows a more nearly hydrostatic pressure application to the film stack and, thus, overcomes the material flow and thickness variation effects which caused the original problem.

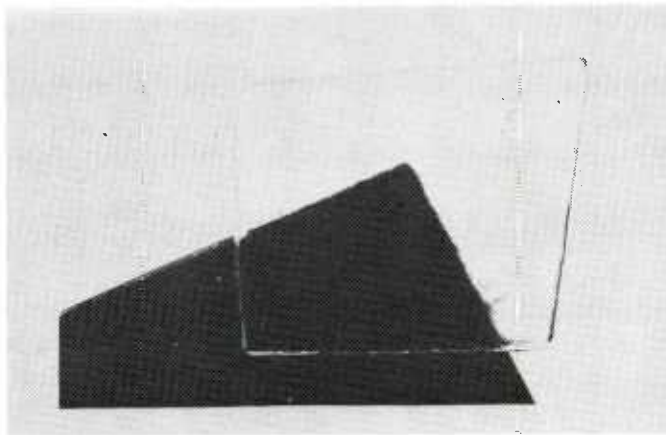


Figure 1 - This Photo Shows the Remarkable Clarity Obtained by Molding the Polypropylene Against 1/32" Silicon Rubber Pads

Ultimately, acceptable panels were produced in a repetitive fashion, such that confidence in the process was established, with the causes of problems which had been encountered, satisfactorily explained.

As a final step a manufacturing demonstration was presented to interested parties from industry and Government. Thus, the successful completion of the project was illustrated.

BENEFITS

No direct production cost savings will accrue to a radar system from the production and application of armor. Rather, there will be indirect benefits since it will be protected from mortar or artillery fire, a considerable benefit because the main system has a very high unit cost and high vulnerability. All radomes requiring hardening could benefit from the application of this material. Current radomes can be put out of action by only one shell burst until affected components are repaired or replaced.

No patent rights are involved.

IMPLEMENTATION

The AN/TPQ-37 artillery locating radar was a prime candidate for radome protection when the project started. However, since its transporter was found to be overloaded, there could be no addition of external armor to the system. Although there have been inquiries from DOD weapon systems contractors and from SATCOM, no specific Army requirements have appeared. The technology, however, will be "on the shelf" in the event that an Army application may develop.

Assistance is being provided to the Navy who are seriously interested in hardening shipboard radars. The Naval Research Laboratory has contracted for the molding of armor panels, their installation on a geodesic dome and measurements of their effect on antenna performance. Comparison will be made among the polypropylene armor, Kevlar armor, and no armor.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Anthony L. Alesi, AMMRC, AV 955-3101 or Commercial (617) 923-3101. Also a technical report, AMMRC TR-80-54 "Molding of Polypropylene Film Armor for Radar Antenna Hardening Applications" was published in January 1981.

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 T78 5062 titled, "Production of Armored Vehicle Vision Blocks" was completed by the US Army Tank-Automotive Research and Development Command in October 1981 at a cost of \$150,000.

BACKGROUND

The performance of the newer lightweight armored vehicles has been severely hindered by the current technology vision blocks. These vision blocks have extremely thick soda-lime glass to provide the ballistic protection desired, resulting in problems of space, weight and poor optical clarity.

Previous R&D programs have made extensive studies in advancing the state of the art in the transparent armor field. The new glass/plastic laminates have lighter weight, improved optical characteristics due to reduced vision block thickness and have eliminated backside spalling. The goal of this project was to study, develop and test comparative technologies, maximizing vision-block visibility and armor-piercing ballistic-defeat capability. This will establish a manufacturing technology to produce vision blocks that provide greater operational performance and protection.

SUMMARY

The two competing designs were glass/plastic and ceramic/glass/plastic laminates shown in Figure 1. The choice of materials is based upon optical transmission, density and commercial availability. The ceramic design was considered because of the very hard surface of the ceramic which allowed a smaller thickness than the glass/plastic design. Goodyear Aerospace Code 706 abrasion-resistant coating was used on the inner surface of the block to protect the polycarbonate ply from chemicals and mechanical abrasion of maintenance. Goodyear Aerospace Code 806 sealant was used to bond the vision block to the metal test fixture because of its low modulus of elasticity and low rate of moisture penetration.

Tests of preliminary laminate specimens were used as a base line for establishing an optimized design. The most significant change was the use of an F6X-2 interlayer which replaced the SR-41 PVB between the glass and ceramic face ply. This facilitated production and demonstrated better adhesion. The shape was also changed from square blocks to a tank vision block form factor.

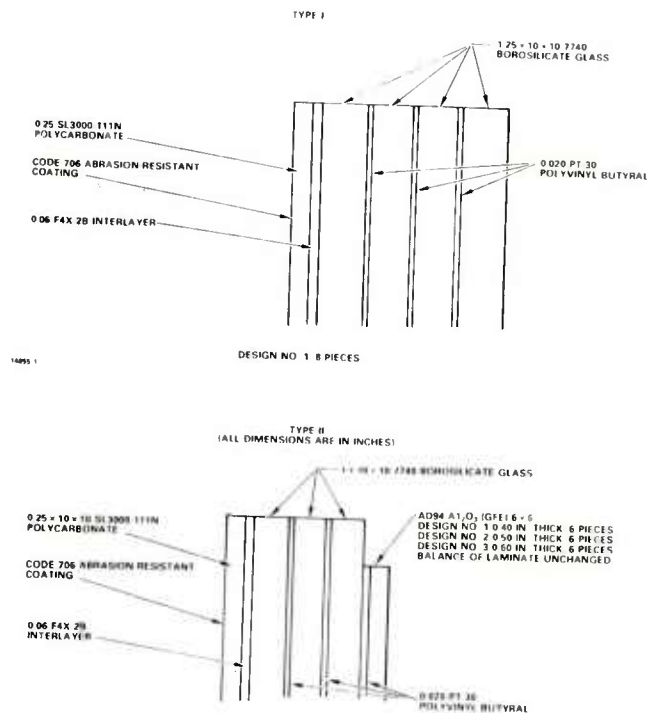


Figure 1 - Phase I Preliminary Designs

Optical tests of the vision blocks indicated a totally acceptable performance for both types. In both the pre and post environmental tests, transmission, haze and distortion were well within the design limits.

The high temperature tests resulted in areas of delamination of the Code 806 sealant on both types of blocks. The low temperature tests resulted in smaller areas of delamination. The temperature shock test resulted in a fracture in the outermost borosilicate glass plate which was probably initiated from an undetected defect on the edge of the glass. The humidity test resulted in small delaminations of the F6X-2 interlayer and the polycarbonate backply.

It was concluded that the glass/plastic design was the more desirable of the two types. The single crystal ceramic would never be cost-competitive with glass although it is superior in ballistic properties. Recommendations were cited to improve the performance of the vision blocks in the environmental tests.

BENEFITS

The Army has now established technology for manufacturing glass/plastic vision blocks for use in many vehicles. These can be modified for use in any area in which there is a significant ballistic threat and where reduced weight is a high premium.

IMPLEMENTATION

The final technical report has been distributed to the various armored vehicle program offices.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Gordon R. Parsons at AMMRC, AUTOVON 955-5514 or Commercial (617) 923-5514.

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 673 7187 titled, "Fabrication for Fiber Optic Fire Control Elements" was completed by the US Army Weapons Command in June 1975 at a cost of \$100,000.

BACKGROUND

Since conventional processes for polishing glass frequently produce scratches, pits and other defects in fiber optic elements, it was determined that there was a need to establish methods and processes which would resolve these problems. These methods would then be published as shop practices and would be recommended to other Government agencies and contractors involved with production of fiber optic fire control elements. This project was conducted to accomplish these objectives.

SUMMARY

This project was an in-house effort at Frankford Arsenal. Highly skilled personnel used equipment and techniques identified with the optical industry for forming, grinding and polishing scratch-free surfaces to exacting specifications. Methods for fiber optic plano-plano, plano-convex and plano-concave surfaces were established. A 6-micron fiber optic boule 3 inches long and 1.4 inches in diameter was used to fabricate the blanks.

The basic production flow for all three types of fiber optic surfaces is as follows:

1. Mount the boule on plate glass with stickum wax.
2. Cut the boule into .475 inch blanks with 6 inch diamond saw.
3. Remove stickum wax with trichlorethylene vapor degreaser.
4. Mount blank horizontally to blocking plate and rough grind.
5. Dismount and remount other side using beeswax.
6. Rough grind and dismount.
7. Bevel edges to 45° to prevent chipping.
8. Mount with beeswax and fine grind.
9. Polish with barnsite compound to three-ring flatness.
10. Dismount and remount other side.
11. Fine grind and polish to three-ring flatness.

BENEFITS

Since this project was based on a previous study of manufacturing parameters to optimize the production process, the results of this project form a reliable process for fabricating fiber optic elements to avoid the defects stated earlier.

IMPLEMENTATION

The methods and processes generated by this project were published as shop practices for Frankford Arsenal and are available to other Government agencies and contractors.

MORE INFORMATION

Further information may be obtained by contacting Mr. Nate Scott, ARRADCOM, AV 880-5631.

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 673 7191 titled, "Fabrication and Testing of Long Wavelength Optical Materials and Components", was completed by the US Army Armament Research and Development Command in August 1975 at a cost of \$275,000.

BACKGROUND

The development of far infrared detectors has been impeded by primitive production methods for refractive IR elements such as domes and lenses. Testing and measurement of the optical properties of the lenses are also in need of development since the techniques used for glass have not been applied to IR optical materials. Project 672 7191 was executed to do an initial study of germanium so that infrared designs could be projected from data for established visible-region optics. An initial study of the testing and processing methods was also made. The goal of this project was to carry these studies to maturity.

SUMMARY

After the initial study, it was evident that the required test procedure would include several tests because of the many parameters which characterize an IR optical element. It was also found that some parameters had a variety of measurement techniques. The techniques explored are enumerated in Figure 1.

The manufacturing process for an IR lens was extrapolated and developed from the processes for glass. These processes are enumerated in Figure 2. It was found that many processes could be carried over with slight modification. The reader is referred to MMT Project 673 7187 titled, "Fabrication Techniques for Fiber Optic Fire Control Elements", in which the techniques for fabrication of fiber optic lenses are similar but different.

BENEFITS

These processes and procedures will permit reduction of raw material waste and minimize breakage of costly lenses.

IMPLEMENTATION

It is intended that the results of this project receive the widest possible distribution through publication of the specifications, tolerances,

<u>MEASUREMENT</u>	<u>TECHNIQUE</u>
Optical Transfer Function	Scanning of Periodic Test Objects Optical Fourier Transform of Slot Spread Function Electro-Optical Fourier Transform Shearing Interferometer
Focal Length	Interferometry Point of Line Source Imaging
Resolution and Contrast	Computer Analysis of Optical Transfer Function
Field Curvature and Distortion	Mechanical Spherometer Optical Test Plates Surface Interferometry
Lens Thickness	Pneumatic Lens Thickness Caliper
Surface Finish	Electron Micrograph FECO Interferometry Scattered Radiation Detection
Material Homogeneity	X-Ray Radiography X-Ray Diffraction Topography Thermal Imaging Infrared Interferometry

Figure 1 - Measurement Techniques

1. Cutting and coring of rough lens blanks from a germanium slab.
2. Surface grinding of blanks.
3. Rounding the edge of a blank.
4. Grinding of surface radii.
5. Rough grinding.
6. Fine grinding.
7. Polishing.
8. Centering.

Figure 2 - Manufacturing Process Flow

quality assurance methods, shop practices, process controls and fabrication methods.

MORE INFORMATION

Additional information may be obtained from Mr. Nathan Scott, ARRADCOM, AV 880-5631 or Commercial (201) 328-5631.

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 677 7741 and 678 7741 titled "Improved Instrumentation for Inspecting Angle and Linearity of Fire Control Instruments", were completed by the US Army Armament Research and Development Command in January 1982 at a cost of \$184,000.

BACKGROUND

Optical items such as periscopes and telescopes are tested for performance requirements by using either auto-collimation, via reticle cross hair superposition, or by bore sighting the unit with a projecting collimator. Analysis showed that both testing procedures require a high degree of operator judgment, and that results can be misinterpreted thus lowering the quality of acceptance testing. This project's goal was to construct an improved angular alignment sensor utilizing birefringent elements to insure optical equipment test fixture alignment and eliminate operator subjectivity.

SUMMARY

Decilog's approach has two channels, one to sense roll and one to sense pitch angular displacement. Yaw information comes from sensing the rotation of the pitch channel through 90°. Figure 1 shows the sensor setup. A polarized output beam from a He-Ne laser is split into two parallel beams for the two channels by use of a beam splitter and mirror/prism arrangement. The pitch channel output passes through an angle sensing crystal. This stationary transmitter unit output is collimated at a 632.8nm wavelength to the receiver which is attached to the test fixture.

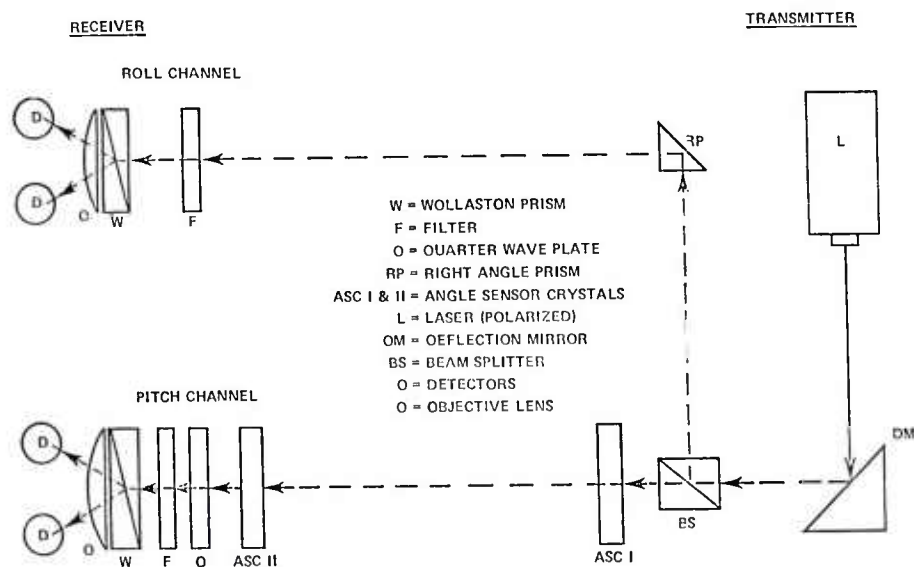


Figure 1 - Roll and Pitch Channel Set Up

The receiver's roll channel consists of a narrow band 632.8nm optical band pass filter, a Wollaston prism and an objective lens. The filter prevents extraneous light (noise) from entering the system. The prism has an index of refraction tensor such that the beam is split into two orthogonally polarized beams diverging at about 15°. Since the incident beam has a set point at 45°, the output of the horizontally and vertically polarized beams should be of equal intensity. The objective lense focuses the beams on two photoelectric diodes which produce a voltage approximately proportional to the intensity of the beams. If the roll angle changes, one beam will become stronger and the other will become weaker. The diode voltages are related to the angular deviation through the equation:

$$\frac{D1 - D2}{D1 + D2} = \sin 2 \theta_r$$

Where, D1 = voltage at diode 1
 D2 = voltage at diode 2
 θ_r = angular deviation from set point

The receiver's pitch channel consists of an angle sensing crystal, a quarter wave plate, a filter, a Wollaston prism and an objective lens. The angle sensing crystal and quarter wave plate are used for exact collimation. The other optical elements perform the same function as in the other channel. This channel behaves according to the equation:

$$\frac{D1 - D2}{D1 + D2} = 2 \sin K \theta_p$$

Where, D1 = voltage at diode 1
 D2 = voltage at diode 2
 θ_p = angular deviation from set point
 K = constant characteristic of crystal

The system is aligned one channel at a time, one element at a time, with some of the steps iterated.

BENEFITS

Analysis showed that the channels were grossly inadequate because of poor sensitivity. Many changes were cited to significantly improve performance; there were no direct benefits realized.

IMPLEMENTATION

Because of poor performance, this MMT project was not implemented.

MORE INFORMATION

Additional information may be obtained from Mr. John Salerno, ARRADCOM, Dover, NJ, AV 880-3628 or Commercial (201) 328-3628. The contract was DAA25-A0120/1119.

Summary report was prepared by Daniel 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 677 7742 titled, "Spot Curing Precision Optical Assemblies", was completed by the US Army Armament Research and Development Command in February 1979 at a cost of \$60,000.

BACKGROUND

Optical elements frequently must be optically aligned to a geometric reference with high accuracy and then cemented together to form a single unified assembly. Complex fixturing is required to provide for, and maintain, precise adjustments; room temperature curing cements must be used in order to have sufficient pot life in the cement for adjustments. Under these conditions, only one assembly can be produced per fixture, per day, thereby greatly increasing cost.

Optical cements which cure with ultraviolet radiation and/or heat are available for bonding optical assemblies. After alignment of the optics in the bonding fixture, selected portions of the cement can be spot cured with an ultraviolet light source to fix the alignment. The assembly can then be removed from the fixture for completion of cure, thus freeing the fixture for a new assembly and also speeding the cure time. The objective of this project is to reduce the cost required to manufacture precision aligned and cemented optical assemblies by using optical cements which cure with ultraviolet radiation and/or heat.

SUMMARY

ARRADCOM evaluated the Norland NOA-61 and Lensbond UV-74 optical adhesive systems by bonding doublets with each. The doublets were cleaned with ethyl alcohol and an even, bubble-free layer of adhesive was sandwiched between the two glass elements. A Ferro-Allied Curing Unit No. 3040 was used to cure the assemblies at the recommended 18 inches. By exposing the doublets for various lengths of time and then attempting to pry them apart, it was found that the optimum exposure time is 4 minutes. There was little photoactivity measured after 4 minutes. The integrity of the cure was found to be just as good when irradiating along the adhesive layer as irradiating the top surface of an element. This means there is a great deal of flexibility in the irradiation orientation of a complex assembly.

The adhesive was found to be rather inert to fluorescent light by exposing uncured adhesive for various lengths of time and then attempting to cure it with ultraviolet light. The experiment revealed that there is a

minimum of 2 hours that can be taken for alignment of a complex system, relieving the technician from time constraints which might result in an alignment error.

The doublets that were cured for 4 minutes were environmentally tested in accordance with MIL-A-3920C. This specifies long exposure periods for extreme temperature and humidity environments. There was no detectable bonding layer disintegration as a result of the tests.

BENEFITS

Spot curing was demonstrated as a desirable alternative to room temperature curing because of the higher throughput of optical assemblies it facilitates, which thereby reduces cost. The curing is not restricted by the geometry of the optics. Figure 1 demonstrates the applications of this bonding method.

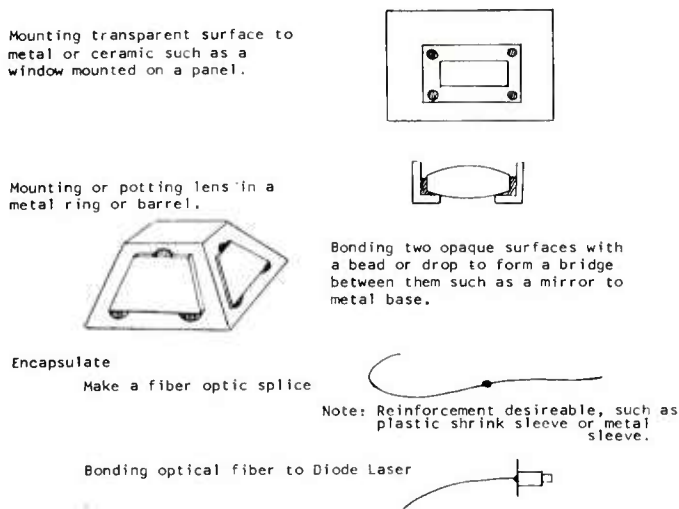


Figure 1 - Bonding Applications

IMPLEMENTATION

Forecasted production volumes of precision optical assemblies are small enough that industry has no incentive to implement spot curing to reduce assembly time.

MORE INFORMATION

Additional information can be obtained by contacting Mr. Jacob Schwartz, ARRADCOM, AV 880-6069 or Commercial (201) 328-6069.

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 776 3551 titled, "Development of a Production Capability for Manufacturing Thin Film Composites Reinforcement, Phase II", was completed by the US Army Mobility Equipment Research and Development Command (MERADCOM) in December 1978 at a cost of \$200,000.

BACKGROUND

Structural components of ribbon bridges and air-transportable construction equipment must be made from high-strength, light-weight materials.

Various R&D studies, including joint ventures by the Air Force and MERADCOM, demonstrated that thin films of metal or ceramic are extremely strong. Some exhibited tensile strengths of 1,000,000 psi with moduli numbers of times greater than the same material in bulk. The minimum grain size for metals and ceramics below which deformation by the usual dislocation mechanism (slip) will not take place coincides with the typical thickness of thin film, approximately 300 Angstrom units. The film, produced by vacuum deposition in a continuous layer, destroys the ability for slip deformation and its near-perfect surface restricts the formation and subsequent propagation of defects. The R&D studies also demonstrated that such films can be deposited, one upon the other, to yield a multilayered composite. Phase I of this Manufacturing Methods and Technology (MMT) project was completed in June 1975 under project number 774 3551. Work efforts included the construction and operation of a bench-scale production apparatus and the investigation of various testing methods to evaluate the strength of the composites.

Both phases were conducted through in-house effort at MERADCOM and contractual effort at Sperry-Univac, St. Paul, Minnesota.

SUMMARY

The overall objective of this project was to establish a process for the production of multilayered composites at a rate of one pound per hour and at a cost well below that of graphite.

Tooling was designed and fabricated for the high rate vacuum deposition of Aluminum-Titanium composite. A schematic of the tooling is shown in Figure 1. A continuously moving looped steel belt, .003 inches thick and coated with photoresist as a smoothing layer and releasing agent, was passed over two independently controlled vapor sources. The aluminum source was a wire-fed intermetallic resistance heated boat while the titanium source was electron beam heated. Both sources operated continuously and were separated by a shield to allow deposition of separate layers of aluminum and titanium. The portion of the belt at the deposition position was passed over a cooling plate to minimize interdiffusion of the two materials.

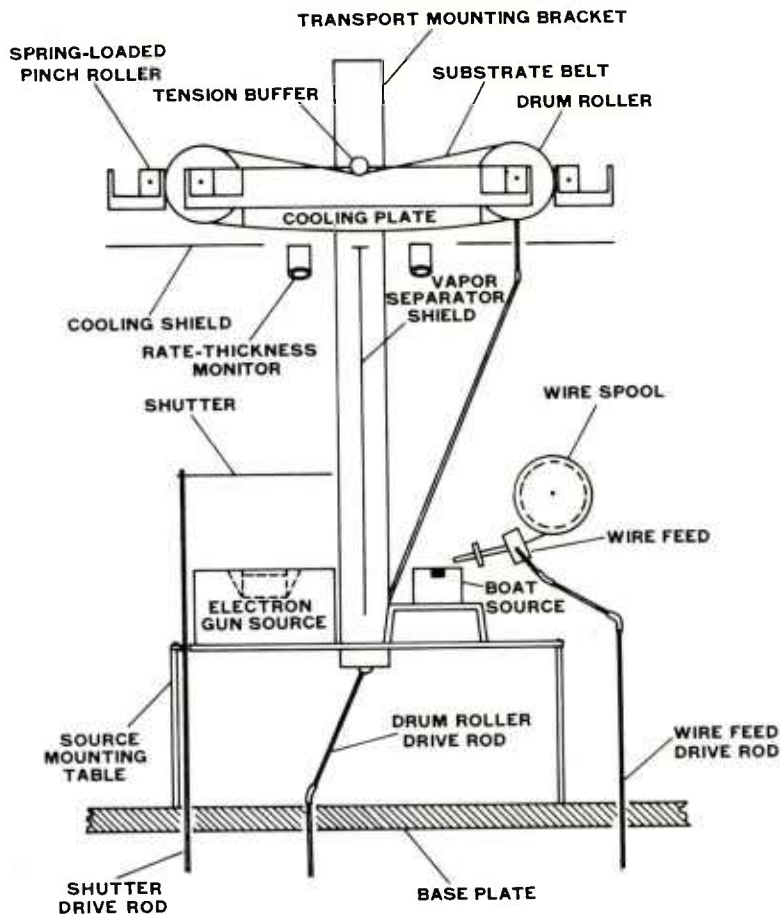


Figure 1 - Tooling Schematic

Manufacturing runs to determine the efficiency of the construction were made. Composite films of titanium-aluminum, silicon carbide-aluminum and alumina-aluminum were fabricated, removed from the substrate (belt), and their ultimate tensile strengths determined. A maximum tensile strength of 540,000 psi was obtained for a titanium-aluminum composite 0.144×10^{-3} inches thick which was comprised of approximately 730 layers of 60 Angstroms thickness.

The chief technical problem which was not anticipated was low tear strength of the composite in spite of its high tensile strength. This caused problems in removing the composite from the substrate after test runs. The substrate and photoresist coating proved satisfactory at lower deposition rates but at higher rates it was not compatible with the higher temperature vacuum environment. The expansion of the steel belt cracked the photoresist layer allowing the composite film to peel during deposition.

BENEFITS

The intended development of a manufacturing method for producing thin film composites was not achieved. The contractor recommended further investigations in the areas of substrate selection, deposition technique and film removal and handling methods.

IMPLEMENTATION

Implementation of this project has been delayed until a more satisfactory manufacturing process can be developed.

MORE INFORMATION

Additional information on this project is available from Mr. Frank Harris, Laboratory 9000, MERADCOM, AUTOVON 354-5471 or Commercial (703) 664-5471. The final technical report from the contractor is UNIVAC DSD Report No. PX 12492.

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 E77 3592 titled, "Improved Graphite Fiber Reinforcement, Phase I", was completed by the US Army Mobility Equipment Research and Development Command in December 1979 at a cost of \$206,000.

BACKGROUND

Aluminum components of military assault bridges are prone to excessive bending during vehicular crossings. In addition, the latest generation of military construction equipment sustains high rates of damage in air-drop operations. In order to allieviate these problems, the materials for these combat engineering items are being updated to improve rigidity and impact resistance. Existing aluminum structures will be replaced or augmented by graphite reinforced plastics. The use of commercial grade graphite fibers can reduce flexure and impart greater resistance to shock loads. However, use of an improved graphite fiber could further enhance operation and reliability. The clear span of a bridge, for example, could be extended by 33 percent and its service life lengthened with no major changes in structural configuration.

The purpose of this MMT project was to develop a capability to produce graphite micro ribbons having higher tensile, compressive, flexural, impact and shear strengths than currently available graphite fibers. The project was conducted through in-house effort at MERADCOM and contractual effort at Fiber Materials, Inc., Biddeford, Maine.

SUMMARY

The objective of this program was to develop a production method for manufacturing high strength, high modulus graphite fiber at the rate of one pound per hour. The method was to be capable of providing fibers with a tensile strength of 750,000 psi and a modulus of elasticity at $60-70 \times 10^6$ psi.

In practical commercial graphite fibers, factors such as internal and surface flaws and weaknesses of the layered graphite structure limit strengths. For a typical fiber bundle of 300,000 psi strength, many individual fibers have low strengths of less than 200,000 psi while others approach the 750,000 psi level. To reach high bundle strengths, the process must yield yarns and tows where all fibers have uniformly high strengths.

During this Phase I effort, an arc-plasma fiber treatment facility was designed, fabricated and optimized. See Figure 1. The facility was capable of heating fiber bundles under tension to temperatures exceeding 3100°C at process speeds up to 100 feet per minute. The reaction atmosphere could be controlled easily and varied at will.

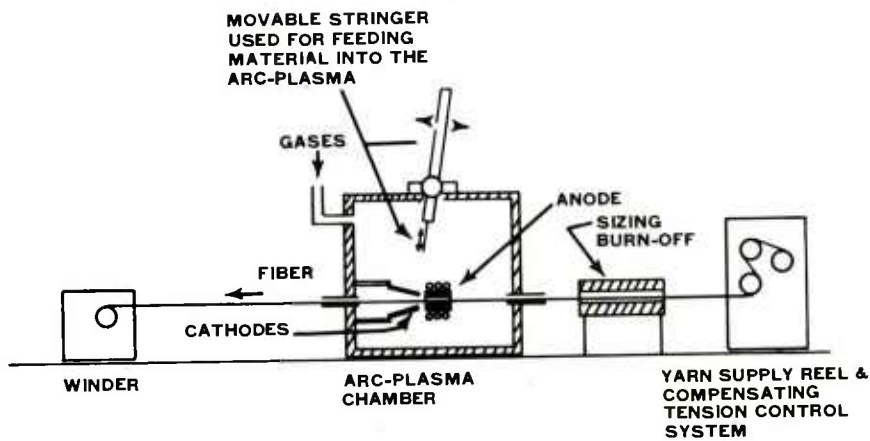


Figure 1 - Arc-Plasma Fiber Treatment Facility Schematic

Cathodes and an anode were fabricated to maintain a stable arc-plasma. See Figure 2. The flame was generated between three carbon cathodes and a cylindrical annular graphite anode. The fiber bundle was passed through the one inch diameter hole in the anode. A two inch long hot zone with an average temperature of 2900°C and a maximum temperature of 3100°C was measured.

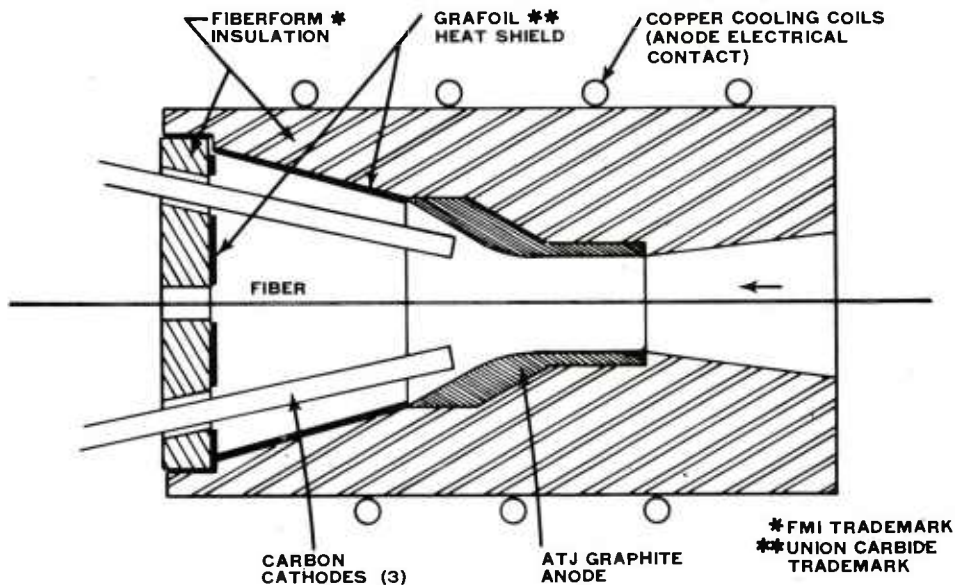


Figure 2 - Optimum Design of Anode and Cathodes for Arc-Plasma Fiber Treatment

Achievements during this phase confirmed past research findings on the effects of boron on graphite. The most successful boron treatment was performed by adding triethylborane, $(C_2H_5)_3B$, to the $Ar/H_2/CH_4$ reaction atmosphere. Average values of 450,000 psi tensile strength at 55.2×10^6 psi modulus were derived from a commercial high modulus fiber (Hercules HM/PVA 3000). The commercial fiber had starting properties of 399,000 psi and 53.9×10^6 psi, respectively.

BENEFITS

Data generated from the boron strengthening process indicated that the predominant strengthening mechanism is the healing of fiber surface flaws. The increase in modulus was thought to be due to straightening of the layer planes of the graphite fiber structure. The modulus increase was accomplished without the customary loss in strength usually experienced in fiber manufacture.

The contractor recommended a scale up of the boron strengthening process to meet the production goal of one pound per hour. Simultaneous processing of seven strands of typical fiber will meet the goal. The attainment of the strength and modulus goals will probably require additional measures. Small diameter polyacrylonitrile (PAN) fibers might be incorporated into the program to maximize both the surface area and the addition of doping elements. A pretreatment of precursor PAN fiber with boron oxide before the carbonization step might be a better way to incorporate boron.

IMPLEMENTATION

Implementation of this project has been delayed pending the results of the follow-on MMT projects; E79 3592 and E82 3592.

MORE INFORMATION

Additional information on this project is available from Mr. Frank Harris, Materiel Tech Lab, MERADCOM, AUTOVON 354-5471 or Commercial (703) 664-5471. The final technical report by the contractor is FM 91178-1, "Improved Graphite Fiber".

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 H76 3126 titled, "MM&T White Starter For Thermal Batteries", was completed by the US Army Electronics Research and Development Command in November 1980 at a cost of \$150,000.

BACKGROUND

Certain thermal batteries used as power supplies in fuzes require an igniter of the White Starter type to initiate the activity of the battery. The M532 E1 fuze, which has a Mobilization requirement, uses this type battery. No industrial capability existed prior to this project for the manufacture of the White Starter. Although these starters have been produced in the past, no capability existed because the equipment used had been dismantled.

SUMMARY

The objective of this project was to establish a modern, improved process and Government ownership of the special equipment required to make White Starters in quantity and at a reasonable price. Prototype equipment was to be constructed to insure availability of the item when needed. This would improve the Mobilization base capability for any fuze using a thermal battery initiated by a White Starter.

The White Starter is the Igniter Assembly, Part 10982040, an acceleration actuated, side-firing starter used to activate various thermal batteries. A cross-sectional view of the Igniter is shown in Figure 1. The one-inch long igniter functions by impacting two pyrotechnic materials (red phosphorus and potassium chlorate) upon being subjected to acceleration in the range from 490g to 650g, per MIL-I-60958.

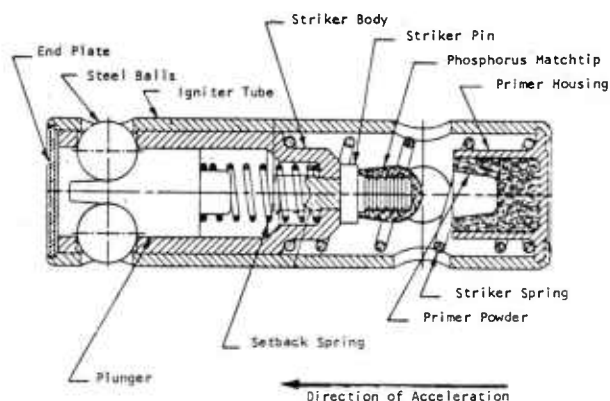


Figure 1 - Cross-Sectional View of 10982040 Igniter

Eagle-Picher Industries (EPI) was awarded the contract and developed the capabilities, methods, processes, specialized tooling, and specialized equipment required to manufacture the White Starter. All production methods are compatible with a design production rate of 100,000 units per month, although, multiple stations would be required to attain full production for certain of the assembly operations. This program included the construction of only one each of the six assembly/testing stations.

Each piece of specialized equipment produced for this program has been satisfactorily demonstrated during a prove-out run. The following table lists the demonstrated production rate and required personnel for each piece of equipment. The personnel required to operate the BIM and FAM could be reduced to one if a sophisticated vibratory feeder loading system were to be designed and incorporated.

DEMONSTRATED PRODUCTION RATES AND PERSONNEL REQUIREMENTS

<u>Equipment</u>	<u>Production Rate*</u>	<u>Personnel Required</u>
Body/Pin Staking	450 units/hr.	1 operator
Striker Assy/Dipping	125 units/hr.	1 operator
Primer Assembly	250 units/hr.	1 operator
Locking-Ball Insertion (BIM)	680 units/hr.	1 operator 3 loaders
Centrifuge Testing	300 units/hr.	1 operator
Final Assembly (FAM)	625 units/hr.	1 operator 3 loaders

*100,000 units per month = 625 units/hr., based on 1-8-5 operation.

EPI prepared a report describing the manufacturing and assembly methods, equipment, and procedures. The report also contains cost statements for the specialized tooling and equipment, maintenance, power, and quality control requirements. A drawing package was made of the specialized equipment.

Based on production with the existing equipment, the estimated unit cost for a quantity of 2,000 Starters is \$5.17. For a quantity of 100,000, the price would be reduced to \$2.67 each.

BENEFITS

This project provided an automatic, high speed, inexpensive manufacturing and testing facility for making White Starters. No such facility existed prior to this program. The principle benefit of this project to the Army is to insure the availability of White Starters when needed, and improved Mobilization base capability for any fuze using a thermal battery initiated by a White Starter.

This project also results in a lower price for the item since a contractor will not have to set up an automated process, or, as is more likely for a small buy, use extensive hand labor in production.

No patent rights are involved in this project.

IMPLEMENTATION

All four thermal battery manufacturers have been informed of the availability of the new White Starter manufacturing facility.

MORE INFORMATION

Additional information can be obtained from Mr. Malcolm B. Templeman at ERADCOM, AV 290-3114 or Commercial (201) 394-3114. A technical report dated 26 January 1979 titled, "Development of Manufacturing Equipment and Methods for Igniter Assembly 10982040", was also prepared.

Summary report was prepared by Wayne R. 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 H79 3504 titled, "Manufacturing Methods and Technology Measure for Advanced Methods for Fabricating Chalcogenide Glass Infrared Lens Blanks", was completed by the US Army Electronics Research and Development Command in December 1981 at a cost of \$305,142.

BACKGROUND

The advent of Mercury Cadmium Telluride (HgCdTe) detectors in Forward Looking Infrared (FLIR) systems has given rise to an infrared optical material combined with germanium for color correction. Prior to contract award, the most extensive infrared color correcting glass used was Texas Instrument's $\text{Ge}_{28}\text{Sb}_{12}\text{Se}_{60}$ (TI 1173).

Design studies, however, indicated that GeAsSe glass, specifically $\text{Ge}_{33}\text{As}_{12}\text{Se}_{55}$ (AMTIR-1), is less susceptible to heat shock and could be used as a TI 1173 substitute in the TOW NIGHT SIGHT and in FLIR devices. Methods for producing ARMY NIGHT TARGET ACQUISITION SYSTEM (ANTAS) lens blanks from 6 inch diameter GeAsSe glass plates were developed and a 125 lens blank per month capacity was demonstrated. However, the ANTAS program for the TOW NIGHT SIGHT alone required over 200 blanks per month. A larger capacity by increasing cast plate diameter and obtaining greater blank quantities was obviously needed.

SUMMARY

The project's objective was to establish production methods for compounding, and casting uniform GeAsSe glass in 8 inch and 10 inch diameter plates. Work was performed by Amorphous Materials Inc. at Garland, Texas. The approach selected provided about 35 ANTAS blanks per plate or a potential production of 1,820 blanks per month.

Processes for recasting glass scrap and slumping (preshaping) glass blanks to curved form were successfully demonstrated. Analysis verified that there was no appreciable difference between first run glass (prepared from the pure elements) and glass prepared from scraps of used plates. The 80 percent cast yield achieved, exceeded the original 70 percent MMT goal.

Plates were compounded and cast in a round chambered compounding and casting furnace, and then annealed over a three day cycle. See Figure 1. Grinding and polishing preceded plate testing for IR transmission and visual inspection for fracture.

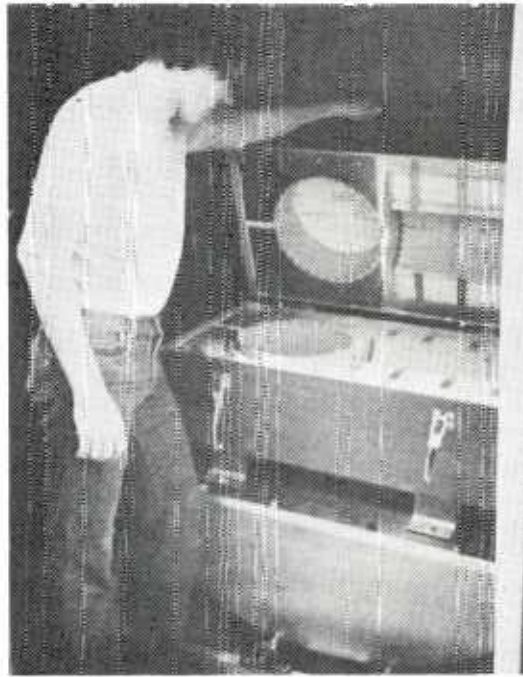


Figure 1 - Round Chambered Compounding & Casting Furnace

After blocking, lens blanks were obtained from plates by diamond core drilling. See Figure 2. Lens blanks were sliced to size using a diamond ID saw, then ground and polished for final evaluation. Final testing was performed using a Diversified Optics Model 1000 Automatic Lens Evaluation Station. Lens blank infrared absorptior, thickness and diameter were recorded and checked against specification requirements.

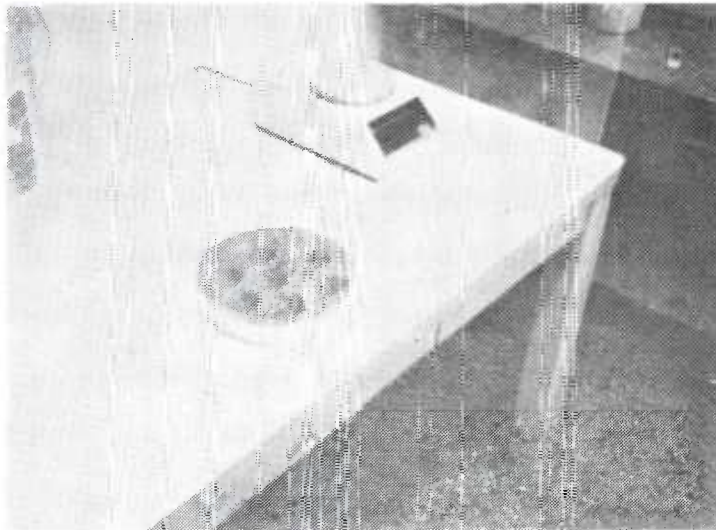


Figure 2 - Core Drilled AMTIR-1 Plate

BENEFITS

As a result of this effort a production capability for compounding and casting GeAsSe glass in 8 inch and 10 inch diameter plates now exists. The number of potential lens blanks per plate was increased 180 percent relative to the previous 6 inch diameter plate casting process.

Additional cost savings resulted from processes developed for recasting glass scrap and for slumping glass blanks to curved form. Slumping lowered unit fabrication cost for curved lenses or domes.

IMPLEMENTATION

GeAsSe lenses fabricated on this project are now used as a direct substitute for the TI 1173 lens in the TOW NIGHT SIGHT manufactured by Kollsman Instrument Company. GeAsSe lenses are also used in the US Army FLIR common modules and in the FLIR version used in the F-16 aircraft.

MORE INFORMATION

Additional information may be obtained from Mr. Eugene R. Lambert, US Army Night Vision & Electro-Optics Laboratory (NV&EOL), Fort Belvoir, VA, AUTOVON 354-1861 or Commercial (202) 664-1861. The contract no. was DAAK70-79-C-0192.

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

APPENDIX I
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