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US ARMY
MATERIEL DEVELOPMENT AND READINESS COMMAND
DIRECTORATE FOR MANUFACTURING TECHNOLOGY

MANUFACTURING METHODS & TECHNOLOGY

PROJECT SUMMARY REPORTS

(RCS DRCMT-302)

JUNE 1984
PREPARED BY

USA INDUSTRIAL BASE ENGINEERING ACTIVITY
MANUFACTURING TECHNOLOGY DIVISION
ROCK ISLAND, ILLINOIS 61299-7260

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This report contains summaries of 100 projects that were completed under the Army's Manufacturing Methods and Technology (MMT) Program. The MMT program was established to upgrade manufacturing facilities used for the production of Army Materiel. The summaries highlight the accomplishments and benefits of the projects and the implementation actions underway or planned. Points of contact are also provided for those who are interested in obtaining additional information.

DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299-7260

REPLY TO
ATTENTION OF:
DRXIB

24 July 1984

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

SEE DISTRIBUTION (Appendix II to Enclosure 1)

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

2. This Project Summary Report is a compilation of MMT Summary Reports prepared by IBEA based on information submitted by DARCOM major subordinate commands and project managers. These projects represent a cross section of the type of efforts that are being conducted under the Army's Manufacturing Methods and Technology Program. Persons who are interested in the details of a project should contact the project officer indicated at the conclusion of each individual report.

3. Additional copies of this report may be obtained by written request to the Defense Technical Information Center, ATTN: TSR-1, Cameron Station, Alexandria, VA 22314.

1 Encl
as

James W. Carstens
JAMES W. CARSTENS
Chief, Manufacturing Technology Division

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INTRODUCTION

Background

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

MMT Program Participation

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

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

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

Contents

This report contains summaries of 100 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. Abstracts were prepared to highlight projects which achieved noteworthy accomplishments.

This report was also organized and bound to facilitate its disassembly. A disassembled report may be used to selectively circulate certain summaries and for filing of selected summaries for future reference.

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

HIGHLIGHTS OF NOTEWORTHY PROJECTS

Project Number	Project Title	Page
H79-5042	Manufacturing Methods for Large Diameter Nd: YAG Laser Crystal	E-12

Neodymium doped yttrium aluminum garnet (Nd:YAG) boules used for fabricating laser rods are now grown exclusively by the Czochralski method, a process developed in the 1960's. This project's purpose was to increase yields of high quality laser rods by producing larger diameter crystal boules. As a result of this effort, cost savings of $300 per rod were achieved, $1.5 million per year savings are estimated giving a $7.5 million total for a five-year production requirement. Project results were directly implemented at Litton Industries, Airtron Division.

H79 9783	Production of High Resistivity Silicon Material	E-18

Increased demand for high purity silicon wafers used for making silicon circuits for phased array radar, optical fuses, and photo detectors for laser seeker ammunition far outstripped domestic manufacturing capacity. The goal of this project was to establish a domestic source for wafers. The Industrial Products Division of Hughes Aircraft Company, Carlsbad, CA, and Westech Systems of Phoenix, AZ, developed a manually controlled zoner for producing detector grade silicon. The manually controlled zoner installed at Hughes is now a domestic source of very high quality silicon. It should reduce the cost of wafers by a factor of 2.8 or 3.

679 7555	Dynamic Pressurization Acceptance Testing of Slide Block Breech Mechanism	I-7

The slide block breech mechanism's functional and proof production acceptance testing is currently performed at a proving ground by live firings. This testing is both time consuming and costly. The objective of this project was to design a testing simulator to reduce time and cost involved with live testing. The primary benefits realized from this effort by the Army was the capability to simulate the slide block breech mechanism production acceptance testing. This simulated acceptable testing has reduced the live firing requirements by 75 percent.

R80 1023 Digital Fault Isolation for Hybrids I-9

The growing use of LSI circuits, microprocessors, RAMS, and ROMS has increased the need for more efficient and economical production testing of the hybrid devices in which they are contained. This effort was funded to establish fault isolation and automotive functional testing for digital hybrid micro-electronic assemblies (D/HMA). Benefits realized include improved techniques for detection, identification, and location of faults in complex D/HMA's. Hybrid circuit test times and operator error were reduced, and testing reliability was increased. An estimated 30 percent reduction in fault costs with savings of $450,000 per year should result.

178, 79 7284 Superplastic Forming/Diffusion Bonding (SPF/DB) of Titanium for Helicopter Airframe Component ME-5

The need for improved performance aircraft has emphasized the need for lighter weight airframes. This project developed a process of (SPF/DB) of titanium for helicopter airframes. The left firewall of an A-64 attack was used as a prototype production component. The process developed reduced the number of fabrication details from 53 to 11, number of fasteners from over 1000 to 314, and decreased weight from 17 to 14.2 pounds. These reductions in materials and operation would save $105 million in production costs and weight savings will save an additional $105 million. Using both left and right firewalls would save $6 million. Implementation is recommended for the AAH-64 helicopter.

T78, 80, 81 5085 Production Techniques for Fabrication of Turbine Engine Recuperator ME-21

In order to reduce welding time and cost, a 2-phase program of screening and verification testing of various welding techniques was undertaken. The machine selected was a 2 kw continuous output CO_2 laser with computer controlled moving output mirrors to allow high speed welding of complex joints. Two recuperators were fabricated and one was engine tested with excellent results. This project is now implemented at Avco-Lycoming, the Army contractor for the AGT 1500 engine. Cost saving of $4.1 million is anticipated based on production forecasts.

681 8113 Establishment of Ion Plating Process for Armament Parts ME-49

Current cadmium electroplating techniques have been found to cause hydrogen embrittlement of high strength steels and alloys, and solid metal embrittlement of cadmium structures. Cadmium is also hazardous to the environment. This project's goal was achieved through the technique of aluminum ion coating. This aluminum coating provides such benefits as: increased thermal operation range 450°F to 925°F and better corrosion protection; no metal embrittlement; allows fuel contact; no toxic waste. Approximately 3,000 armament components will benefit from this coating change.

578, 79 80 4469 Automated Insertion of Grenade Layers MU-22

The objective of this effort was the design, fabrication and prove-out of an automated system to insert prepacked grenade layers into the M483A projectile at a rate of six layers per minute while checking for all possible defects. The machine chosen was an Allen Bradey Programmable Logic Controller (PLC). The system was thoroughly tested and determined to be acceptable for the task. The PLC is also readily adaptable to the same task with the M509 projectile. With this system, operator cost will be reduced, many personnel hazards will be eliminated, and product reliability will be increased - realizing a $1,700,000 savings annually. Installed at Kansas Army Ammunition Plant.

579, 80 4498 Development of Methodology for Consolidation and Automated Assembly of Small Mines MU-26

The objective of this effort was to increase the reliability, safety, and quality of the manufacturing processes for systems to deliver scatterable mines through automation. Prototype equipment was developed which will reduce human involvement and chances for error, and increase assembly safety and reliability. A faster manufacturing process will reduce manhours of direct labor and production cost. The results of this effort have been implemented at Iowa AAP.

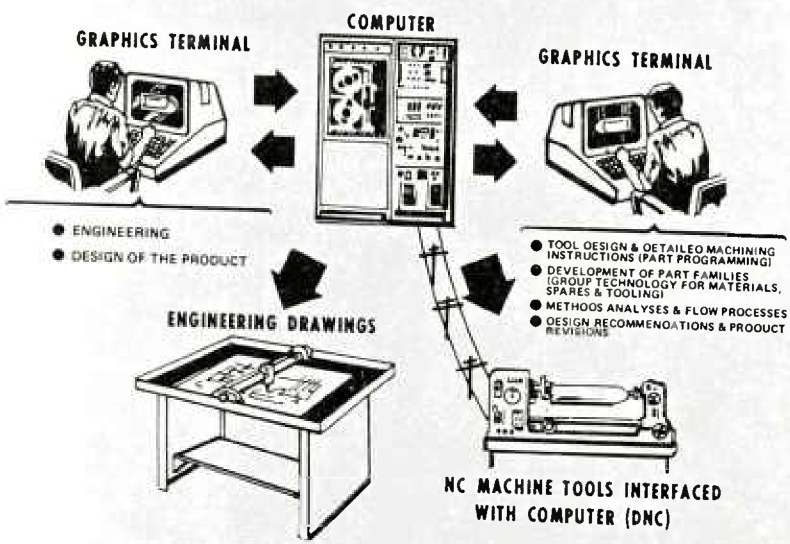
681, 82 7966 Manufacture of Tritium Powered Radioluminous Lamps N-44

The goal of this effort was to improve the method of manufacturing radioluminous lamps by establishing new process controls which would prevent accellerated brightness decay. Four contractors provided a total of 600 samples which reflected the condition of the lamps and their constituents at seven different stages of completion in the manufacturing cycle. Prior to this MMT effort, the lifespan of tritium lamps ranged from two to four years. By improved production methods, the lifespan will increase to six and possibly eight to 10 years. New specifications for tritium lamp manufacture will be released during the fourth quarter of FY84.

R79, 80 3142 Production Methods for Low Cost Paper Motor Components N-55

The cost of a typical missile case has frequently been as much as 50% of the cost of the total rocket propulsion system. The objective of this effort was to establish the appropriate manufacturing methodology for producing low cost paper motor components. Kevlar Paper is the preferred material for the usage planned, given its cost and weight savings and increased strength; however, implementation must wait for a commercial source of Kevlar paper in widths of 72 to 100 inches.

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



INFORMATIONAL FLOW IN A COMPUTER SYSTEM

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

MMT Project **381 1072** titled **"Multiple High Reliability/Low Volume LSI Manufacturing (CAM)"** was completed by the US Army Missile Command in June 1983 at a cost of $1,540,000.

BACKGROUND

The Department of Defense pays excessively when procuring integrated circuits (ICs) for mature systems where parts are no longer available. DoD procurements are typically low volume for any particular IC type while the semiconductor industry is geared to supply parts in high volume for industrial or consumer items. DoD needed a source for discontinued or obsolete semiconductors. This problem was magnified by the many technologies used to manufacture semiconductors for the individual Services.

SUMMARY

The program's objective was to develop a new approach for making ICs using multiple technologies in a single facility. This would be done by dividing the processes into manageable process building blocks and, using the group technology approach, establishing a common technology for those blocks.

Initially, a survey of current and near future industry methods was made and the results analyzed to form a basis for a fabrication plan. Next, a processing plan was developed to show fabrication techniques, process flows, process specifications, equipment needs, and capacity required.

First, common process steps were developed for both positive and negative photoresist methods. Then the problem of handling a large mask inventory was addressed. Logic arrays were used to cut mask inventory where possible and the mask inventory was computer controlled.

After analyzing various etching methods, optimum techniques were selected for each of the photolithographic steps. Demonstration lots were run to prove the processes at the specified rate and provide data for evaluation.

Next, a multi-dopant source was obtained and exercised; procedures were demonstrated for both liquid phosphorous and liquid boron deposition systems and a diffusion furnace programmed for the diffusion and oxidation steps. Finally, chemical vapor deposition of either nitride or polysilicon was demonstrated.

Control of the above procedures was defined in "computer aided manufacturing" language and software written to serve as a data bank for process parameters. As needed, this data is transferred to the process building blocks for operator-less control.

BENEFITS

Benefits cannot be fully realized until Task II, Project 382 1072, is completed. Metallization was not covered in Task I and, thus, wafers cannot be tested, diced into chips, or the chips tested.

IMPLEMENTATION

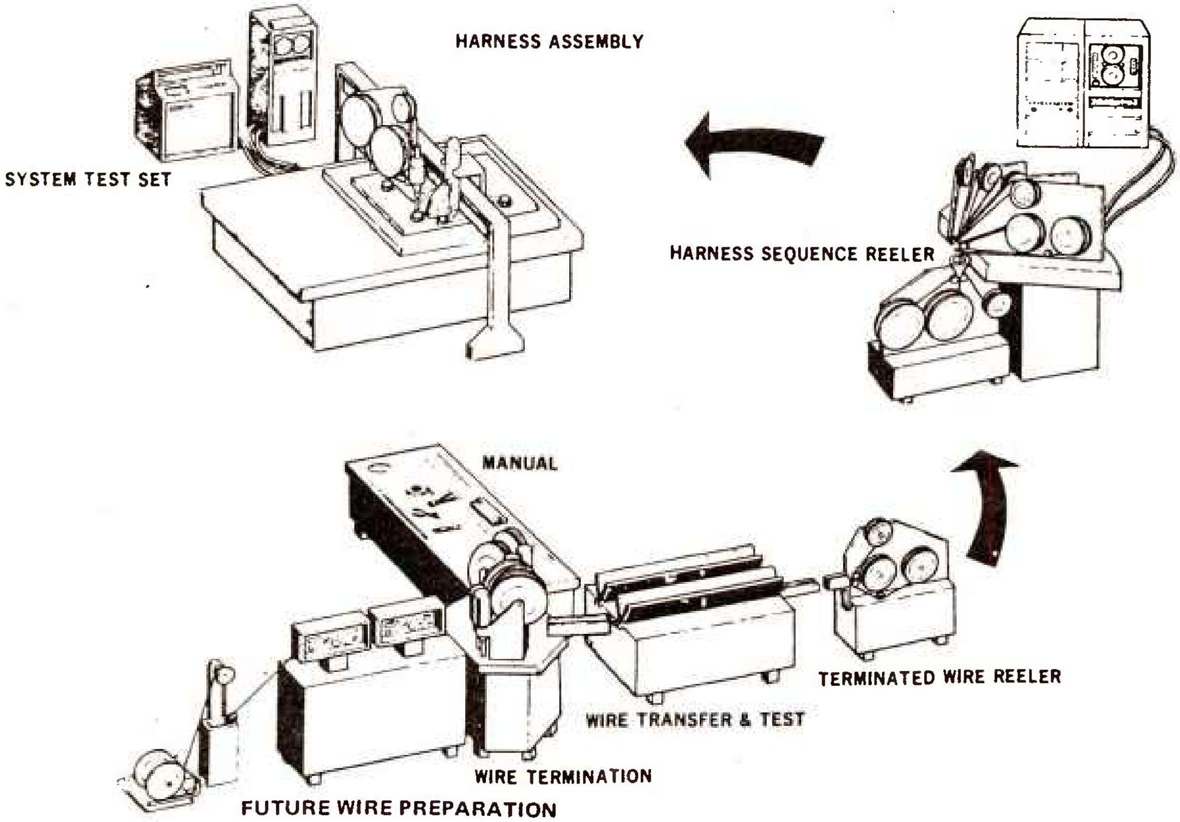
Plans for use of project results were accomplished through distribution of the final technical report and by a technical seminar that presented the results of Task I to industry representatives.

MORE INFORMATION

Additional details can be obtained from the project officer, Mr. Daron Holderfield, US Army Missile Command, Attn: DRSMI-RST, Huntsville, AL 35809, AUTOVON 746-8487 or Commercial (205) 876-8487. The contract number was DAAH01-81-D-A029/0001.

Summary report, Jun 84, was prepared by C. McBurney, Manufacturing Technology Div, 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)

MMT Projects **277 9835** and **279 9835** titled **"MMT - Integrated Thin Film Transistor Display"** were completed by the US Army Electronics Research and Development Command in December 1982 at a cost of $449,000 and $600,000, respectively.

BACKGROUND

Large scale display integration through active matrices formed by thin-film deposition techniques is a technology currently undergoing expansion.

Aerojet Electrosystems developed a small 256-character flat panel, active-matrix addressed Thin Film Transistor (TFT) electroluminescent display. This device was built in the laboratory with manually-operated vacuum systems using "variable-aperture" masks and evaporation deposition techniques to define thin film patterns on glass substrates. Manufacturing techniques for multiple evaporations that reduce blemishes and cycle time while maintaining TFT uniformity over the glass substrate were now needed for production.

SUMMARY

Aerojet Electrosystems Company at Azusa, CA was awarded a multi-phase MMT contract to establish low cost production methods for flat panel thin film transistor addressed displays. The active panel display area consisted of 224 X 80 (17,920) elements (Pixels), each controlled by two TFT transistors, a capacitor, and a set of interconnecting busbars. This matrix was fabricated on the single 2.5 inch by 5 inch glass substrate shown in Figure 1.

The process profile for fabricating the display is outlined in Figure 2. Panels were built in four major layers or "stacks" listed below:

(1) EL stack contains the electroluminescent phosphor and all thin films needed for an EL display.

(2) Counterelectrode stack includes the pixel electrode and divider capacitor, and ground plane.

(3) TFT stack includes all pixel circuit elements.

(4) Addressing stack includes the row and column lines with intermediate dielectric.

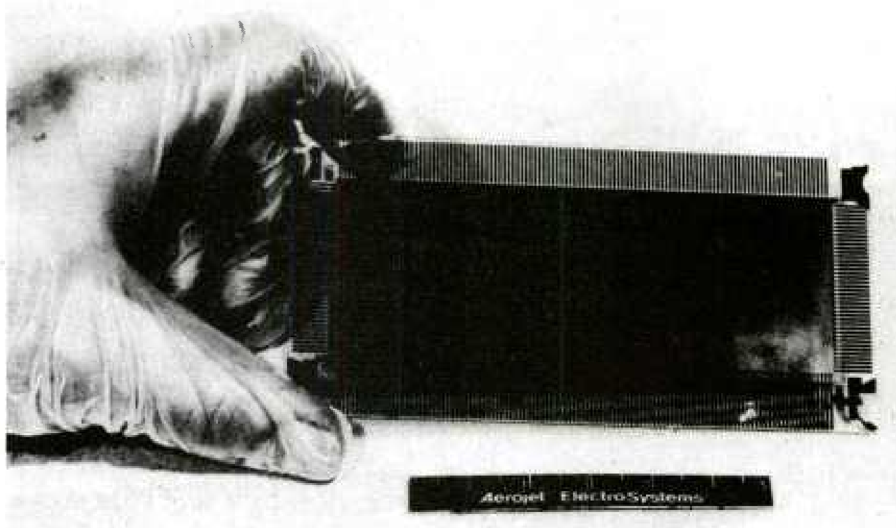


Figure 1 - Flat Panel EL Display

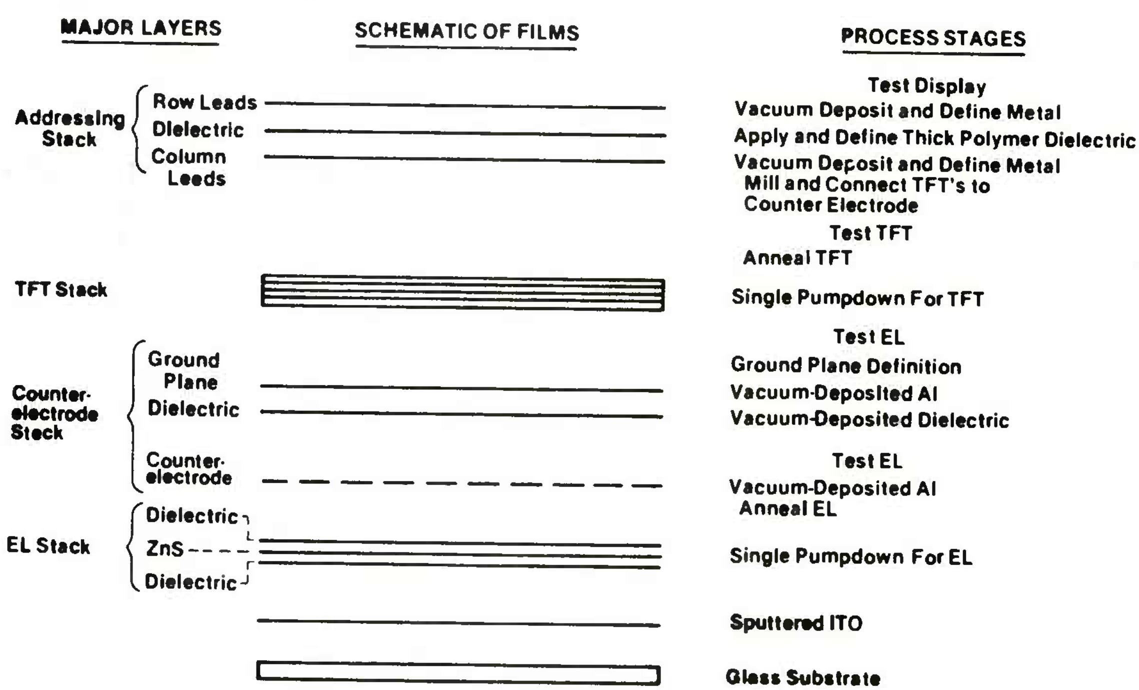


Figure 2 - Process Profile

Panels were made using 15 kovar metal vacuum deposition masks with fixed aperatures. The masks, dedicated to a particular design, were constructed utilizing computer aided design (CAD). Sputtering was accomplished with a magnetron S-gun sputtering machine purchased from Sputtered Films, Incorporated. Vacuum deposition was performed by a four-pocket rotary electron beam source and resistance heated boats. The deposition fixturing was furnished by CHA Industries.

Indium Tin Oxide (ITO) sputtered on the glass substrate provided a transparent conductive front electrode for the EL stack. The EL phosphor material was ZnS with Mn/Cu as the primary activator. Y_2O_3 and Al_2O_3 were used for the dielectric material. TFT materials vacuum deposited were aluminum oxide (Al_2O_3) for the insulator cadmium selenide (CdSe) for the semiconductor, and nickel gold (Ni/Au) for the source-drain.

Significant equipment innovations were the following:

(1) Ball and race aligned tooling set for mask and substrate registration.

(2) Magnetic pulldown for mask clamping to substrate.

(3) Tool and mask carousel for in-chamber vacuum interchange.

(4) A three chimney vapor vacuum deposition chamber.

Results included a basic cell redesign and a greatly simplified aperture mask set which changed substrate processing from a 43 step process to a 31 step process. The need to ion mill was eliminated by using overlapping additive mask deposition. Capacitive coupling was minimized through geometric design of overlapping areas.

Despite these improvements, the resulting displays did not operate satisfactorily. The yields of the four separate stacks (EL, counterelectrode, TFT, and addressing) were high, however all the stacks could not be built upon each other monolithically and operate properly. It was determined that the roughness of each surface was replicated and amplified as additional layers were deposited. This was responsible for the final surfaces being too rough to perform without breaking down electrically.

BENEFITS

Problems experienced relating to surface morphology precluded continuation of the work. It was concluded that the overall process was not sufficiently mature for a pilot plant operation.

IMPLEMENTATION

Because of failure to achieve stated objectives, this MMT project was not implemented.

MORE INFORMATION

Additional information may be obtained from Mr. Robert Miller, CECOM, Ft. Monmouth, NJ, AUTOVON 996-5205 or Commercial (201) 544-5205. The contract was DAAB-07-77-C-0583.

Summary report, Jun 84, was prepared by S. Yedinak, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **576 3062** titled **"Pellet Thermal Power Supply Technology"** was completed at Harry Diamond Laboratories for the US Army Armament, Munitions and Chemical Command in September 1983 at a cost of $150,000.

BACKGROUND

Most production thermal batteries use the Ca/LiCl-KCl eutectic - $SiO_2/CaCrO_4$ electrochemical system. The cells are chemically inert at ordinary ambient temperatures (-54 to +74°C) because the melting temperature which activates the battery is 335°C. Hence, long shelf lives (up to 25 years) are possible. The system is generally highly reliable (99.998% at a 90% confidence level) and suitable for nuclear applications.

The electrolyte-cathode comprises three major components: 1) Depolarizer $CaCrO_4$, 2) Electrolyte, LiCl-KCl eutectic and 3) Binder, SiO_2 and is called DEB powder. The powder is made by a series of heating, sieving, grinding, and mixing procedures. At the end, the powder is pelletized into the desired shape by pressing at a nominal force of 20 tons/in^2.

In developing a new more demanding battery, the PS132, a new problem arose. Of five DEB powders supplied by a commercial source, one was successful in the PS132, one was apparently successful but of limited quantity, one produced frequent battery failures, and two produced batteries that failed almost invariably. An analysis showed that the major cause of battery failure was the formation of an excessive amount of $CaLi_2$ molten metal. The $CaLi_2$ forms during normal operation of the battery and can cause electrical short circuits.

The DEB powder manufacturer had no test for the quality of the powder except for its performance in an actual battery. Testing the powder in this way is time consuming and subject to error because factors other than improperly processed DEB powder can cause battery failure.

SUMMARY

The goal of this project was to establish better methods for DEB preparation and inspection so that batch-to-batch variations could be minimized. Hence, it was hoped to establish processes, process controls, and methods for materials evaluation to accomplish this. A typical pellet cell is shown in Figure 1.

The ultimate criterion for powder acceptability in this study was proper powder performance in the PS132. The PS132 design was particularly appropriate as a test vehicle because a large quantity of PS132 electrical performance data was available from the development program at Harry Diamond

Laboratories (HDL). Also, the PS132 was designed to meet rather severe requirements of size, life, and power. Hence, small differences in DEB characteristics have a much greater effect on battery performance than would be seen in a battery having more relaxed requirements.

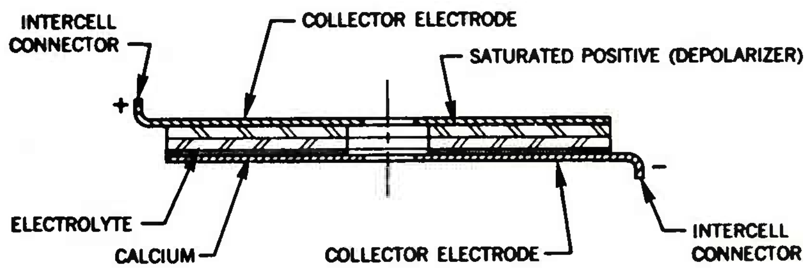


Figure 1 - Cross Section of a Typical Pellet Cell

After finalizing the PS132 design, commercially available DEB powders were tested for their performance in the PS132. Laboratory tests to distinguish usable from unusable powders were then examined. Commercial and in-house prepared depolarizer-electrolyte-binder (DEB) powders and constituents were characterized in terms of chemical composition, homogeniety, surface area, impurity content and flow characteristics in the molten state. These characteristics were correlated with the electrochemical performance of batteries built with these powders.

While no quick and simple test for powder acceptability has been found, it was determined that for thermal batteries with severe performance requirements, the binder content of the DEB powder used is the critical element. Also, uniformity of the powder is very critical. Finally, it was shown that unacceptable powder with the proper binder content can be made acceptable by reheating and/or reblending to improve uniformity.

BENEFITS

The principal benefits from this project are improved thermal battery quality and lower rejection rate. This comes from the knowledge learned that homogenity of DEB powder is the critical element when they are to be used in thermal batteries of severe performance requirements.

IMPLEMENTATION

For pertinent thermal power supplies, TDP's now include requirements for guaranteed powder homogeniety.

MORE INFORMATION

Additional information on this project can be obtained from the project officer, Dr. J. T. Nelson, Harry Diamond Laboratories, AV 290-3114 or Commercial (202) 392-3114.

Summary report, June 84, 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)

MMT Project **579 3960** titled **"Prototype Producing Equipment for Printed Circuit Boards"** was completed by Harry Diamond Labs (HDL) in February 1982 at a cost of $405,000.

BACKGROUND

Printed Circuit Boards (PCBs) made separately or as multiples on small sheets experience processing problems when transferred to large sheet multiple array commercial production. Problems with very fine line width and spacing, wave solderability, registration between layers, and in-process handling show up in volume production. A Technical Data Package (TDP) for a prototype usually needs revision to reflect modifications needed to accommodate production and this revision dictates retesting.

SUMMARY

This program was aimed at simulating a commercial environment within the laboratory. Equipment used in industry was procured, installed and used at HDL. Several preliminary design packages were verified on the line and problems found in circuit board manufacture were documented and fed back to the design engineers. They took these requirements into consideration during design revision.

Other items of equipment were procured and installed at HDL to permit fabricating multilayer boards and larger circuit array sizes using both the common subtractive etching process and the newer additive plating process. Items procured include a ComputerVision plotter, an exposer, developer, etcher and laminator. Two items are shown in Figures 1 and 2. A multi-drill and router procured on another project were also used.

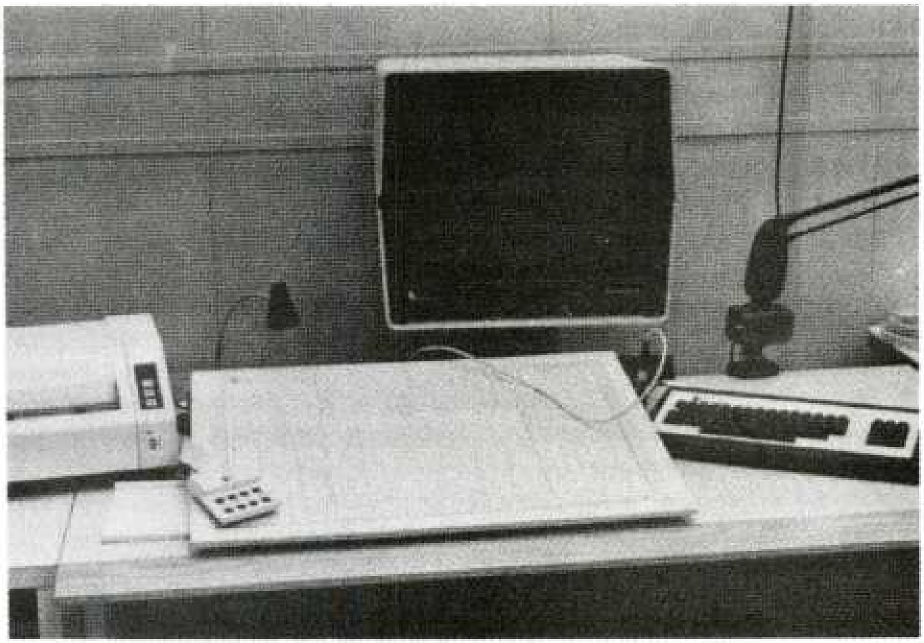


Figure 1 - Computer-Terminal Work Station

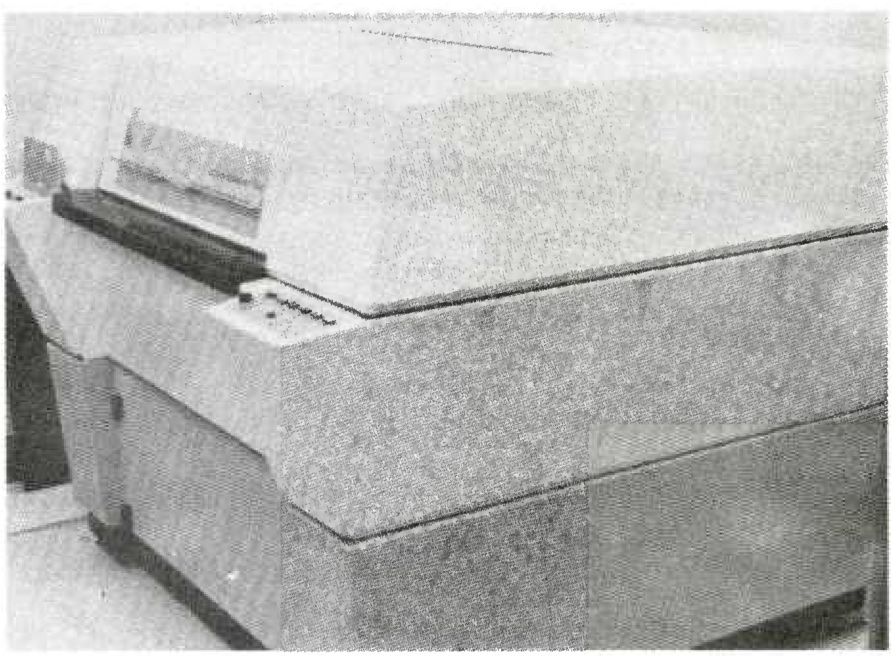


Figure 2 - CV 150 Photoplotter

BENEFITS

Several systems have had their preliminary design packages for PCBs tested on this system: SEAGNAT fuze, unattended expendable jammer, multiple launch rocket system, M732 fuze product improvement program circuitry, M817 fuze circuitry, and others as required.

IMPLEMENTATION

This project was self-implementing at Harry Diamond Laboratories. A brochure illustrating the support capabilities of the Electronic Engineering Technology Branch may be obtained from NTIS or DDC. Its title is "Electronic and Microelectronic Capabilities", HDL-SR-82-5.

The facility is available to support prototype electronic manufacturing needs of any Government agency. It can be used to make both PCBs and hybrid circuits.

MORE INFORMATION

Additional details may be obtained from Mr. Raymond Baker, HDL, Adelphi, MD, 20783, AUTOVON 290-2840 or Commercial (202) 394-2840.

Summary report, Jun 84, was prepared by C. McBurney, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **H78 3511** titled **"Fabrication of Submicron Photomasks for Integrated Circuit Devices"** was completed by the US Army Electronics R&D Command in July 1982 at a project cost of $732,000.

BACKGROUND

When this project was initiated, optical lithography using incandescent light limited the fabrication of integrated circuits (ICs) to line widths of two to three microns (millionths of a meter) and line lengths to five millimeters. Very large scale integrated circuits (VLSIs) required submicron line widths, and line lengths to 10 mm. This project would attempt to demonstrate an ultra-violet lithographic system capable of use in a production environment for fabricating 1.25 micron devices over a one-centimeter area with 0.1 micron alignment accuracy and at a cost lower than competing methods.

SUMMARY

Hewlett-Packard, Rockville, MD and Optimetrix, Mountain View, CA, developed and specified machine design parameters that permit production of equipment within which shorter wavelength (ultra-violet) optics can be used and higher alignment accuracy achieved. Using this equipment submicron device geometries are being produced on substrates in a production environment. Both the wafer stepper X-Y table and pattern generator parallel plate exposure system had to be modified for finer movement.

The first phase of the program was to develop specifications for purchase of a modified pattern generator interfaced to a computer-type controller to provide on-line correction of pattern faults and detection of gross pattern errors.

The second phase was to modify an industry standard pattern generator-image repeater to produce half-micron patterns. A higher quality reticle was used in the image repeater and the pattern generator was modified to produce hard surface reticles with finer (0.025°) angular resolution. A shorter wavelength ultra-violet light source was used to produce an even finer direct printing on the device substrate.

BENEFITS

This program demonstrated an optical system capable of fabricating submicron devices over an area one centimeter square in a production environment at a cost lower than other competing methods. The direct wafer stepper with on-line error correction and image pattern reversal are in use at Harry Diamond Laboratories.

A paper describing the system was given at the 13th Annual MTAG Conference in San Diego, CA, in April 1981. A presentation on the system was also made to VHSIC contractors.

IMPLEMENTATION

The project was self-implementing in that the prototype exposure system was demonstrated and then put into use at Harry Diamond Laboratories in the exposure of submicron integrated circuit mask sets.

It is said that all six contractors producing VHSIC devices are using this technology for the 1.25 micron phase of the program.

The concepts proven here may be put to use on any of one-hundred existing pattern generator-image repeaters operating in the United States today. Economics and need drive this conversion; a 10-year potential savings of up to $3 million is predicted.

MORE INFORMATION

Additional details may be obtained from Mr. Robert Reams, Project Officer at HDL, AUTOVON 290-1390 or Commercial (202) 394-3190. The contract numbers at Hewlett-Packard were DAAG-39-F-5452 and 1175, and the number at Optimetrix was DAAK-80-B-9037.

Summary report, Jun 84, was prepared by C. McBurney, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **H79 5042** titled **"Manufacturing Methods for Large Diameter Nd:YAG Laser Crystals"** was completed by the US Army Electronics Research and Development Command in June 1983 at a cost of $469,224.

BACKGROUND

Neodymium doped yttrium aluminum garnet (Nd:YAG) boules used for fabricating laser rods are now grown exclusively by the Czochralski method, a process developed in the 1960's. At the time of contract award, production boules grown were approximately 1.25-1.50 inch (32 mm - 38 mm) in diameter. This project's purpose was to increase yields of high quality laser rods by producing larger diameter crystal boules. Preliminary investigation indicated that a 2.0 inch (50 mm) boule diameter was attainable. This size could nearly double rod yields per boule. In addition to crystal growth, the effort included rod fabrication and quality testing.

SUMMARY

Litton Industries, Inc., Airtron Division, was funded to refine the Czochralski method to produce larger diameter 2 inch (50 mm), Nd:YAG crystal boules. In current production, this method consists of seeding and pulling a crystal from a melt contained in an iridium crucible. The crucible is heated by means of KHz radio frequency (RF) induced currents.

A conceptual view of the basic crystal growth station is presented in Figure 1. The iridium crucible is size optimized at 4.5 inch diameter, and 4.5 inch height. It is supported by concentric zirconia tubes, surrounded by zirconia grain insulation, and enclosed in a quartz cylinder.

Factors which affect Nd:YAG boule growth are a three component system, operating temperatures, a 1975°C melting point, low distribution coefficient (0.18) for Nd, faceting phenomena, and high melt thermal convection. In addition the Nd:YAG growth rate from the melt is a low 0.5 mm/hr. This places an extremely high demand on the temperature control system.

It was determined best results could be achieved by growing the crystal with a very steep solid/liquid interface projecting down into the melt. While this highly convex shape results in a core formation from facets developed at the tip of the growth interface, most of the strain is confined to a 3-4 mm diameter core region. High quality laser rods can then be extracted from the outer portion of the crystal cross section and in between the radial strain lines.

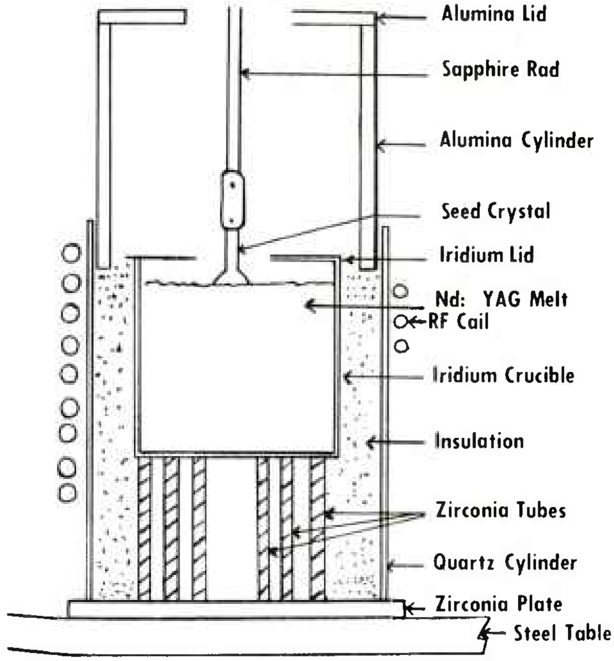


Figure 1 - Outline of Basic Growth Station

Initial runs presented difficulties in enlarging the seed crystal to the finished diameter. Most boules were strained and cracked spontaneously. A technique for gradual enlargement of the seed worked more satisfactorily and allowed short sections of two inch boules to be grown. Cracking of boules was related to blossom formation after seeding, and was caused by large radial gradients in the melt. Measurements were made to define and minimize these gradients for increased chances of large boule growth. The radial melt gradient was reduced by replacing the top two inches of zirconia insulation surrounding the crucible with an alternate insulation. Zirconia with a stabilizing additive of Dy_2O_3 rather than Y_2O_3 or CaO was the substitute. Also melt isotherms were matched to the growth interface by an optimized 15 rpm rotation rate. The growth process which was developed produced boules meeting the goal of 50 mm diameter and 75-100 mm length.

Laser rods were core drilled from the boule utilizing a diamond drill. See Figure 2. After core drilling, rods were ground and polished in a batch processing fixture 15 rods at a time. Antireflective and dielectric coating were applied to opposite rod ends. A group of six laser rods completely fabricated and coated is shown in Figure 3.

An autocollimator was used to measure end face perpendicularly. Scratch and dig standards were utilized to check the polished rod faces, and a Cary spectrophotometer was used to measure reflectivity of the end coatings. A final check for rod optical distortion was performed by means of a Twyman-Green interferometer.

Quality control passive tests showed that specifications were retained by more than 90 percent of the extracted rods.

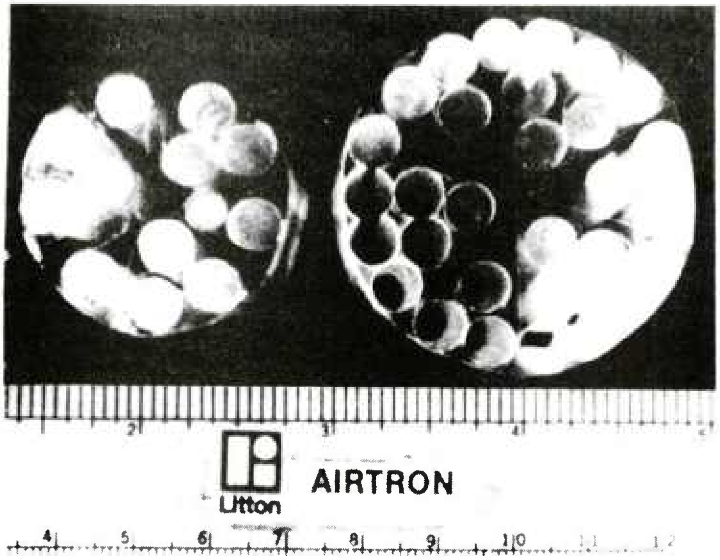


Figure 2 - Core Drilled Nd:YAG Section; Left, Normal Production; Right, Large Diameter Boule

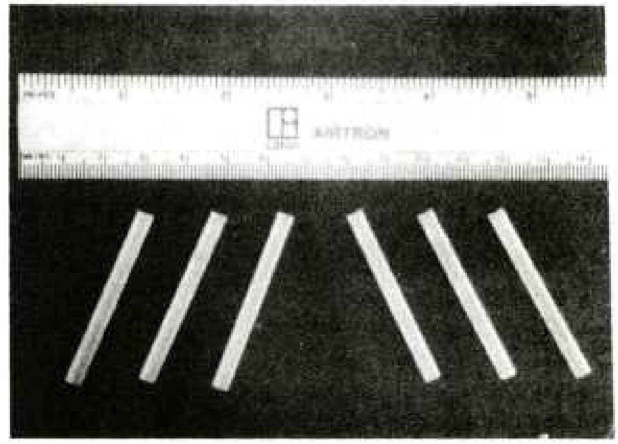


Figure 3 - A group of six laser rods completely fabricated and coated

BENEFITS

As a result of this effort, considerable cost savings were achieved. AN/GVS-5 laser rod cost has been reduced from $600 per rod to $300 per rod. Cost saving for one year is estimated at approximately $1.5 million. Total saving of $7.5 million is anticipated, based on a five year production requirement.

IMPLEMENTATION

Project results were directly implemented into production at Litton Industries, Airtron Division. Five new crystal growth stations for producting larger Nd:YAG boules have been installed and are operating. In addition to the Army AN/GVS-5 Laser Rangefinder, Navy TRAM, Air Force PAVE TACK and NATO projects are relying on production of this material.

MORE INFORMATION

Additional information may be obtained from Mr. Albert Pinto, US Army Night Vision and Electro-Optics Laboratory, Fort Belvoir, VA, AUTOVON 354-4766 or Commercial (703) 664-4766.

Summary report, Jun 84, was prepared by S. Yedinak, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **H80 5110** and **H81 5110** titled **"MMT for Common Module Detector Array"** were completed by the US Army Night Vision and Electro-Optics Lab, US Army Electronics R&D Command, in September 1983. Total project costs were $1,150,000 and $955,000 for the respective fiscal years.

BACKGROUND

Yield and throughput of Mercury Cadmium Telluride (HgCdTe) detector arrays and dewars (cold fingers) were low when this program was initiated in July 1980. Yield was only 12 percent and throughput was only four lots or 16 wafers per month. Goals of the MMT program were to raise the yield to 15 percent and throughput to 10 lots or 40 wafers per month.

Yield is dependent on the ability to characterize the material early in the process, to automate the lapping and polishing procedures, and to install the cold shield without damage to the detector array.

SUMMARY

This was a multi-contractor, multi-year effort to develop new methods for mechanized lapping and polishing of HgCdTe wafers, automatic non-contact thickness measurement, batch wafer passivation, automatic single measurement for cold shield placement, application of bulk anti-reflective coating, and computerized wafer spectral scan. These methods were successfully mechanized at each contractor's facility, although somewhat differently because each contractor manufactures the detector/dewar in different manners. An illustration of the array fabrication procedure is depicted in Figure 1. Not all of the processing steps and none of the inspection procedures are shown. They add considerably to the manufacturing complexity.

Improvements made at Santa Barbara Research Center (SBRC) consist of mechanized lapping of wafers, non-contact thickness measurement, automatic optical microscopic inspection, bulk wafer passivation, computerized spectral scanning and evaluation with a printout of each wafer, bulk application of improved anti-reflective coating, and batch wafer passivation.

Honeywell initiated a pre-process material screening technique, a better array beveling method, an improved kovar coldshield, and several process improvements which were passed on to the production department as soon as they were proven.

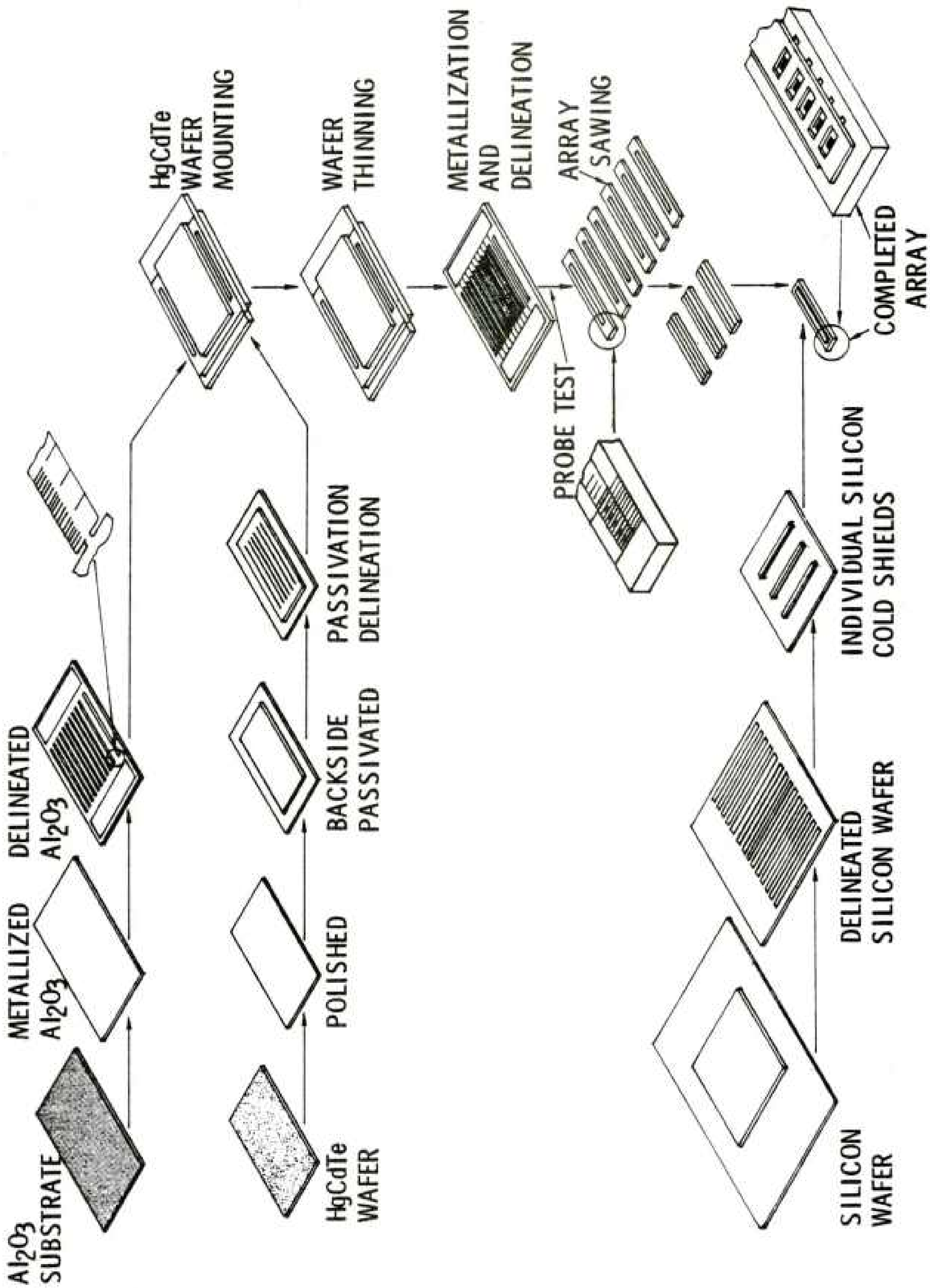


Figure 1 - HgCdTe Array Fabrication

As a second part of this project, Honeywell Electro-Optics Operations at Lexington, MA, developed a procedure to test dewars (coolers) in a dynamic mode. The need for the test became apparent when the detectors were attached to the motorized coolers; the vibration of the compressor piston showed up in the output of the IR detector. The solution was to use a bellows between the cold finger and the cold well. Now a microphonics test is part of the acceptance procedure for all detectors.

At the time these contracts were being negotiated, the Air Force Materials Labs let a contract with Hughes Santa Barbara Research to improve the electrical leadout and interconnect system. This action reduced the amount of funding needed by Army to pursue its work.

BENEFITS

The work at SBRC resulted in raising the yield from 12 percent to 16 percent and the throughput from 16 to 64 wafers per month. Labor hours were reduced 40 percent, staff 63 percent, and floor space 35 percent.

Work at Honeywell resulted in a yield improvement of from 0 to 15 percent and a throughput of from 0 to 4 detectors per day. Work on the microphonics resulted in a baseline test station that will become part of the Initial Production Facility.

IMPLEMENTATION

Results were implemented at Honeywell Electro-Optics Center, Lexington, MA, and at Santa Barbara Research Center, Goleta, CA. The detector arrays/dewars are used in the common module employed in a number of items: AAH TADS Target Acquisition Designation System, PNVS Pilot Night Vision System, Drivers Viewer, M1 Tank Thermal Sight, Fighting Vehicle Sight, AN/VSG-X, and other viewers.

MORE INFORMATION

Additional details may be obtained from Mr. Eugene Lambert and Mrs. Marilyn Jasper, US Army Night Vision and Electro-Optics Labs, AUTOVON 354-1861/1263 or Commercial (703) 664-1861. The SBRC final report on Contract DAAK70-80-C-0073 was authored by Mr. Kaye D. Treese and titled "Manufacturing Methods Report" and is available from DDC. The Honeywell final report on Contract DAAK70-80-C-0072 is classified Confidential and is available to qualified requestors.

Summary report, Jun 84, was prepared by C. McBurney, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **H79 9783** titled **"Production of High Resistivity Silicon Material"** was completed by the US Army Electronics Research and Development Command in August 1982 at a project cost of $918,00.

BACKGROUND

Increased demand for high purity silicon wafers used for making silicon circuits for phased array radar, optical fuses and photodetectors for laser seeker ammunition far outstripped domestic manufacturing capacity. Wafers were obtainable from Wacher Chemical Corporation of West Germany on a commercial basis but it was considered important that a domestic source be established. A previous MMT Project H76 9783 at Hughes developed a small machine for making small boules but a larger, automation-ready machine was sought for greater economy.

Two main processes are needed for the manufacture of high purity silicon. The first is purification of silane from a special sand and formation into rods of polycrystalline silicon. The second is vacuum zone refining of the polycrystalline rod into single crystal rod. A subsequent finishing process consists of cutting the rods into wafers and polishing both sides.

SUMMARY

The Industrial Products Division of Hughes Aircraft Company, Carlsbad, CA, and Westech Systems of Phoenix, AZ, developed a manually controlled zoner for producing detector grade silicon having resistivity of 9,000 to 30,000 ohm-cm with dislocation densities under 1,000 per sq. cm. See Figure 1. High purity silicon is processed from high purity polysilicon rods using multiple-pass vacuum float zoning equipment, the subject of this project. The new equipment is unique in that it uses no cruicible to hold the material. A rod of silicon is held at top and bottom and is rotated and lowered through RF heating coils to permit single-crystal growth. The facility established at Hughes is now a domestic source of high purity silicon and supplies specified material to detector manufacturers. The zoner is adapted for addition of automatic controls which will include zoning program control and a computerized molten zone sensing system.

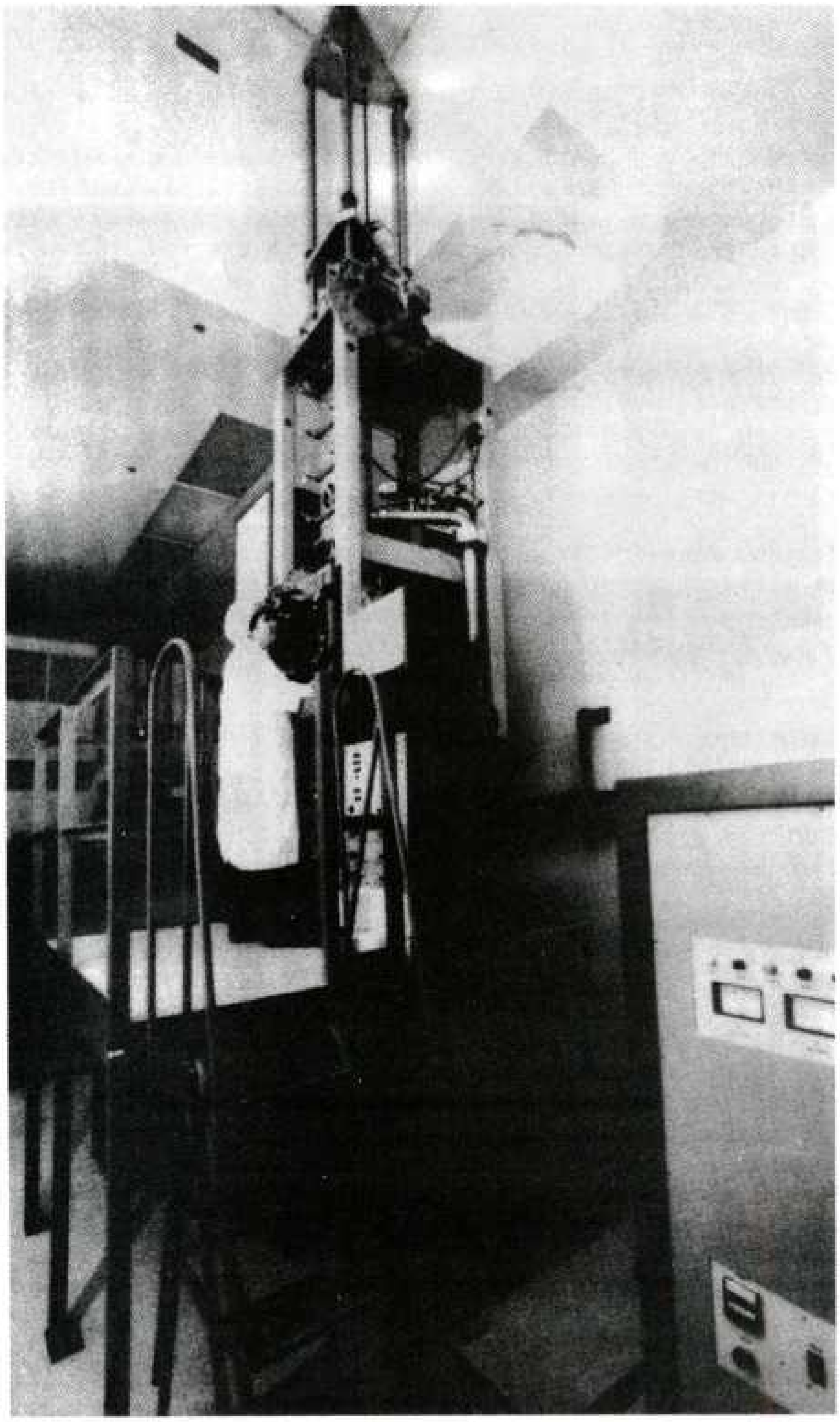


Figure 1 - Intrinsic Silicon Prototype Zone Refiner

Procedures were previously developed for cutting wafers by diamond gang-sawing the long rods, and then lapping and polishing both sides to precise dimensions and surface finish. Double sided free polishing of the wafers was employed; using special pads and compounds, it chemically-mechanically polishes both sides of the wafer at the same time. A zirconium-silicate slurry is used in the rough cut and silicon gel in the final polish with different pads used in each step.

High resistivity wafers are sold to several firms for processing into phased arrays, optical fuzes, and quadrant detectors. Results confirmed the suitability and high quality of the slices. Quadrant detectors have lower dark currents than those made from other material and are excellent detectors of 1.06 micron laser radiation. High resistivity results from low boron concentration and uniform resistivity gradient across the slice.

BENEFITS

This and previous work at Hughes resulted in the establishment of procedures and equipment for vacuum zone refining of polycrystalline rods into high purity single crystal rods which are cut and polished into wafers for use in several high priority items named above.

Data from these pilot operations were analyzed with respect to yield and cost and it is apparent that cost could be further reduced by automating the zoning process. Follow-on Army Project H82 5183 addresses this improvement with computer control being applied to the new zoner.

IMPLEMENTATION

The manually controlled zoner installed at Hughes is now a domestic source of very high quality silicon and is capable of producing material to the specifications of detector manufacturers. Two zoners provide 3.5 kilograms per month; to produce 15 kilograms per month would require nine manually operated zoners or four automated machines. Project H82 5183 was initiated to develop automated vacuum zone refining equipment and procedures. It should reduce the cost of wafers by a factor of 2.8 or 3.

With the double sided polishing procedure implemented into production on a previous project, high resistivity P-type silicon is available for rangefinders, designators, and quadrant detectors for Copperhead, Hellfire, Maverik, and Paveway missiles, and N-type silicon is available for phased array radar and optical fuses.

MORE INFORMATION

Additional information may be obtained from the Final Technical Report 5142-001 titled "Manufacturing Technology to Establish Processes and a Domestic Source of Detector Grade Intrinsic Silicon" or by contacting Mr. Robert Savage, ERADCOM, AUTOVON 995-2887 or Commercial (201) 544-2887. The contract number was F33615-79-C-5142. A second report is available from DTIC titled "Automatic Zoning of Detector Grade Silicon" AFWAL-TR-82-4057.

Summary report, Jun 84, was prepared by C. McBurney, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **H79 9877** titled **"Light Emitting Diode (LED) Array Common Modules"** was completed by the US Army Electronics Research and Development Command in December 1982 at a cost of $626,000.

BACKGROUND

At the time of contract award, there were two problem areas associated with high production rate LED common modules.

(1) High quality GaAsP array material was not normally available from commercial suppliers.

(2) Hand labor and low yield array fabrication techniques were utilized which were not compatible with production.

Project objectives were two-fold

(1) Establish a Vaphor Phase Epitaxial (VPE) growth capability for uniform GaAsP material.

(2) Improve manufacturing techniques for array lead geometry, resistor placement, array identification on wafer, and flange focal length measurement.

SUMMARY

Honeywell Optoelectronics at Richardson, Texas, was awarded the contract to perform the above tasks. An existing VPE reactor was rebuilt with improved fittings and controls. See Figure 1. New mass flow controllers and automatic sequencing provided smooth grading, needed for minimizing wrap and other defects. The epitaxial structure used consisted of a GaAsP epitaxial layer grown on a GaAs substrate. A GaAs buffer layer deposition preceeded the GaAsP epitaxial growth.

Following epitaxial growth, wafers were characterized to determine quality, composition, and doping levels of the epitaxial layers. Measurements were performed on each slice except for conductivity which was measured on a lot basis. GaAsP epitaxial layer composition was evaluated with a photoluminescent test system. This apparatus schematically shown in Figure 2 included a He-Ne laser, lock-in amplifier, monochromator, and preamplifier.

Warp was evaluated using the ADE Microsens. Slice thickness and variation were measured by a non-contact, capacitively coupled technique. The Van Der Pauw method was used to measure conductivity and carrier concentration. This measurement was performed on a chrome doped semi-insulating substrate included in each run.

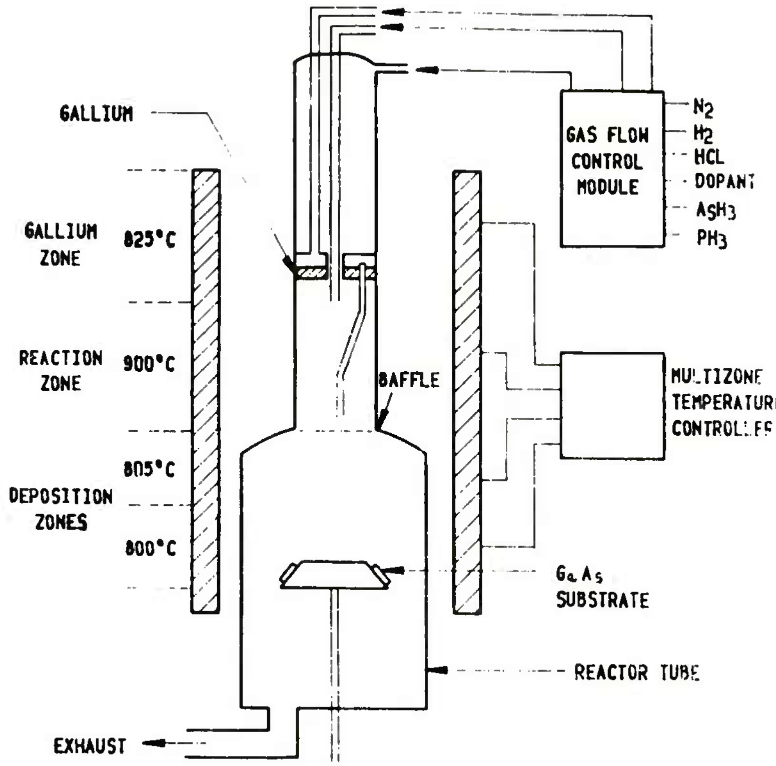


Figure 1 - GaAsP VPE Reactor

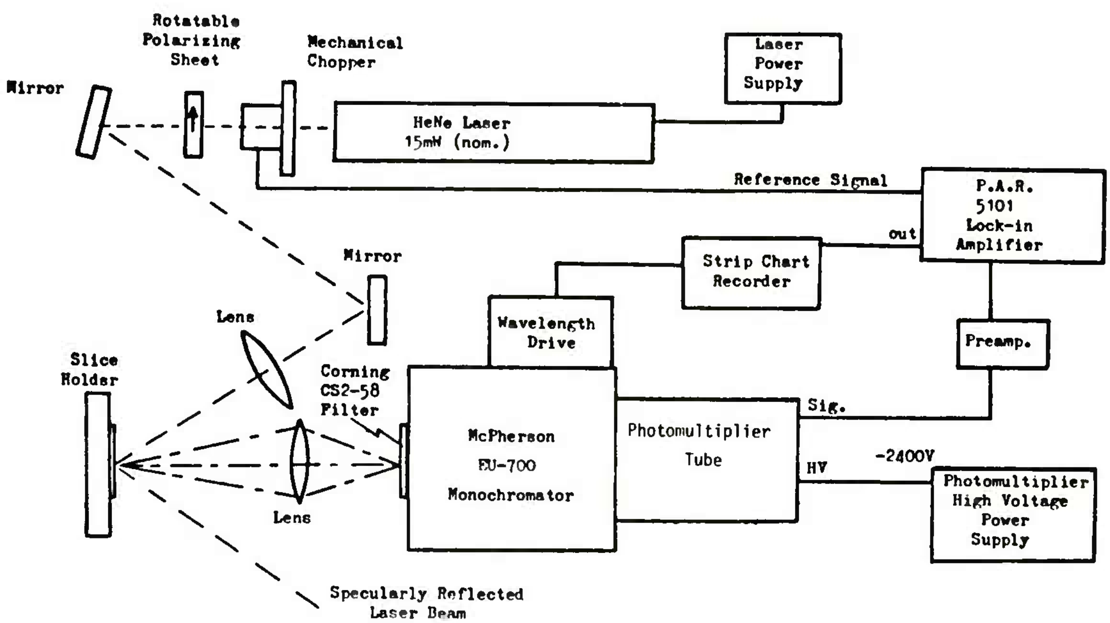


Figure 2 - Apparatus for Measurement of Wavelength of Peak Photoluminescence of Gallium Arsenide Phosphide Wafers

GaAsP slices were processed into the LED array front end area by forming P-N junctions and performing surface metallization. Processes included zinc diffusion into the epitaxial material to form the P-N junction, vacuum disposition and sinter of top and bottom metal contacts, vacuum deposition of the anti-reflection coating, and lapping.

After front end processing, good arrays were identified by wafer probing. These were diced, visually inspected, and eutectically solder die attached to a metallized ceramic header. Die anode contacts were wire bonded to the header. All subassemblies were subjected to a 150 hour burn-in. Major fabrication improvements were the following:

(1) A new alumina substrate with integral laser trimmed thick film tantalum nitride resistors replaced a printed circuit board with discrete resistors. The alumina substrate was fabricated in two 90 resistor element halfs which were joined to provide an 180 element array.

(2) Automated inking with solenoid type inkers for array identification superseded marking by a probe operator.

(3) Uniform element geometry problems were alleviated by modifying metallization masks to provide contacting from only one array side.

(4) Flange focal length measurement operation was relieved by demonstrating a rate capability in excess of that required under the contract.

Confirmatory samples comprising LED modules which met the common module specifications were fabricated with material grown by this effort and delivered to NV&EOL. All contract goals relating to material parameters were met or exceeded.

BENEFITS

This project established a production capability for epitaxially growing GaAsP wafers which met Government specifications. A VPE reactor for producing the GaAsP material has been demonstrated and verified, and LED array fabrication and testing improvements reduced device cost and increased reliability.

IMPLEMENTATION

Fabrication and assembly improvements resulting from this effort were incorporated into the production line for GaAsP LED arrays at Honeywell's Richardson, Texas plant.

MORE INFORMATION

Additional information may be obtained from Ms. Marilyn A. Jasper, NV&EOL, Ft. Belvoir, VA, AUTOVON 354-1861 or Commercial (703) 664-1861. The contract was DAAK70-79-C-0120.

Summary report, Jun 84, was prepared by S. Yedinak, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **H78,81 9889 Task B** titled **"18MM Third Generation 0.9 Micron Wafer Intensifier Tube"** were completed by the US Army Electronics Research and Development Command in June 1983 at a cost of $1,159,500 and $259,000, respectively.

BACKGROUND

Third Generation 18mm intensifier tubes consist of a 0.9 micron glass-sealed GaAs photocathode; input-filmed, high resolution microchannel plate (MCP); and fiber optic inverter output window with a P-20 phosphor screen. See Figure 1.

Figure 1 - Varian Third Generation VLI-238 Lightweight Tube

This device incorporates state-of-the-art design including reduced size and weight; low noise MCP; high resolution fiber optic inverter; InGaAs/AlGaAs/glass photocathode, and reduced input and output gaps to restrict halo size and improve resolution. Tube characteristics include indexing input and output seals to control both proximity gaps and condition of critical sealing edges. This project is Task B of a two-task effort to provide a second source for Third Generation Image Intensifier Tubes.

SUMMARY

Task B was contracted to Varian Associates Incorporated, Palo Alto, CA. The purpose of this task was to establish production techniques and processes for Third Generation Image Intensifier Tubes. Major fabrication areas selected for improvement included tube exhaust/processing.

An exhaust batch system was analyzed and optimized at four ports, a size that minimized equipment costs and insured ten tubes per station per week. The four-port system is shown in Figure 2. Major exhaust process and sealing steps performed with this system were the following:

(1) Tube body and cathode load.
(2) Tube body and cathode bake and cool.
(3) Microchannel plate and phosphor screen electron scrub.
(4) Photocathode preparation (including heat clean).
(5) Cathode activation by applying cesium and and oxygen.
(6) Tube seal and unload.

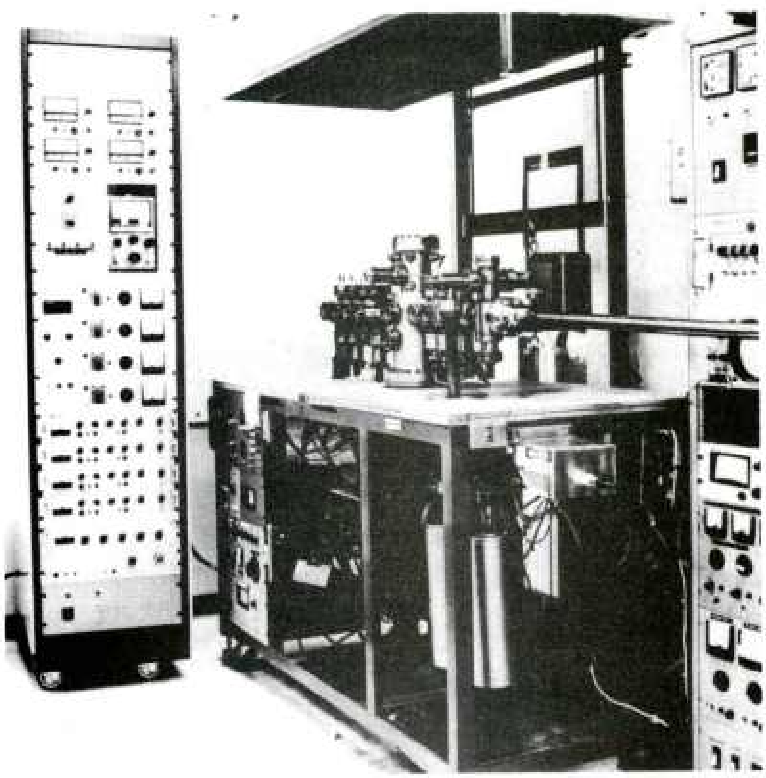


Figure 2 - Varian Four-Port Process Station

The cathode was heat cleaned and activated with cesium and oxygen in a separate chamber before being transferred to the tube chamber for final sealing. Several exhaust equipment modifications were performed, including forced heater block cooling to reduce processing time, double transfer arms to improve component manipulation within the vacuum chamber, and improved current-sensing techniques during cathode activation.

Manufacturing capabilities were also refined for the brushed fiber optic phosphor screen. Screen fabrication processes optimized included fritting, contact metallization, lacquer spin, phosphor brush and bake, Kasil fog and bake, lacquer bake, aluminization, and scrub.

Tube Equivalent Brightness Input (EBI) was enhanced by eliminating outgassing and cathode contamination during processing. This was achieved by remodifying the cesium channel mounts. Tube photoresponse was improved by correcting MCP contamination. An 8-hour MCP vacuum bake, with higher bakeoff temperature prior to final film quality test eliminated the problem.

Principal electrical tests were photocathode sensitivity ($uA/_{lm}$), Ion barrier film quality, photocathode, MCP and screen quality, EBI ($lm/_{cm}{}^2$), luminance gain, veiling glare, halo, and signal-to-noise ratio.

BENEFITS

This effort provided a firm base to improve overall quality and manufacturing yields for 18mm intensifier tubes. Increased production yields and improved performance qualities accomplished should result in overall tube cost reduction. It is estimated tube fabrication costs will be reduced approximately $836 per device.

Since specific processes established are similar to those used in related Third Generation devices, documentation generated may be utilized by companies other than Varian.

IMPLEMENTATION

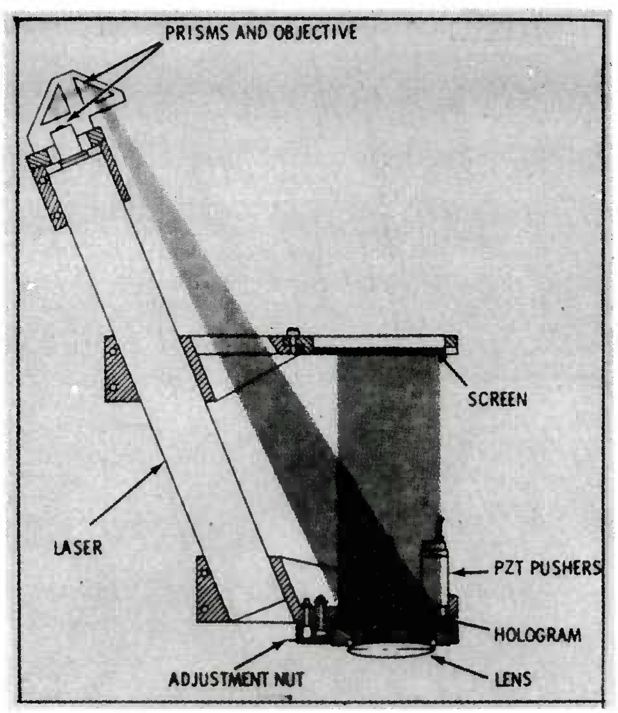
Processes generated by this project were incorporated into standard manufacturing procedures at Varian and are now utilized in ANVIS production. This documentation was also made available to all tube manufacturers for upgrading manufacturing techniques.

MORE INFORMATION

Additional information may be obtained from Mr. Kurt Villhauer, Night Vision and Electro-optics Laboratory, Ft. Belvoir, VA, AUTOVON 354-1725 or Commercial (703) 664-1725. The contract was DAAB07-79-C-0055.

Summary report, Jun 84, was prepared by S. Yedinak, Manufacturing Technology Div, 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)

MMT Projects **179 7371, 180 7371,** and **181 7371** titled "**Integrated Blade Inspection System (IBIS)**" were completed by the US Army Missile Command in February 1983 at a cost of $670,000.

BACKGROUND

The Army's T-700 turbine engine airfoil components', blades' and vanes' inspection requirements specify a high degree of accuracy, reliability, repeatability and thoroughness. The inspection requirements for the turbine airflow components include contour, grill holes, internal and external surfaces. The conventional inspection methods, currently employed, such as visual, airflow, waterflow and probe, do not have the capability to achieve the required accuracies. Also, these methods are very time consuming and costly.

SUMMARY

The development of the IBIS system is a DoD Tri-Service funded program. The objective of this program was to automate and improve the inspection accuracy, reliability, repeatability and thoroughness of the turbine engine airfoil components, blades and vanes. The Army's portion of the program was primarily directed at assuring that the IBIS system has the capability to inspect the T-700 turbine engine.

The IBIS system is comprised of four automated inspection modules, interconnected through a computerized data management network. Each module is designed to perform a specific type of inspection required during manufacture and/or overhaul of stationary and rotating airfoil parts. The inspection modules are:

- Visual Inspection Module (VIM) inspects for airfoil surface defects, such as dents, nicks, and scratches. These indications are detected using an optical profile sensor.

- Fluorescent Penetrant Inspection Module (FPIM) inspects for surface flow indications. The FPIM and the VIM are similar in design, construction, and performance. However, they differ significantly in function, as the FPIM detects fluorescent penetrant indications resulting from flaws such as tight cracks, laps, and porosity.

- X-Ray Inspection Module (XIM) inspects for internal casting flaws, such as gas porosity and manufacturing flaws, such as internal hole position and dimensions. The XIM is being established to perform filmless x-ray inspections with advanced computer software to automatically determine the quality status of turbine airfoil parts.

- Infrared Inspection Module (IRIM) inspects for internal cooling passage and surface cooling hole blockages. The IRIM utilizes infrared thermography techniques to detect cooling flaws in air-cooled ports. It is capable of detecting thermal conditions attributed to these flaws both at the surface and within internal passages of the part.

Each of the above modules interfaces to an information computer system (ICS). ICS provides for the orderly management of inspection data. The ICS maintains an integrated airflow data base, Figure 1 below.

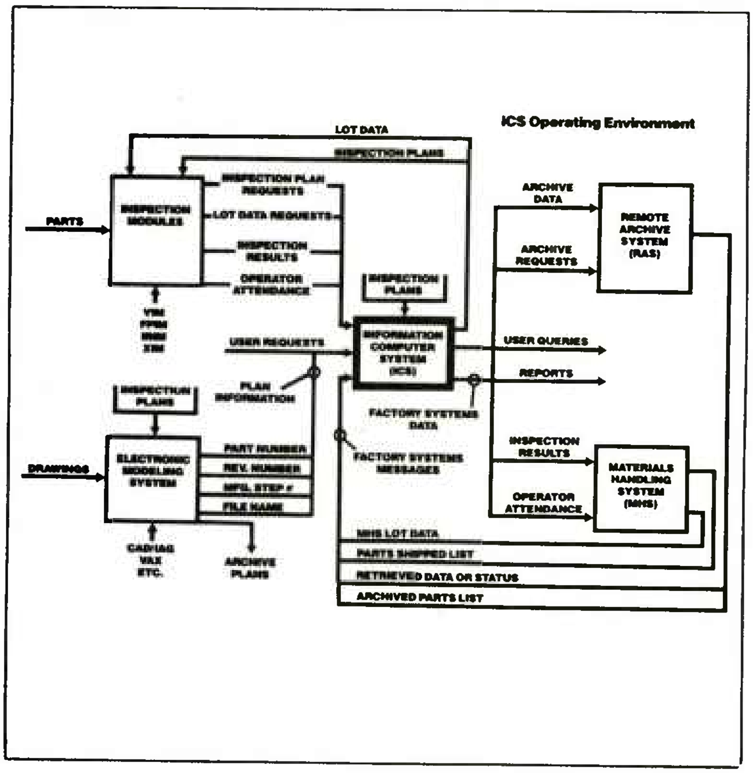


Figure 1 - Information Computer System

BENEFITS

The computer-based automatic preprocessing and inspection systems of IBIS will offer, when completed, numerous benefits to DoD and the Army:

- Improved inspection reliability and repeatability
- Enhanced inspection thoroughness
- Increased inspection productivity
- Automatic information storage and retrieval
- Feedback for process control

IMPLEMENTATION

This IBIS system, for the most part, is planned to be installed at the Air Force's San Antonio Air Logistics Center, San Antonio, Texas. (The only exception is the X-ray Inspection Module (XIM) which will be installed at the engine manufacturer's plant.) Recently, the first module, Fluorescent Penetrant Inspection Module (FPIM) was delivered and installed. Currently the FPIM verification testing is underway. The Infrared Inspection Module (IRIM) and Visual Inspection Module (VIM) are scheduled for installation in 1985 and 1989 respectively. Once the IBIS program has been completed, the Army will have the opportunity to purchase the IBIS system and software for the T-700 turbine engine inspection at Corpus Christi Army Depot.

MORE INFORMATION

Additional information on this effort is available from B. Park, AVRADCOM, St. Louis, MO, 63120, AUTOVON 693-1625 or Commercial (314) 263-1625.

Summary report, Jun 84, was prepared by D. Brim, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **277 9809** titled "**Measurement Techniques for Chemicals Used in the Manufacture of Solid State Microwave Devices**" was completed by the US Army Electronics Research and Development Command, Electronics Technology and Devices Lab in March 1982 at a cost of $659,471.

BACKGROUND

It was anticipated that in 1981 the Federal Government would spend $47 million for silicon microwave devices with an annual 20 percent increase. The cost of the devices was high because the overall yield of the manufacturing steps was very low (about 5 percent). The major cause of the poor yield was the introduction of unusually high levels of critical contaminants in some of the 50 processing steps. This is most likely the result of material purity specifications which improperly address the 35 critical contaminants. This can account for a manufacturer temporarily "loosing the recipe" until the contaminated material is used up. Improved material specifications would be of great benefit if the critical contaminants in the material were known.

SUMMARY

The goal of this project was to form the basis for an automatic test and control system, which would include all the appropriate sensors to detect impurity levels in the chemical reagents and particulate matter which might be present in microwave semiconductor processing. This control system would have the capability of analyzing all the chemical inputs to the process, solid, liquid and gaseous. The functions of this detection and control system were to have been several: to provide warning of excessive contamination as early in the process as possible; to allow contaminated material to be discarded, rather than accrue further manufacturing costs; to be able to identify specifically the critical contaminants to microwave technology and the threshold levels necessary to precisely control the process; and to provide lot traceability throughout the process so that final yields of end products could be correlated with known contamination levels and appropriate yield improvements could be made.

The approach to the problem was first to develop an analytical model of the semiconductor manufacturing process. The model would relate the concentration levels of each contaminating element in each reagent to the yield. These quantitative relationships would be expressed in terms of a set of parametric transfer ratios or coupling coefficients. The model would be exercised in parallel with the operation of the production line. Each intermediate step, as well as the final yields of the process, would be correlated with the corresponding step predicted by the model.

When reasonably stable correlation coefficients could be established between the model and the process, the model would be reduced to a set of linear-programming objective functions suitable for optimization against any given set of constraints. From these, a set of contaminant threshold levels and monitoring points would be established that would assure a specified yield/cost target. A specification for a system which could monitor and optimize a microwave semiconductor manufacturing process would then be generated.

Microwave Associates provided the semiconductor production facilities and technology, fabricated the high voltage PIN diodes, performed all chemical analyses, and evaluated the yields. Harris Corporation provided project management, system engineering, computer facilities, analytical modeling and performed all statistical analyses.

Equipment decisions made early in the project proved faulty and detrimental to the project. The computer controlled plasma coupled emission spectrometer, Jarrell-Ash Plasma Atomcomp, was purchased and installed at Microwave Associates. Operation of the instrument proved to be time consuming because of the frequent maintenance it required, the number of manual controls to adjust, the long recalibration time and the long period of training required. Also, automatic test equipment for measuring the electrical characteristics of the diodes was assumed to be available, but was not. The device yield had to be determined manually.

The lack of adequate test data precluded the completion of a model for predicting manufacturing yields or to establish the feasibility of the project's objectives. Of the 4,500 sample runs anticipated in the original program plan only 90 were accomplished, of which many were invalid or of doubtful value.

The statistical analyses performed on the database yielded no significant relationships between levels of contamination and the final yield of the wafers. However, these analyses suggest that the measurement for yield developed is ineffective from a statistical point of view, indicating a possible problem in defining yield.

The direction indicated for future attempts to predict yield must be to develop a methodology for actually monitoring a diode production line in order to build a sufficiently large database upon which to conduct extensive sophisticated statistical investigations.

BENEFITS

Because only a small portion of the required work to reach the goal was actually accomplished, no benefits are foreseen from this project. The purchased equipment currently in place at Microwave Associates has been used very successfully in failure analysis.

IMPLEMENTATION

No implementation of this project is possible.

MORE INFORMATION

Additional information may be obtained by contacting Mr. George Morris, ERADCOM, AUTOVON 995-2825 or Commercial (201) 544-2825.

Summary report, Jun 84, was prepared by D. Richardson, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **679 7555** titled **"Dynamic Pressurization Acceptance Testing of Slide Block Breech Mechanisms"** was completed in February 1983 by US Army Armament, Munitions and Chemical Command at a cost of $132,000.

BACKGROUND

The slide block breech mechanism's functional and proof production acceptance testing is currently performed at a proving ground by live firings. This testing is both time consuming and costly. If this production acceptance testing could be simulated, the cost and time would be reduced substantially.

SUMMARY

This is the second phase of a two-phased effort. The first phase produced the design, fabrication and test of the slide block breech gymnasticator acceptance testing simulator (see Figure 1). The objective of this effort was two fold: (1) provide an instrumentation package and (2) modify the dynamic pressurization stand for the slide block breech gymnasticator testing simulator.

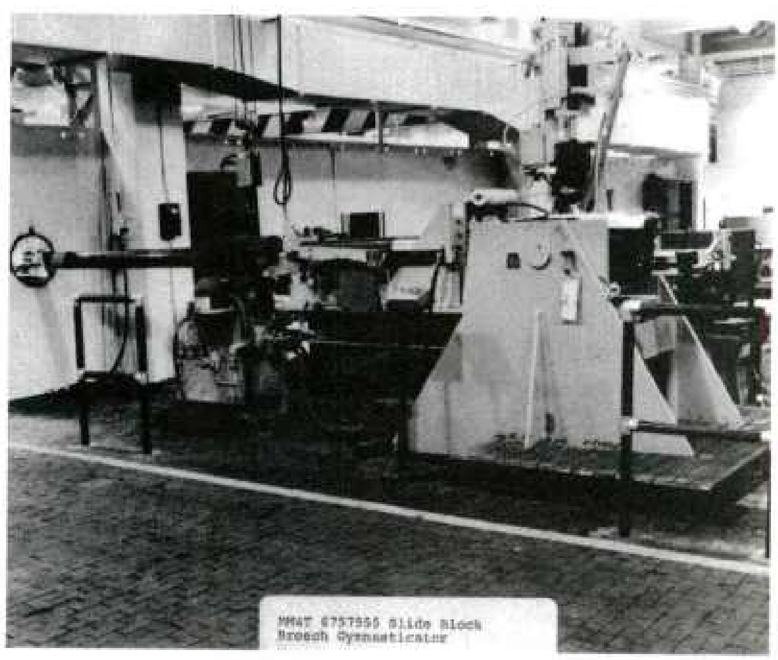


Figure 1 - Slide Block Breech Gymnasticator

To improve the performance of the gymnasticator, an add-on instrumentation package was developed to measure the forces required to open the breech and trip the extractors. To measure the breech opening forces, a handle extension is used which measures the force required to depress the plunger and the force required to rotate the operating handle. With the add-on instrumentation package, the test breech mechanism is placed on the gymnasticator, the linear velocity transducer is mounted on the breech, the photocells are mounted behind the breech, and the handle extension is attached to the operating handle. When the breech is opened, a trace of the plunger force and opening torque is generated on the x-y recorder. A shell casing is then loaded into the breech so that it just contacts the extractors. An instrumented rammer is placed against the shell casing. The shell casing is rammed into the tube, tripping the extractors. The gymnasticator is cycled to record and counter recoil the breech mechanism. During the counter recoil phase, the linear velocity transducer and the photocells are energized and the breechblock opening velocity recorded and the time required for ejecting shell casing is detected by the photocells and recorded.

Major modifications were made to the original dynamic pressurization test stand. The original test stand included a stub tube simulating the gun tube, a top piston to simulate the shell casing, a base plug with integral seals and a filler base. The test stand fixture was modified to incorporate a top piston with a hallite seal backed by a wedge ring and the base plug and stub tube were combined to eliminate the bottom seals. These modifications were required as the sealing system was very poor, failing every seventy to one hundred cycles.

BENEFITS

The primary benefits realized from this effort by the Army was the capability to simulate the slide block breech mechanisms production acceptance testing. This simulated acceptance testing has reduced the live firing requirements by 75 percent.

IMPLEMENTATION

This slide block breech mechanism dynamic pressurization acceptance testing simulator was first used as a production acceptance test method was in January 1978 at Watervliet Arsenal.

MORE INFORMATION

To obtain more information, contact the project officer, J. M. Paine, AUTOVON 974-4238 or Commercial (518) 266-4238.

Summary report, Jun 84, was prepared by D. Brim, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **R80 1023** titled **"Digital Fault Isolation for Hybrids"** was completed by the US Army Missile Command in December 1982 at a cost of $300,000.

BACKGROUND

The growing use of LSI circuits, microprocessors, RAMS, and ROMS has increased the need for more efficient and economical production testing of the hybrid devices in which they are contained. This project sought to adapt the digital fault isolation techniques and test equipment for printed circuit boards produced under MMT R77,78 3242 to the special circuitry and probing requirements of hybrid assemblies.

SUMMARY

This effort was funded to establish fault isolation and automotive functional testing for digital hybrid microelectronic assemblies (D/HMA). Work was performed by Hughes Aircraft Company, Fullerton, CA. Tasks were to provide a single D/HMA test probe automated for X, Y, Z position and hardware/software compatible with Hewlett Packard's DTS-70 host Automatic Test Equipment (ATE) computer. See Figure 1.

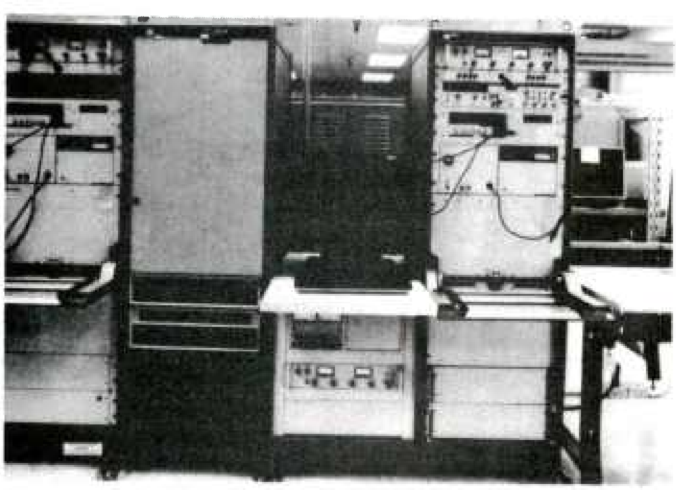


Figure 1 - Host ATE System, Hewlett-Packard DTS-70

Based on hardware/software performance, cost, and schedule, the Hughes HMC-2460 automatic wire bonder was chosen for autoprobe application over four other positioner candidates. As an autonomous device, HMC-2460 salient features included 6809 microprocessor, software, firmware, $\pm$ 0.1 mil X, Y position accuracy with 20-pound bearing payload, 450-mil Z stage travel with ultrasonic touchdown sensing, and software alignment of the D/HMA for X, Y, and θ coordinates. HMC-2460 adaption for autoprobe usage required the following modifications:

(1) Remount the Z stage and CCTV camera to the X, Y stage.

(2) Provide a test probe with ceramic capillary and tungsten tip suitable for ultrasonic touchdown control.

(3) Produce a fixed platform D/HMA socket mount for the test candidate.

(4) Incorporate the IEEE-448 bus electronics cord for host computer control of the autoprobe.

Figure 2 is a closeup of the HMC-2460 autoprobe hardware adaption at a time shortly before completion. Figure 3 depicts the Hughes autoprobe system equipment after modification for the hybrid fault isolation program. A closeup of the D/HMA in its test socket is shown in Figure 4.

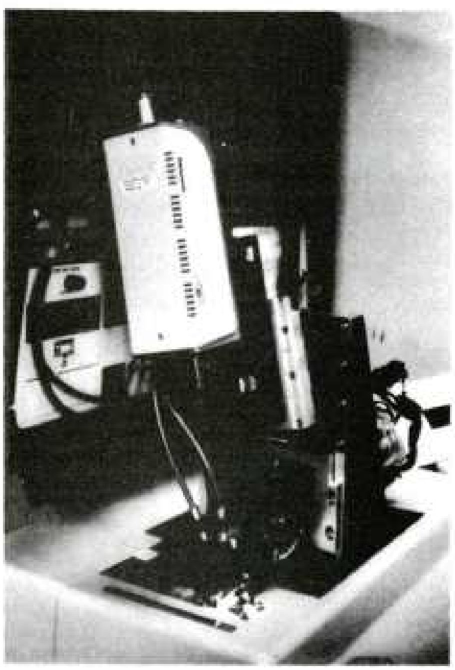


Figure 2 - The Hughes HMC-2460 Automatic Wire Bonder Adapted for Autoprobe Testing

Figure 3 - Hughes Modified HMC-2460 Autoprobe

Five system interface software elements were produced for expedient autoprobe control. The HMC 2460 and Hewlett Packard DTS-70 combined software required 3225 and 2250 program lines distributed among respective terminals.

Test software was purposely minimized by selecting a simple 22 pin D/HMA flatpack. This hybrid consisted of TTL NAND gates and inverters with 5 logic levels input to output. A specially built test adapter provided interconnections and switch selected test conditions at nodes for SAI or SAO faults.

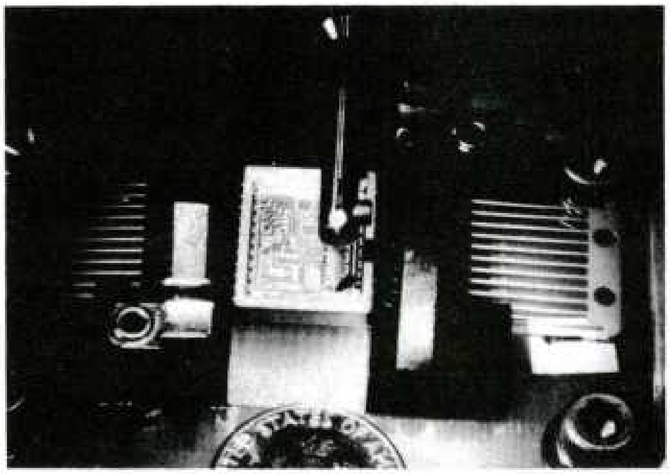


Figure 4 - Closeup View of the D/HMA Test Socket and Ceramic Capillary Mounted to the Ultrasonic Bar

DTS-70 TESTAID and FASTRACE software were utilized to generate a test program which required 170 lines and achieved a 0.94 percent detection comprehension (ability to detect all faults.)

D/HMA GO/NO GO functional test time was 5 seconds. Fault isolation was within 0.6 to 2.5 minutes with a major contribution provided by ATE system overhead.

BENEFITS

In general, benefits realized include improved techniques for detection, identification, and location of faults in complex D/HMA's. Hybrid circuit test times and operator error were reduced and testing reliability was increased. An estimated 30 percent reduction in fault isolation costs with savings of $450,000 per year should result.

IMPLEMENTATION

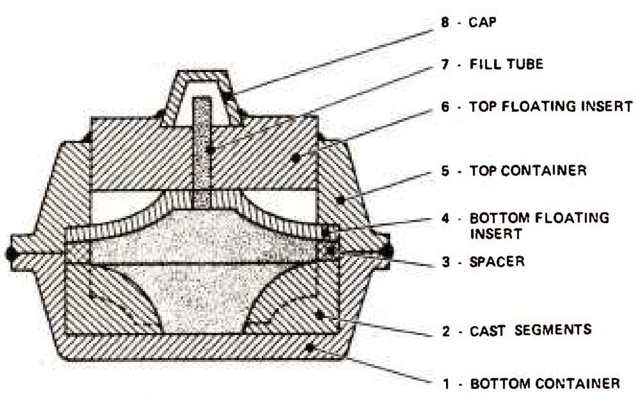
The resultant system is scheduled for implementation into Hughes Aircraft's Tucson GOCO facility for testing missile systems.

MORE INFORMATION

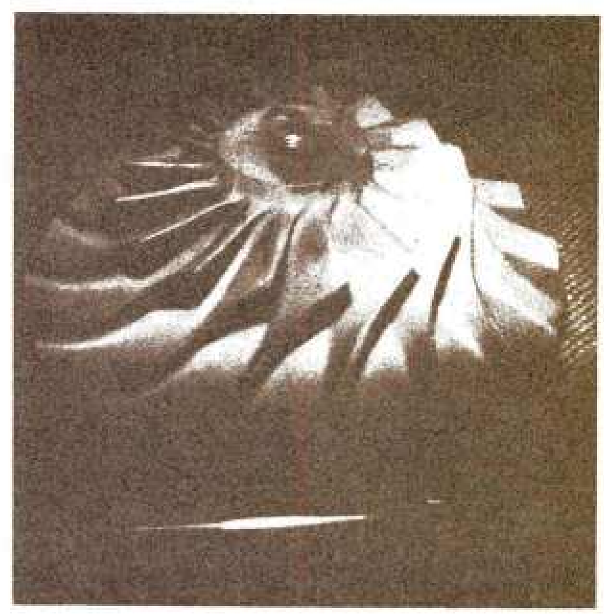
Additional information may be obtained from Mr. Gordon Little, MICOM, Redstone Arsenal, AL, AUTOVON 746-3604 or Commercial (205) 876-3604. The contract was DAAH-01-81-D-A002.

Summary report, Jun 84, was prepared by S. Yedinak, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

METALS



DETAIL	MATERIAL SHAPE
1	BAR OR TUBING AND PLATE
2	INVESTMENT CAST SEGMENTS WELDED INTO A RING
3	PLATE OR TUBING
4	PLATE
5	BAR OR TUBING
6	BAR OR PLATE
7	TUBING
8	BAR



FLUID DIE SCHEMATIC AND RESULTING IMPELLER

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

MMT Project **178 7055** titled **"Ultrasonic Weld Bonding of Primary Structure"** was terminated by the US Army Aviation Research and Development Command in December 1982 at a cost of $208,309.

BACKGROUND

This project was to develop and optimize a process for ultrasonic weld bonding helicopter primary structures. Conventional adhesive bonding was time consuming and expensive.

SUMMARY

The purpose of this project was to expand ultrasonic welding technology and apply it to weld bonding of primary airframe structures. This combination of ultrasonic welding and adhesive bonding processes will be directed toward a cost effective process which can be applied to production components of the AH-64 Helicopter.

The YAH-64 Wing Flap was selected as the primary structural component to expand ultrasonic weld bonding technology. The wing flap was selected in order to facilitate fit and function tests and implementation on the AH-64 production aircraft. Problems were encountered in developing a satisfactory metal surface preparation process to accommodate ultrasonic weld bonding. The ultrasonic weld bonds made during the coupon test program failed and were unsatisfactory. The project was terminated. The surface preparation required for adhesive bonding was not compatible with ultrasonic welding.

BENEFITS

The project was technically unsuccessful and was cancelled without expending all of the funds. The surface preparation required for adhesive bonding was not compatible with ultrasonic welding.

IMPLEMENTATION

This project will not be implemented.

MORE INFORMATION

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

Summary report, June 84, 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)**

MMT Projects **177 7238** and **179 7238** titled **"Precision Forged Aluminum Powder Metallurgy Helicopter Component"** were terminated after expenditures of \$22,600 and \$130,700 for Fiscal Years 77 and 79. The remaining contractual funds were returned to the US Army.

BACKGROUND

The development of high strength powder metallurgy (P/M) aluminum alloys has established an improved range of engineering properties for the aerospace industry. Producing P/M billets of superior properties is an expensive and complex process requiring isostatic compaction, vacuum preheating and hot pressing of a canned billet. This effort was to develop a low-cost precision forging process for production of airframe components from P/M alloys that would by-pass several of the processing steps associated with current processing.

This MMT effort was a joint service investigation, funded by both Army and Air Force, under contract with the Aluminum Company of America (ALCOA).

SUMMARY

The overall objective of this effort was to establish manufacturing methods for the production of precision airframe and helicopter components by aluminum P/M methods. The achievement of this objective consisted of a three-phase effort.

The main goals of Phase I were to determine the workability of the X7091 P/M alloy and to optimize compaction/forging parameters of pressure, temperature and atmosphere to insure sound, full density preforms for finish forging. The optimized process was then to be used to fabricate prototype P/M forgings for complete mechanical property and microstructural evaluation. The applicability of standard NDE techniques was also evaluated for the P/M forgings. Phase II involved scaling up the process for production of several airframe and helicopter structural components by ALCOA with the assistance of General Dynamics, Lockheed, and Boeing Vertol, as subcontractors. Phase III of the program was to involve full-scale component testing, both static and dynamic, by each participating subcontractor. Forgings of both the P/M X7091 alloy and an ingot metallurgy (I/M) standard were to be evaluated for each component. Final material and process specifications were to be prepared and a cost trade-off of P/M versus conventional I/M products was to be formulated.

The program was terminated at the convenience of the Air Force in April 1982 and only preliminary mechanical property testing was completed on the General Dynamics and Lockheed components in Phase II.

Results of the effort prior to termination include:

1. The mechanical properties of the Phase I prototype forgings met the program goals except for fracture toughness. This has been linked to poor vacuum degassing of the compacts prior to hot densification.

2. Usable vacuum forging tooling was developed in Phase II. The design was adaptable to several candidate forgings by using interchangeable punches.

3. Mechanical property testing of the conventionally processed P/M forgings (for the prototype, die 45016 and die 50711) has shown these P/M components to have a marked advantage in properties when compared to their I/M counterparts.

4. Nineteen vacuum-die forged P/M wing attach fitting preforms were produced and subsequently blocker and finished forged under plant production conditions. None of these forgings produced a defect free forging.

5. The original program cost estimates of producing P/M components for less than their I/M counterparts were not met. The projected practice of eliminating the blocker/preforming/multiple finishing operations of precision forging by a one step direct forge (in vacuum die) to the final shape proved not to be feasible for the components selected.

BENEFITS

Extensive workability criteria for X7091 powder compact preforms were developed and successfully modeled using sintered 1202 powder. Usable vacuum forging tooling was developed in Phase II of the program. Mechanical property testing of the conventionally processed P/M forgings has shown these P/M components to have a marked advantage in properties when compared to their I/M counterparts.

IMPLEMENTATION

This effort was not implemented due to its termination.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. Mohan Kumar, AUTOVON 880-5816 or Commercial (201) 724-5816.

Summary report, Jun 84, was prepared by J. Bruen, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **178 7284** and **179 7284** titled **"Superplastic Forming/Diffusion Bonding (SPF/DB) of Titanium for Helicopter Airframe Component"** was completed by the US Army Aviation Systems Command in December 1983 at a cost of $558,000.

BACKGROUND

The need for improved performance aircraft has emphasized the need for lighter weight airframes. This problem has been addressed through the use of stronger, lighter materials and improved structural design concepts. However, these concepts have, in many instances, been executed in high part-count structural assemblies. Such assemblies exceed optimal cost due to the fabrication and assembly cost content, and exceed optimal weight due to the design constraints imposed by a built-up shape.

SUMMARY

Superplastic forming (SPF) of titanium is a process by which very large material displacements can be achieved under certain controlled conditions of temperature and strain rate. Diffusion bonding (DB) of titanium is a joining phenomenon which occurs at the atomic level under typical SPF pressures, and in the same temperature regime as is required for superplastic forming. By combining these technologies into one operation, it is possible to develop structural components whose strength is maximal per unit of material used. This capability exists because material can either be displaced into the critical stress areas, or placed, bonded, and formed into optimally effective structural shapes within critical stress areas. Through the use of this process, fabrication and assembly labor can also be held to a minimum.

This program demonstrated the repeatability and cost saving of the SPF/DB process in a production environment. This was accomplished through the design and fabrication of the left-hand engine firewall of the AAH-64 advanced attack helicopter.

Four prototype firewalls were fabricated using production rate tooling in a production environment. The production tooling resulted in parts which consistently maintained the dimensional tolerances of that tooling and had the physical and mechanical properties necessary to meet the structural criteria.

The SPF/DB firewall design is interchangeable with the baseline titanium firewall now being fabricated. The SPF/DB design reduces the number of details required to fabricate the firewall from over 53 to 11, reduces the number of fasteners from over 1000 to 314, and theoretically reduces the weight from 17 pounds to 13 pounds. See Figures 1 and 2 depicting the existing and proposed engine firewall design.

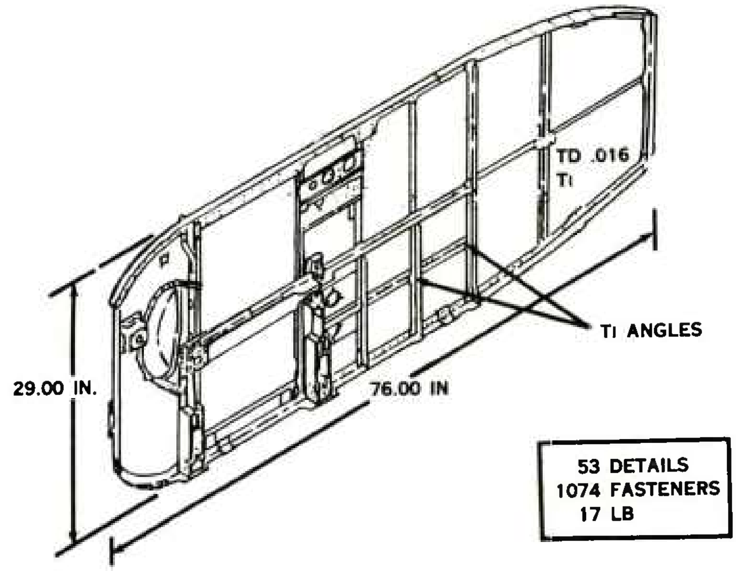


Figure 1 - Existing Engine Firewall

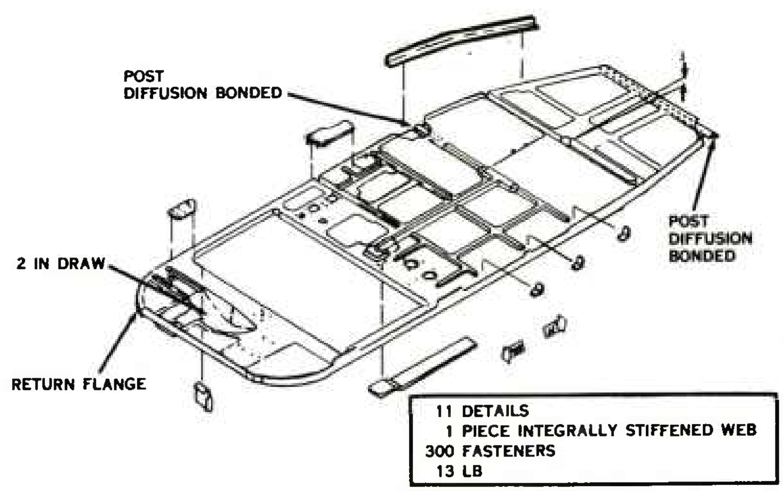


Figure 2 - SPF/DB Firewall Design

BENEFITS

The reduction in the number of fabrication details would allow total production cost savings of 1.5 million dollars. Although the design weight of 13 pounds was not achieved due to thickness variation, the actual weight saving compared to the baseline firewall was 2.8 pounds. This weight saving would contribute over 1.5 million dollars in fleet life-cycle cost savings. Extrapolating these savings to the fabrication of both left and right-hand firewalls would yield a total savings of over 6 million dollars, with a savings to investment ratio of 6.7.

IMPLEMENTATION

Based on the results of this program, it was recommended that the SPF/DB firewall be implemented into production of the AAH-64 helicopter. Basic design and engineering have been completed, and the program has provided tooling capable of supporting fabrication of the firewall in production.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Arthur Ayvazian at the US Army Materials and Mechanics Research Center, AV 955-5233 or Commercial (617) 923-5233.

Summary report, June 84, 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)

MMT Project **182 7389** titled **"Superplastic Forming (SPF) of Aluminum Helicopter Airframe Components"** was completed by the Army Aviation Systems Command in July 1983 at a cost of $280,000

BACKGROUND

The benefits offered by the superplastic forming capability of certain metals have become increasingly clear as a result of numerous R&D and manufacturing methods and technology programs involving titanium alloys. Significant cost and weight savings have been demonstrated by modifying titanium designs to utilize superplastic forming. R&D efforts have proven that similar benefits are possible with aluminum structures; however, the manufacturing technology for assuring that such a component was highly producible and could be fabricated cost effectively still remained to be demonstrated.

SUMMARY

The purpose of this three-phase effort is to establish and demonstrate the manufacturing methods and technology for fabricating low cost aluminum airframe components for a current Army helicopter. The end item of this effort will be a superplastically-formed cockpit floor beam web, for the AH-64 Apache Helicopter, which is lower in cost and weight, but equal or better in performance, than the bill-of-material part. The total program will be accomplished through refining the superplastic forming process for this component; component design refinement; fabricating an adequate number to demonstrate the process; and laboratory testing to verify the design and manufacturing quality.

In the first phase of this effort, the material process characterization and the preliminary design refinement trade-off study were completed. Of the materials which can be supplied on a production basis, Alcoa E-111, a fine grained 7475 aluminum alloy, was felt to possess the best superplastic properties. The preliminary design tradeoff study indicated a 40% cost savings and 10% weight reduction potential for the superplastically formed part.

Figure 1 - AH-64 Apache Helicopter

BENEFITS

This project accomplished the initial planning and analysis necessary for the process development and demonstration phases.

IMPLEMENTATION

The results of this project are consolidated in the continuing effort.

MORE INFORMATION

Additional information may be obtained by contacting Ms. Deborah Leslie at the Army Aviation Systems Command, AV 693-3079 or Commercial (314) 263-3079.

Summary report, June 84, 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)

MMT Projects **174 8017** and **175 8017** titled **"Erosion Resistant Leading Edge for Helicopter Rotor Blades"** were completed by the US Army Aviation Research and Development Command in August 1980 at a total cost of $393,500.

BACKGROUND

Rain and dust erosion damage can severely decrease the useful life of helicopter rotor blades. Blade tip airfoil configuration, for example, can be destroyed in minutes over sandy terrain. To protect blades in erosive environments, erosion resistant leading edge caps have been adopted as essential features of rotor blade design, especially for blade designs incorporating composite materials. Unfortunately, none of the currently used materials (titanium, nickel, stainless steel, polyurethane tape) are entirely satisfactory. In searching for an alternative approach, recent promising work accomplished for the purpose of increasing the life of turbine engines offered a potential solution. In this approach, the life of compressor components (blades and vanes) was increased more than 3 times by the application of boride coating. Since the application of boride coating to substrate metals suitable for helicopter rotor blade erosion strip applications appeared to be feasible, this subject MMT effort was funded to determine its applicability and to establish fabrication techniques.

SUMMARY

The first phase of this effort consisted of optimizing the boriding process to obtain a well supported boride on a metallic substrate (clad), evaluating erosion resistance and other critical properties of a clad substrate, and developing adhesive bonding processes for attaching the cladding to the leading edge of composite and metallic rotor blades. Four alloys, SAE 1010, SAE 410, SAE 430 and Ti-6Al-4V in 0.010 and 0.020 inch thicknesses, were selected as cladding substrate materials. Small, flat specimens were borided by a proprietary slurry and subsequent heat treatment process in which temperatures ranging from 1500 to 2100°F were applied for a period of 4 hours. Results indicated that the 0.020 inch thick clads were superior to the 0.010 inch clads in overall performance. With the thinner gage materials, distortion was more severe in the boriding process and ductility was sharply reduced. Coating thicknesses from 0.00052 inch (Ti-6Al-4V) to 0.0043 inch (SAE 1010) were achieved, and hardnesses of 1495, 1815, 1910, and 3250 KHN were measured for the SAE 1010, SAE 430, SAE 410 and Ti-6Al-4V alloy coatings, respectively. The specimens were subjected to metallographic analysis, dust erosion, retained mechanical properties, salt spray exposure, and ballistic impact tests. Of these tests, dust erosion and salt spray corrosion resistance were weighted most heavily. The salt spray corrosion test results determined that the SAE 1010 and 410 alloys were unacceptable (they would require protective coatings), that 430 was fair, and that Ti-6Al-4V was excellent (unaffected). The erosion resistance of 3 of the clads and nickel was determined. Overall, the borided titanium alloy gave the best performance of the 4 alloys evaluated in erosion, corrosion and impact resistance, and was followed by the SAE 430 alloy. Only these 2 alloys were selected for subsequent work.

Subsequent work consisted of optimizing adhesive bonding of the cladding to metallic and glass epoxy substrates, forming the 2 alloys to airfoil shapes before and during boriding, scale-up of the process to small section rotor blades, rain and dust erosion whirl tests on these sections, and the fabrication of specimens for evaluation by 3 major helicopter manufacturers according to their acceptance criteria. The results of this work are as follows:

° That adhesion of the cladding to metal and glass/epoxy substrate was best accomplished with unsupported epoxy film adhesive.

° That boriding could be accomplished simultaneously with the forming of the cladding to airfoil shapes.

° That the borided cladding could be successfully incorporated in the fabrication of rotor blades.

° That rain and erosion tests on boride cladded (430 and Ti-6Al-4V) composite and metal substrate rotor blade sections resulted in insignificant damage.

In the rain tests, no visible effect was noted. In the dust tests, in which 43-74 um particle size Arizona road dust was impinged normal to the front edge at 650 to 700 fps for 40 minutes, the surfaces of the borided Ti-6Al-4V was smooth and polished with a 1 mg weight loss, and the surface of the borided SAE 430 were clearly polished with a 4 mg weight loss.

The final fabrication process for forming boride cladded nose caps for metallic and composite rotor blades was to form-to-shape and boride 0.004 inch thick Ti-6Al-4V and SAE 430 alloy clads in graphite and mild steel tooling, respectively, of the configuration shown in Figure 1.

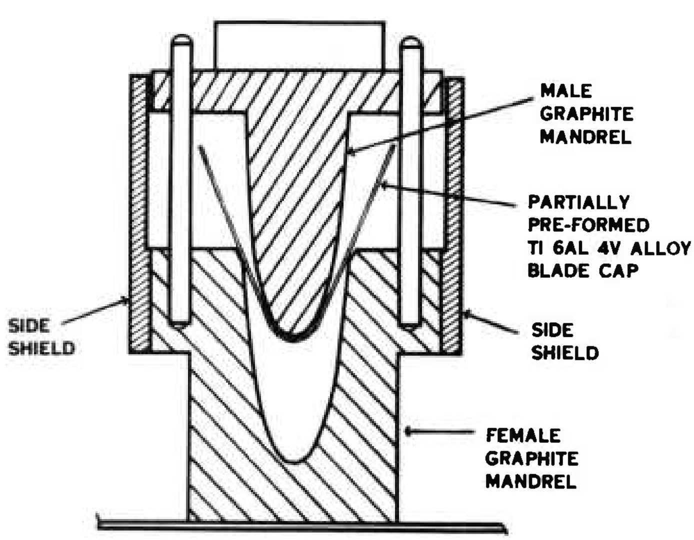


Figure 1 - Graphite Boriding Tooling

This technique, and those discussed earlier, were used to prepare the specimens for independent evaluation by Hughes Helicopter, Sikorsky Aircraft, and Bell Helicopter Textron.

The conclusions reached were that the SAE 430 stainless steel performed poorly in comparison to Ti-6Al-4V, and that borided Ti-6Al-4V displayed unsurpassed erosion properties in the rain tests and in the dust erosion tests at impingement angles less than 30°. At dust impingement angles of 90° to 45°, borided Ti-6Al-4V is not acceptable. The unacceptable dust erosion test results were attributed to the large dust particle sizes (up to 100 micron and larger).

These results are not in conflict with those gained earlier in the program since the smaller size of the selected standard dust (Arizona road dust, 43-74 micron) under the conditions imposed did not enable any particle to achieve an impact energy above the coating failure threshold. This behavior is typical of ceramics. They exhibit threshold failure behavior where they fail by brittle fracture.

BENEFITS

In view of the negative results gained in the 3 contractors' tests, a detailed cost analysis was not performed. If the borided coating had been successful in all tests, the longer life this process would have provided to the strips would have compensated for their higher fabrication costs. The process is beneficial for applications where erosive particle impingement angles are less than 30°.

IMPLEMENTATION

The process has not been implemented on helicopter rotor blades. A potential area of implementation is on rotor blade components that experience erosion particle impingement angles of less than 30° inch such as wing tip covers. Implementation for this application was considered by one contractor, but it has not been accomplished to date.

MORE INFORMATION

Additional information can be obtained from Mr. G. Harris, AMMRC, AV 955-5103 or commercial (617) 923-5103. Detailed technical reports are available. They are entitled "Development of Erosion Resistant Claddings for Helicopter Rotor Blades" (AMMRC CTR 76-9 and Contract No. DAAG46-74-C-0054) dated March 1976, and "Manufacturing Process Development for Dust and Rain Erosion Resistant Coated Metallic Clads for Helicopter Rotors" (AMMRC TR-80-F-31 and Contract No. DAAG46-76-C-0033) dated June 1980.

Summary report, June 84, 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)

MMT Project **382 1086** titled "**Cobalt Replacement in Maraging Steel for Rocket Motor Components**" was completed by the US Army Missile Command in August 1983 at a cost of $655,000.

BACKGROUND

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

In order to overcome the cobalt dependency in rocket motor components, a 3-phase effort was initiated to establish a manufacturing methodology for producing rocket components using the new cobalt free (Free-Co) maraging steel. The first phase of this effort entailed the fabrication of TOW launch motor cases. The effects of various forging/annealing temperatures on the mechanical properties of the material were evaluated relative to forging, drawing, and shear forming operations. Manufacturing characteristics and mechanical properties were compared to those obtained with the cobalt containing 18Ni 300 grade maraging steel, which is now used in the TOW launch rocket motor cases. The successful results of this initial phase were reported under the 381 1086 summary report in June 1983.

SUMMARY

This second phase of the effort addressed the extension of Free-Co manufacturing technology to other potential rocket motor applications, of larger (14-inch) diameter, through an investigation of scaled-up Free-Co hardware. This portion of the program encompassed forging, shear forming of cylinders (to a wall thickness of 0.143-inches), Electron Beam welding, and mechanical properties evaluation, including fracture toughness testing. Some of the most significant findings of this effort were:

1. The Forging Optimization Program, conducted in sections from the 8" RCS billet, confirmed the results obtained previously in 3" diameter reforging bar. The Free-Co alloy appears to be non-sensitive to "C-Curve Embrittlement" and, therefore, may be forged with high forging temperatures (2100°F).

2. Shear forming trials demonstrated that reductions of nearly 80% could be achieved without the need for inter-stage annealing operations.

3. Electron beam welding of cylinder sections was successfully accomplished with no difficulties. Post weld inspection by x-ray and penetrant confirmed the excellent weldability of this material.

4. Post-shear form annealing at 1500°F and aging at 900°F for 4 hours resulted in yield strengths greater than 255 ksi, and tensile ultimate strengths greater than 265 ksi with 4 to 8 percent elongation.

5. Fracture toughness tests of specimens generated from the shear-formed cylinders indicate that the Free-Co material possesses excellent toughness and crack growth rate characteristics.

The relevant details of the fabrication of the Free-Co Scaled-Up Solid Rocket Motor Case assemblies are presented in the process flow chart, Figure 1.

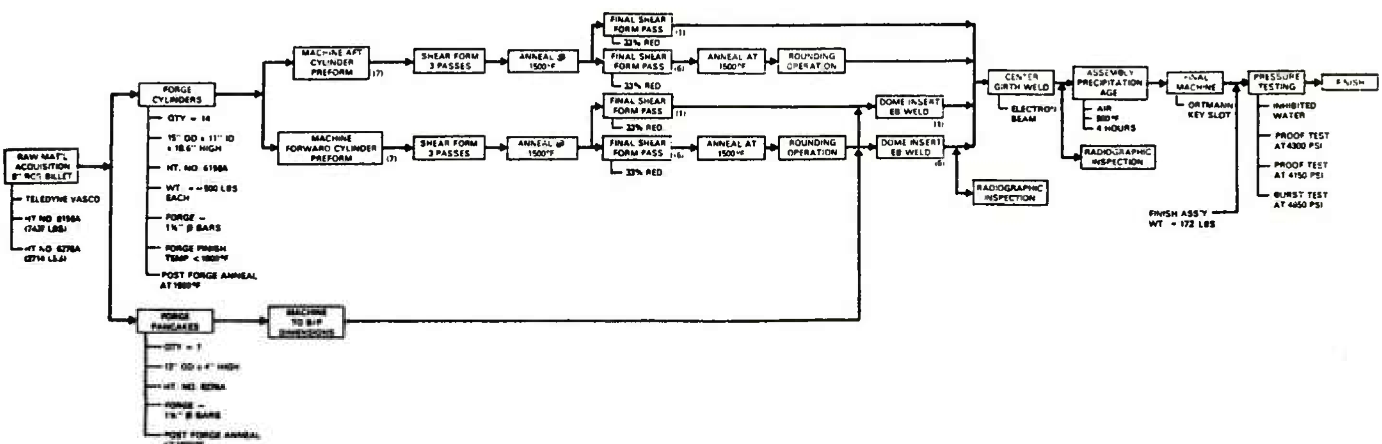


Figure 1 - Process Flow Chart - Scaled-Up Free Co Motor Case Assembly

This program has demonstrated that cobalt-free (Free-Co) maraging steel is a viable alternate material for rocket motor applications where cobalt-containing grades are currently specified.

BENEFITS

This project provides the strategic benefit of reducing U.S. dependency on foreign sources of cobalt. This second phase, of the 3-phase effort, completed the fabrication, inspection, and static pressure testing investigation and has provided six motor assemblies for test firing.

IMPLEMENTATION

The use of Free-Co is now implemented in the TOW rocket motor case and is under active consideration for the STINGER system. The results of this scale-up phase investigation will be documented in the final technical report and industry demonstration. This information will be provided to contractors and Program Managers of missiles using large diameter rocket motors.

MORE INFORMATION

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

Summary report, June 84, 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)

MMT Project **479 4575** titled "**Laser Welding Techniques for Military Vehicles - Phase II**" was completed by the US Army Tank Automotive Command in August 1983 at a cost of $450,000.

BACKGROUND

Recent developments in laser technology have made available high energy industrial equipment which can be utilized for welding. High energy lasers are a heat source which is of high intensity and purity. The high intensity allows melting and subsequent joining of materials at high linear rates. The purity of the heat source eliminates or minimizes exterior sources of contamination.

SUMMARY

This is the second phase of a 3-phase effort. The objective of this phase was to establish laser welding process parameters that would produce a sound, cost-effective joint in 1 1/2-inch armor plate. Sufficient test and production data was prepared to permit a detailed analysis of this objective and an evaluation of the repeatability of the process. The first phase effort proved that welding of armor with a laser as the heat source is feasible and cost effective. The second phase of this effort established a preliminary production process which will be further implemented in the Phase III portion of this effort. Figure 1 shows the laser welding station.

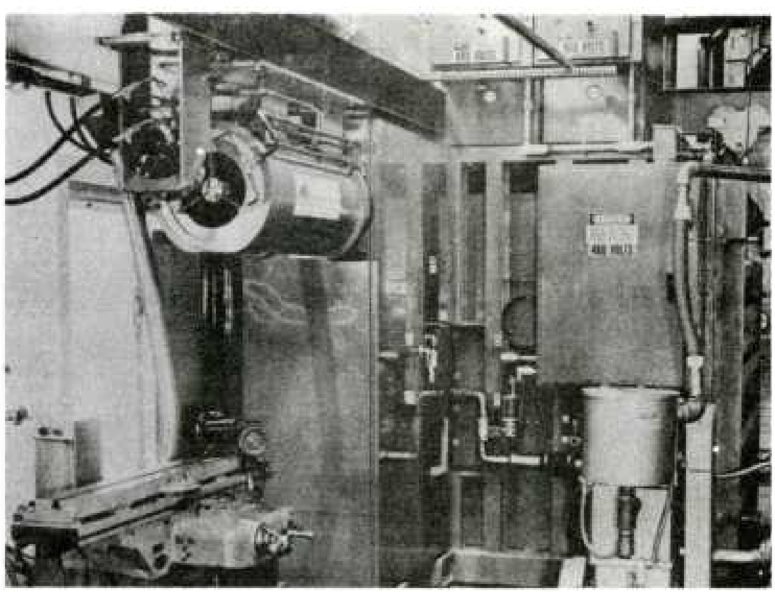


Figure 1 - Laser Welding Station

The indicated preliminary process utilized a higher F/No. telescope (e.g.,F/18). Such telescopes have characteristically broad beams and large focal depths. Weld beads made with these telescopes were found to be easier to set up and seemed to exhibit fewer defects as a result of setup variation during the run.

The relationship between the gas nozzle beam and placement of wire feed were found to be the most critical. The broader, more tolerant beam (high F/No.) telescope provided much more latitude to this relationship. Ballistic test plates were prepared and the tests produced satisfactory results.

BENEFITS

Laser welding of thick section armor plate will produce weld joints with better metallurgical and ballistic properties. Higher weld deposition rates are also a benefit which should result in lower production costs. The Phase III effort of ths project will further refine the process for adaptation to actual production.

IMPLEMENTATION

Based on the positive results of the Phase I and Phase II effort, Phase III has been initiated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. David Pyrce at AV 786-6722 or Commercial (313) 573-6722.

Summary report, June 84, 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)

MMT Project **T81 5054** titled **"Laser Surface Hardened Combat Vehicle Components (Phase II-Task A)"** was completed by the US Army Tank-Automotive Command in September 1983 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, longer service life and lower surface hardening costs for these track components would result. Laser surface hardening is possibly such a method.

SUMMARY

Laser heat treating methods for precision surface hardening is being investigated. Previous studies have demonstrated that surface hardening requirements for both track end connectors and center guides can be met adequately by heat treatment with a CO_2 laser beam. In those studies, end connector wear locations were hardened by development of three heat treated stripes on each of its curved ends. Each heat treated stripe was separated by nearly 2mm. This was necessary to prevent formation of a thin stripe of back tempered region with surface hardness less than that of the core. Localized surface areas where hardness is either comparable to or lower than the core may not exhibit adequate abrasive wear resistance. It was therefore necessary to develop uniform wear resistance by uniformly surface hardening locations subject to abrasive wear. To develop uniform surface hardness, heat treatment was conducted with a laser beam shaped to cover the entire width of an end connector to produce a continuous heat treatment pattern along the curved regions subject to abrasive wear. See Figure 1. This was accomplished by indexing and rotating each of the two curved regions of an end connector under an elliptical or rectangular cross-sectioned laser beam.

Laser beam shaping optics for heat treating track components and separately utiliizng either lens or mirrors, were designed and fabricated. With these optical tools it was feasible to obtain separate elliptical cross-sectioned laser beams having major axis ranging from 41.0 to 50.8mm and

minor axis ranging from 5.0 to 19.5mm, and a square cross-sectioned laser beam of size 25.4 X 25.4mm. Stand-off distance between beam shaping optics and workpiece surface was 280 to 870mm depending on the choice of beam size.

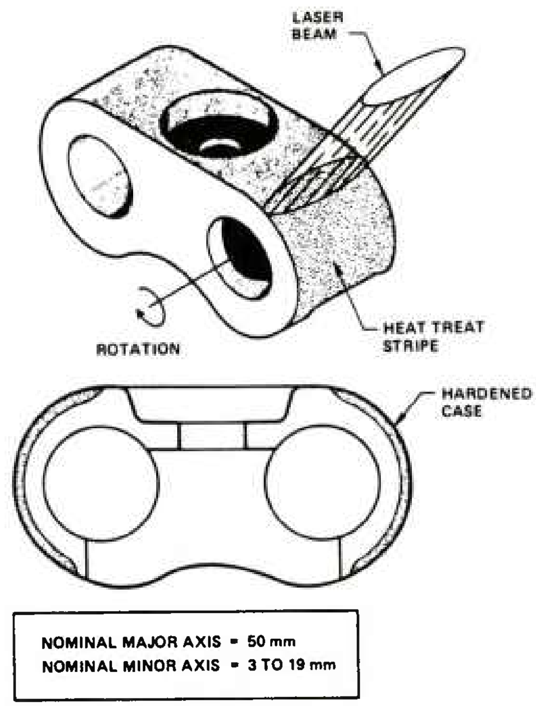


Figure 1 - Schematic View of End Connector Illustrates a Continuous Heat-Treated Pattern Along Each End of the Specimen

Continuous wave and multimode CO_2 laser beam shaped by these optical tools was used to heat treat AISI 4140 steel plates 50.8mm wide and 12mm thick. Heat treating experiments were conducted with 2,000 to 5,000 W of laser beam power on work surface and workpiece travel speed of 0.42 to 8.46mm/s. Laser power density on work surface ranged from 620 to 1,901 W/cm^2 depending on beam size. Self-quenched heat treated casings ranging from 10.0 to 50.8mm wide and 0.5 to 10.6mm deep were obtained. Hardness of casings ranged between R_c50 and 59 depending on case depth. With a 5,000 W elliptical cross-sectioned beam shaped by mirrors and having 50.8mm major axis and 5.0mm minor axis, heat treated stripe 50.8mm wide and 2.3mm deep (surface coverage rate = 107.7mm^2/s) was obtained.

Abrasive wear tests revealed that laser heat treated specimens had smaller wear scars and lower weight loss than untreated specimens. Increased resistance to abrasive wear is due to martensitic casings with adequate hardness formed during laser heat treatment. With these optical tools, it is now possible to apply precision surface-hardened patterns on end connectors and center guides used in combat vehicles.

Task B of Phase II is the follow-on task which includes the heat treatment of several track components for laboratory and field testing.

BENEFITS

The potential result from this and follow-on tasks 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 II-Task A of a two-phase effort. Task B of Phase II is the follow-on task and will complete the total effort. Therefore, the results of this effort are not ready for implementation.

MORE INFORMATION

Further information may be obtained from Mr. Mike King, TACOM, AV 786-6065, or Commercial (313) 574-6065. Reference TACOM Technical Report No. 12727, titled "Laser Heat Treatment of Track Components in Combat Vehicles (Phase II-Task A)", January 1983.

Summary report, June 84, was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Projects **T78 5085, T80 5085** and **T81 5085** titled "**Production Techniques for Fabrication of Turbine Engine Recuperator**" was completed by US Army Tank Automotive R&D Command in October 1983 at costs of $1,047,532, $237,000 and $250,000, respectively.

BACKGROUND

Avco Lycoming's AGT 1500 gas turbine, selected to power the XM-1 Tank, is a recuperative engine with a multiwave plate recuperator of advanced design. This recuperator is a thin plate heat exchanger made by welding together about 580 convoluted plates, each .008-inches thick. There are over 10,000 feet of weld joining the plates; so improved, higher speed welding techniques would offer significant cost reduction opportunities. The fabrication of a recuperator core basically involves joining of the detailed parts and pressure testing. During the early development phases of recuperator core design and fabrication, various joining processes were considered. Among these were several welding techniques such as inert gas-tungsten arc, plasma arc, and electron beam welding. The results of tests of these processes using subsized specimens showed problems with each. Resistance seam welding eliminated the requirement for precision alignment, offered a reliable joining method, and therefore became the standard process.

However, resistance seam welding was also limited by a maximum travel speed of about 50-inches per minute. Satisfactory welds were obtained, but the process was slow and labor intensive.

SUMMARY

In order to reduce welding time and cost, a 2-phase program of screening and verification testing of various welding techniques was undertaken. The requirements established for the welding process were to maintain the reliability and the low sensitivity to deviations in fit-up of the resistance welding process and to significantly increase the speed of welding. Laser welding was selected as the most promising technique for accomplishing this. Laser welding does not require contacting electrodes as does resistance welding nor vacuum chambers, as does electron beam welding. The laser was capable of high welding speeds. Major effort was, therefore, concentrated on developing and testing laser welds for the recuperator plate hole peripheries.

The machine selected for this application was a 2KW continuous output CO2 laser with computer controlled moving output mirrors to permit high speed welding of the complex air passage periphery joints. Also designed and built were the output mirror support structure, prototype work handling and welding fixtures, and a safety enclosure. Figure 1 shows a schematic of the laser welding station.

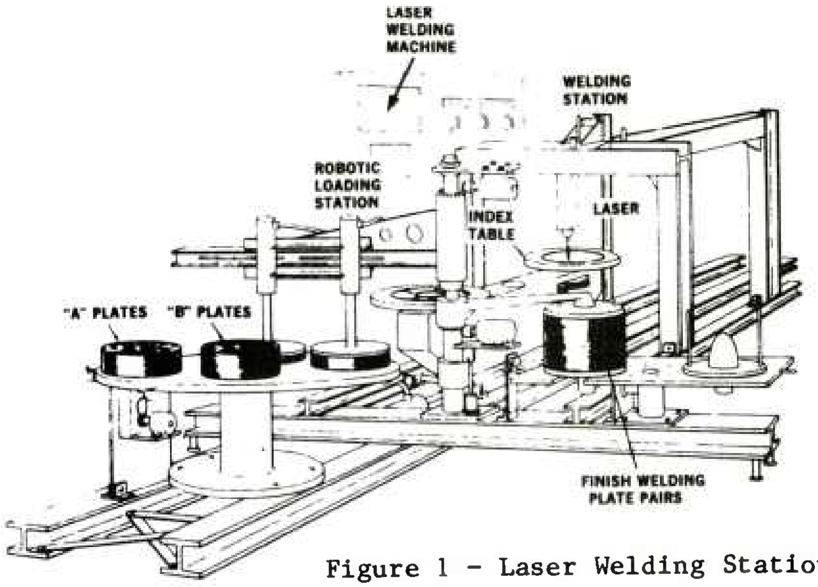


Figure 1 - Laser Welding Station

Computer programs were developed to allow for computer guidance of the laser beam during welding of the air input and output holes. The final program utilized a series of circular arcs to approximate hole shape. The welds produced were smooth, accurate, reliable and leak proof.

Over 800 plate pairs were welded during laser system testing. These were used to fabricate two complete recuperators, one of which was engine tested with excellent results.

BENEFITS

Benefits resulting from this project include decreases in expenditures fo labor, electricity, water and electrodes. A cost savings of $548 per recuperator was realized. A total cost savings of $4.1 million dollars is anticipated based on production forecasts. Higher quality welds were also obtained.

IMPLEMENTATION

This project was a self-implementing pilot production system. It is now operating on-line at Avco Lycoming, the Army contractor for the AGT 1500 gas turbine engine.

MORE INFORMATION

Additional information is available from Mr. David Pyrce, TACOM, AV 786-6722 or Commercial (313) 574-6722.

Summary report, June 84, 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)

MMT Projects **T80 5090** and **T81 5090** titled **"Improved and Cost Effective Machining (Phases II and III)"** were completed by the US Army Tank and Automotive Command in March 1983 at costs of $229,000 and $30,000, respectively.

BACKGROUND

Many tracked vehicle components are subject to high recurring costs and long lead times, as a result of poor manufacturing system performance when the choice of machining technology is made without the benefit of specific machining data. Suboptimal tooling is chosen and inefficient metal removal, longer lead times, poor scheduling and higher manufacturing costs often result. Identification of effective combinations of cutting tools, cutting fluids, and machining conditions (speed, feed, and depth of cut) for important machining operations and various materials could lead to reduced manufacturing costs.

SUMMARY

A variety of machining factors were addressed in this project. Processes investigated included rough turning, milling, drilling, and tapping. Forty primary alloys, 21 heat treatments, 31 material micro-structure types, 49 cutting tool materials and 9 categories of cutting fluids were also included in the optimization testing efforts.

Machining tests were planned using statistical design models. The machinability testing variables such as work piece hardness, heat treatment, cutting tool geometry and material, speeds, feeds, and depth of cut were established by analyzing present tracked combat vehicle (TCV) components and their machining processes.

Machining tests were conducted using these statistical models. The emphasis was placed on difficult-to-machine parts and on alloys used in high volume components.

The resulting data was used for detailed machining economic analyses in order to pinpoint cost effective machining conditions. These analyses and data will also be compiled into a machinability handbook.

BENEFITS

Upon completion of the machinability handbook in the follow-on project, expected benefits include greater accuracy and reduced machining time and cost.

IMPLEMENTATION

Results of this project will be reviewed in a presentation to Government and industry officials given by the contractor. The machinability handbook will also be made available to companies performing Government contracts.

MORE INFORMATION

Additional information can be obtained from Ms. Janice Dentel, TACOM, AV 786-8718 or Commercial (313) 574-8718.

Summary report, June 84, was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **482 6067** titled **"MMT Frame Welding Fixture"** was completed by the US Army Tank Automotive Command in September 1983 at a cost of $49,400.

BACKGROUND

The purpose of this project was to develop a welding fixture with universal capability for application in manufacturing weld assemblies on small production or prototype basis. This universal weld fixture was to reduce the costs of manufacturing welded frames and assemblies with long, continuous welds. Fabrication of pilot and small production runs is costly due to the large amount of setup and welding labor involved.

SUMMARY

The universal weld fixture was conceived as a means to reduce setup time and labor. The working envelope of the welder and fixture, as designed, was 40 feet by 8 feet horizontally and 4 feet vertically. Programming of the welding controller can be done either by external programming or operator guided teach method. The welding can be controlled and corrected by a seam tracking system to allow for irregularities in the work pieces. The fixture, as designed, was cumbersome to use and was not cost effective.

BENEFITS

This project was technically unsuccessful. The weld fixture, as designed, was too cumbersome to be cost effective.

IMPLEMENTATION

This project will not be implemented.

MORE INFORMATION

Additional information covering this project may be obtained from Mr. Robert Culling, TACOM, AV 786-5161 or Commercial (313) 574-5161.

Summary report, June 84, 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)

MMT Project **580 4189** titled **"High Fragmentation Steel Production Process"** was completed by the US Army Armament, Munitions and Chemical Command in March 1984 at a cost of $1,048,000.

BACKGROUND

This multi-phase effort was established to address the many problems experienced during low volume production of the 155mm M549 warhead. The project was designed to refine and optimize the more critical and/or costly processes, and to identify the root causes of the difficulties experienced.

The initial phase of this effort, funded under 579 4189, included the purchase and metallurgical characterization of two 200-ton heats of HF-1 steel obtained from two different vendors. All steel was identified by vendor, location of steel within the heat, and the cooling method used in its manufacture. This identity was retained throughout both phases of the project to determine the metallurgical differences, as well as the differences in forging results, machinability, and quality associated with each sample group.

SUMMARY

This project was the second and final phase of the high fragmentation steel production process investigation. The objective of this project was to investigate the processes, techniques and tools for the manufacture of the M549 warhead, using the HF-1 steel characterized and identified in Phase I. Figure 1 shows the warhead at each stage of manufacture and summarizes the operations investigated.

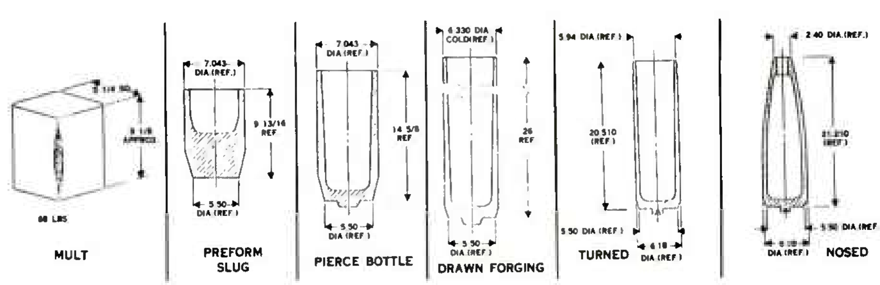


Figure 1 - M549 Warhead At Each Stage of Manufacture

On the basis of this project, the following conclusions were drawn:

1. Surface grinding of billets at the steel mill created metallurgical notches which propagated into surface defects during forging.

2. Nicking of the billet, in the nick-and-break operation, caused the formation of a mixed structure in the nicked area resulting in cracks traversing into the substrate of the mult. The cracks varied from 0.010 inches to 0.040 inches.

3. No defects were attributable to the different cooling methods employed by the steel vendors.

4. The method employed by Chamberlain Manufacturing Corporation, Scranton Division, for cooling forgings to room temperature, produced material that was machinable in the "as forged" condition. Therefore, no spheroidize annealing operation was required.

5. Load requirements for forging the M549 (HF-1) were all within the capabilities of the presses used in the study (800 ton rating).

6. When forgings enter the hot draw operation at temperatures of 1450°F or below, cold tears in the I.D. mouth area result.

7. A cleanup problem in the "boat tail" area was detected during rough turning and was traced to a tool problem at the hot-draw operation. (This condition can be remedied with a slight modification to the forge tooling.)

8. When the as-forged projectile bodies were cut to length, chipping occurred on the inside diameter.

9. Forging eccentricity values were within design limits, using mults produced by either the nick-and-break or sawing methods.

10. The minimum mult weight of 29.93 kg (66 lbs.) provided sufficient material for all operations.

11. Steel of ASTM grain size number 4 required a higher forging load than ASTM grain size number 1.

12. The nick-and-break operation was not affected by the difference in grain size.

13. One hit nosing was used during this study, and the only problem encountered was wall variation. Visual inspection of the nosed bodies revealed that cracking had not occurred.

14. No problems were encountered in sawing mults from any of the HF-1 sample groups.

Based on these conclusions, the following recommendations were offered:

1. Surface conditioning of billets at the steel mill should be controlled to avoid heat buildup on billet surfaces.

2. Caution must be exercised in the nick-and-break process because it may induce metallurgical notches, which can propagate into major defects.

3. Larger production than is now planned would be required to justify further optimization of tools at the rough turning operation.

4. Further investigation into the maximum allowable mult temperature should be considered as a means to minimize cold tearing in the hot draw operation.

5. If the chipping which occurs in the cut-to-length operation creates problems in subsequent operations, facing the open end is recommended prior to nosing.

6. Where forging press capacity is marginal, the use of larger grain size material should be considered.

7. Further experimentation should be conducted to optimize one hit nosing.

BENEFITS

This project established the manufacturing process and parameters for the mult-parting, preforming, piercing, drawing, turning and nosing operations for the full scale production of the M549 warhead. The design and development of the related tooling was also accomplished.

IMPLEMENTATION

The results of this project are being used by Norris Industries in the production of the 155mm M549 warhead. The results are also being used by the forging subcontractor of the 8" M650 warhead.

MORE INFORMATION

Additional information may be obtained by contacting Mr. William Sharpe of AMCCOM, Dover, at AV 880-6505 or Commercial (201) 724-6505.

Summary report, June 84, 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)

MMT Project **579 4335** titled **"Alternative Processes for Titanium Gyroscopes"** was completed by the US Army Armament, Munitions and Chemical Command in March 1982 at a cost of $450,600.

BACKGROUND

In 1979, the Copperhead Engineering Development Program was essentially complete and initial production facilitization was underway. Cost studies showed that the current method of producing titanium gyro components by conventional machining techniques resulted in high fabrication costs due to material waste and time consuming machining efforts. Desk top studies indicated that the most economically feasible techniques are the ones which minimize scrap. This is due to the great difference between the cost of titanium for stock and the salvage value of titanium chips, turnings and flashings.

SUMMARY

This effort investigated several near net shape processes for the manufacture of each component including warm and cold forging, forging of powder metal preforms, hot and cold isostatic pressing, double action cold pressing and post-vacuum sinter pressing.

Several companies involved in powder metallurgy (P/M) were provided detailed technical information related to the gyro parts and asked to provide judgment on the producibility of these parts using P/M processes. One company responded stating they would be able to produce all parts. TRW was subsequently awarded the sub-contract.

Processing tools were designed and fabricated for part production. Test specimens were hot isostatic pressed using different titanium compositions and sent to Martin Marietta for impact and tensile tests.

Initial fabrication of four of the five components was successful. The gyro base, because of its complex configuration, could not be fabricated to near net shape by hot isostatic pressing.

Problems with the base were resolved and six sets of the gyro components were delivered for testing and configuration compliance inspection. The quality of the inner gimbals was unacceptable and they were returned for further pressing technique development.

All previous design and production problems were alleviated and machine components were assembled. The components were tested for static and dynamic properties, acceptable bearing strength, static crush levels, and canister firings. They were found to have approximately 94% of the strength of components fabricated from wrought stock, well within the acceptable limits.

BENEFITS

Scrap rates using powder metallurgy manufacturing methods are confirmed to be low, approximately 5% of those resulting from conventional machining. A technical data package was developed to describe powder metallurgy as an alternative processing method.

IMPLEMENTATION

The results of this project were not implemented due to insufficient cost savings. The technology is available in the event of a marked rise in wrought titanium stock prices or a case of national emergency.

MORE INFORMATION

Additional information on this project can be obtained from Mr. Ben Perlmutter, ARRADCOM, AV 880-3194 or Commercial (201) 328-3194.

Summary report, June 84, was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **580 4480** titled **"High Speed Head Turn Tool Module for Small Caliber Ammunition Production"** was completed by the US Army Armament, Munitions and Chemical Command in November 1982 at a cost of $184,000

BACKGROUND

Since its installation, the Small Caliber Ammunition Production (SCAMP) case submodule has continually experienced an excessively high usage rate of head turn tool modules. This high usage rate is due more to the tool module going out of adjustment than to tool breakdown. Efforts to improve the current tool module have increased the tool modules average life to 20,000 parts. Performance is still sporadic, however, and attempts at further improvement by minor change have been unsuccessful. In order to achieve the average life of 40,000 parts required for acceptable machine down time and repair cost, it was necessary to undertake a major redesign of the case tool submodule.

SUMMARY

The objective of this project was to decrease the cost of small arms ammunition by improving the production life of the high speed head turn tool module from the current average of 10,000 parts to over 40,000 parts, and to develop the capability to process M-200 cartridge cases on the SCAMP production lines. An engineering review of the original head turn tool module design revealed that it was too complex and did not provide for adequate lubrication of moving parts. Consequently, the head turn module was redesigned to include fewer moving parts and to increase bearing support areas wherever possible. In addition, the oil bath lubrication system was eliminated and sealed grease bearings were incorporated in the design. The redesgined head turn module is shown in Figure 1.

The redesigned module was evaluated for two months in the production of 5.56mm M-193 ammunition. The average tool life was between 39,000 and 45,000 parts, required electrical current decreased from 10 to 15 amperes, and the operating temperature stabilized at approximately 115°F. The redesigned module was also used to satisfactorily produce over three million M-200 cartridges with an acceptable tool life of 38,000 parts.

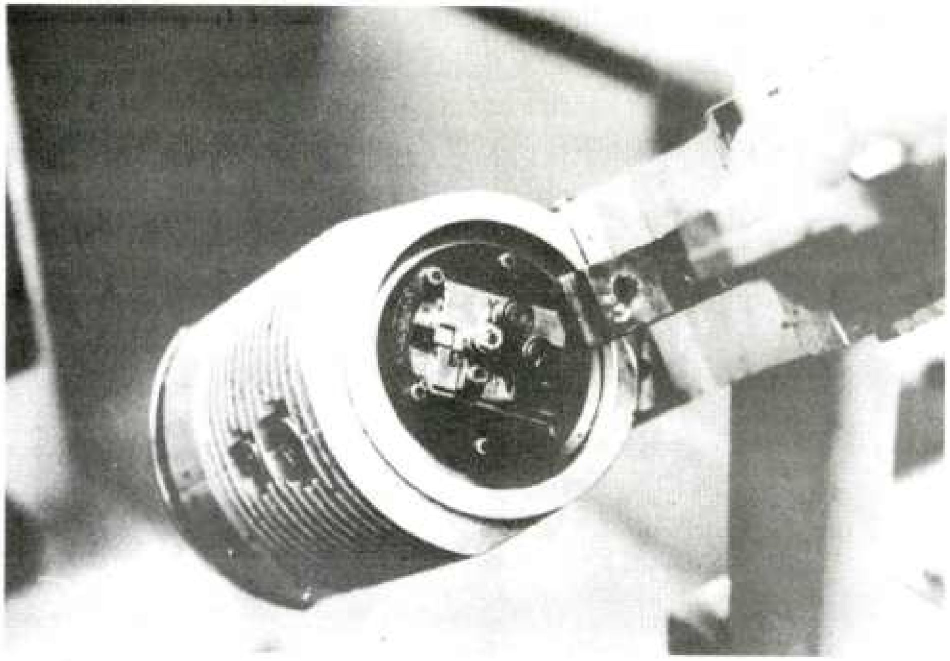


Figure 1 - MOD 3B Design Tool Module

BENEFITS

The successful execution of this project has resulted in the elimination of one off-line tool setter per production line per shift, a reduction in the number of rejected cartridges, improved reliability and less down time, and the ability to produce M-200 cartridges. Total annual savings is calculated to be $108,000.

IMPLEMENTATION

The results of this project have been implemented at Lake City Army Ammunition Plant, Independence, Missouri. Production funds are being used to replace old tool modules on a normal attrition basis. In addition, facilities projects 583 2201 and 583 2202 will be used to provide one complete set of the newly designed tool modules for production lines 3, 4 and 5.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Mark Lang, US Army Armament, Munitions and Chemical Command, AV 880-3737 or Commercial (201) 724-3737.

Summary report, June 84, was prepared by Alan Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Project **679 7317** titled **"Optimization of Step Thread Tooling"** was completed by the US Army Armament, Munitions and Chemical Command in March 1983 at a cost of $72,000.

BACKGROUND

Significant advances in the design and production of new generation step thread machines have occurred in recent years. Efficient step thread tool maintenance methods, however, have not been developed along with these new machines.

The material used to produce conventional thread cutters does not result in good tool life. Further, when the cutter is sharpened, a relatively large portion of the tool is ground away. Because of the tool's configuration, the sharpening operation cuts deeply into the back of the tool destroying the clamping area and resulting in greatly reduced tool life. Finally, resharpening must be done to very close tolerances ($\pm$ .002 inch). Accuracy is maintained by manual adjustment of the grinding tool. The operator is aided by two different positioning dials, but the process is time consuming, tiring, and has an appreciable potential for error.

SUMMARY

Improvements in tool design, new cutting tool materials, and modifications to the tool sharpening methods were investigated and evaluated during this project. First, a search was made to determine the most promising tool steels for application to step thread cutters. Four steels which demonstrated both durability and grindability were chosen for testing. These were:

Vasco Wear Tool Steel
AISI M-41 Tool Steel
CPM10V Crucible Tool Steel
UHB ASP 60 High Speed Steel

These tool steels were evaluated for durability to determine optimum feeds and speeds while maintaining tool life. They were also tested for grindability to reduce the maintenance and resharpening costs.

The material which proved to be the best suited to step thread machining was the AISI M41 tool steel. The M41 steel maintained a cutting edge after a complete rough machine operation while the other materials showed significant edge deterioration. The grindability test showed no difference between the various steels.

Step thread cutters (Figure 1) were produced from AISI M41 steel and tested on typical component materials. The average time for machining threaded components was reduced by 0.5 hours per component. This time and cost reduction resulted from the increased feeds and speeds which may be used with the more durable AISI steel tools.

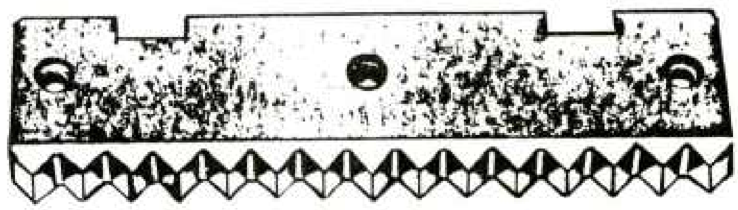


Figure 1 - View of New Generation Step Thread Cutter

Next, a special grinding and wheel dressing fixture was designed to accommodate step thread cutters for both breech ring and breech block machining. The previous method, without a fixture, required the operator to manually index each cutting tool 15 different times and to readjust wheel and cutter alignment to within .002 inches each time. The new fixture accurately locates the cutter for precise grinding of the cutting edge with minimal operation effort and incorporates a built-on wheel dressing unit to assure quick and accurate wheel forming. The operator simply engages a precision ground pin into a precision ground slot, automatically locating tooth spacing to the required tolerances. The use of the fixture results in a reduction in cutter servicing time of approximately 0.5 hours per cutter.

Finally, the cutter itself was redesigned to allow for a through pass of the grinding wheel during sharpening. This new design eliminated the wear to the clamping surface, resulting in significantly longer cutting tool life.

BENEFITS

Use of fixtures and improved cutter design have reduced grinding time and cost by 0.5 hours per cutter, lessened operator strain, minimized error, and increased tool life. New cutter materials have reduced machining time by 0.5 hours per component part. Total savings are estimated as $45.37 per component or $15,600 annually.

IMPLEMENTATION

Following prove-out through production testing, the cutters will be submitted to the Technical Working Group for MM&T planning and then will be used at Watervliet Arsenal in place of conventional step thread cutters.

MORE INFORMATION

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

Summary report, June 84, was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

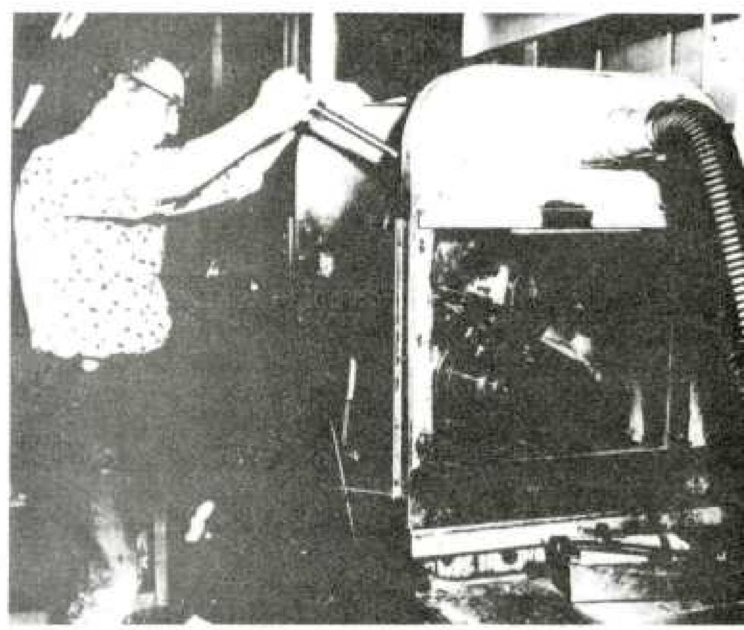
MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

MMT Project **679 7730** titled **"Manufacture of Split Ring Breech Seals"** was completed by the US Army Armament, Munitions and Chemical Command in January 1982 at a cost of $137,000.

BACKGROUND

The split ring is a precisely manufactured and complex item which is used to provide a safe, reliable, and efficient high pressure sealing system in the breech mechanism of large caliber guns containing a rotary block. Present manufacturing methods, (Figures 1 and 2), used since the development of the split ring, are outdated and costly, requiring considerable hand finishing and highly skilled personnel. Rejection rate for the split ring is high and it has a significant replacement history during the life of a gun tube.

Technique for Hand Lapping
Split Ring Opening



Abrasive Disk Sawing (Splitting)
For Split Ring Opening

SUMMARY

The objective of this project was to develop an automated process for the manufacture of split rings. An initial engineering study revealed that the manufacturing difficulties historically encountered in the production of split rings are associated with three operations: kinking the ring, splitting the ring, and polishing split surfaces.

Present kinking methods are slow and inconsistent. In order to minimize the errors associated with manual operations, a hydraulic powered kinking unit was designed and built. Kinking force is supplied via three hydraulic cylinders, two on top of the fixture holding the ring and one under the ring itself to provide the actual kinking force. Preliminary testing has confirmed the feasibility of using the hydraulic powered kinking machine in production, and has also identified areas where improvements should be made. Modifications have been made and will be tested under a follow-on project.

The splitting operation is currently performed with a manually operated pivotal arm saw; its success depends entirely on the skill of the operator. Initial investigations into alternative methods for splitting the ring dealt with wire electric discharge machining. After extensive testing at a contractor's manufacturing facility, it was concluded that the use of wire electric discharge machining, while technically feasible, was too slow to be of practical value in a production environment. Consequently, a machine specification was prepared for automated ring splitting equipment. This equipment will incorporate power clamping, adjustable wheel feed, constant surface feed per minute wheel speed, wheel wear compensation, wheel guides, and a self-contained coolant system. The equipment will be procured, installed, and tested under a follow-on project.

Polishing of the split surfaces is a critical operation performed manually by highly skilled operators. Inquiries to many manufacturers of polishing and lapping equipment have all resulted in negative replies. It was thus decided to develop a special polishing unit through modifications to a commercially built sander. These modifications have begun and will be completed under a follow-on project.

BENEFITS

The execution of this project has resulted in the development of specifications for equipment designed to automate the manufacture of split rings. This new equipment should increase quality while at the same time eliminate the need for highly skilled operators.

IMPLEMENTATION

This project is the first year of a three-year effort. Implementation will be addressed upon completion of follow-on projects.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Gary Conlon, Benet Weapons Laboratory, AV 974-5737 or Commercial (518) 266-5737.

Summary report, June 84, was prepared by Alan Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Project **678 7802** titled **"Establish Machine Load Performance Specification"** was completed by the US Army Armament, Munitions and Chemical Command in January 1981 at a cost of $195,000.

BACKGROUND

Procurement, acquisition, and application of new and used machine tools are both physically and economically inefficient due to the lack of meaningful test procedures. No government or non-proprietary industry standards exist for accurately testing both physical and economic productivity of machine tools. As a result, the cost of machine tools and manufacture of weapons are higher than necessary.

SUMMARY

The objective of this project was to establish and apply test procedures for the procurement and operation of machine tools, with guidelines for procurement according to specific requirements and efficiencies; and for storage and transfer with recorded performance capabilities. Machine tool test methods were reviewed with representatives of all Services, the Department of Energy, machine tool builders, private industry and university researchers. A complete review of all actions affecting machine tool production peformance was conducted, including aspects of justification, specification, procurement, selection, inspection, testing, operation, and maintenance. Scheduling, numerical control programming, rebuilding, and replacement practices were also reviewed. A detailed study of typical production parts, specifications for existing machine tool accuracies, maintenance records, and parts quality records was conducted. The technical effects of static and dynamic forces, workpiece weight and rigidity, clamping, thermal changes, vibration, material handling, cutting fluids, tool changing, and controls were also studied.

Specific machine tool tests were outlined (Figures 1 and 2) for laboratory and shop floor verification, and an overall methodology was developed and flow charted. A computer program was developed and tested at Rock Island Arsenal. This program determines comparative machining times for different numerically controlled machine tools via the use of a post processing system. A comprehensive technical report describing and documenting the results of this project has been written and is being staffed for publication.

BENEFITS

This project has resulted in the initial development of a methodology which will enable qualitative and economical procurement of machine tools by providing a means to establish specifications for improved cutting parameters and increased quality assurance.

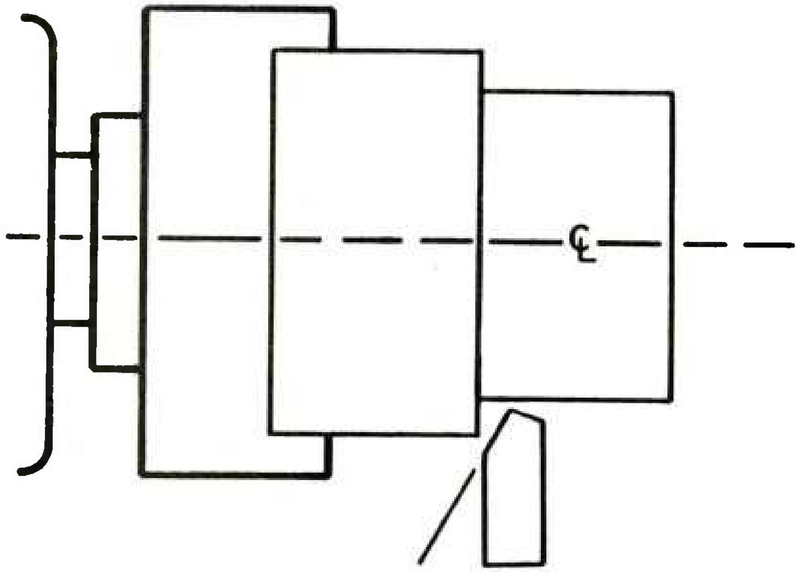


Figure 1 - Setup for 50% Full Power Test

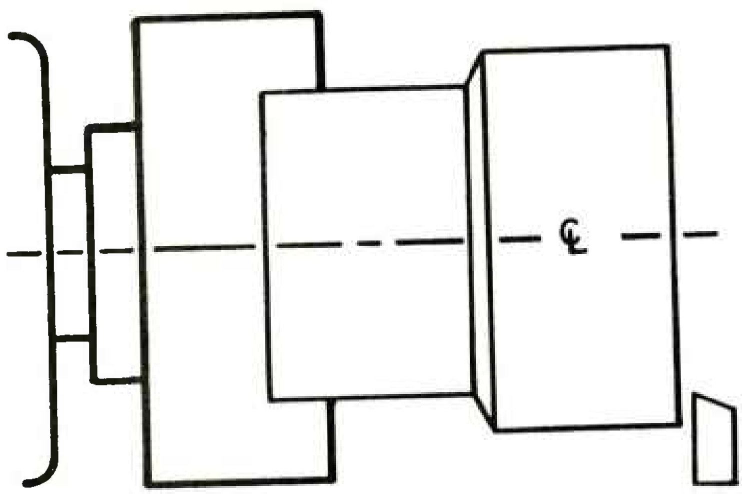


Figure 2 - Setup for Full Power Test

IMPLEMENTATION

This project is the first year of a two-year effort. Implementation will be addressed upon completion of MMT 679 7802.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Ray Kirschbaum, Rock Island Arsenal, AV 783-5363 or Commercial (309) 794-5363.

Summary report, June 84, was prepared by Alan Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Project **680 7925** titled "**Bore Evacuator Boring**" was completed by the US Army Armament, Munitions and Chemical Command in March 1983 at a cost of $112,000.

BACKGROUND

The chamber evacuator for the 105mm M68 gun tube is a weldment that requires the end bores to have a coincident centerline. These bores are machined one end at a time with two different setups. The procedure is both expensive and of questionable accuracy.

The chamber evacuator is placed on end in a vertical turret lathe. Different tools are then used for facing, boring, grooving and chamfering. (See Figure 1). Each tool change requires operator time and care in setting cutting tools for the proper location. Care must also be taken when the chamber is turned end for end and repositioned. Since the chamber is 24-inches long, even a slight error in positioning will be greatly magnified at the opposite end. A process allowing for simultaneous end machining would reduce machining and setup costs and improve component accuracy.

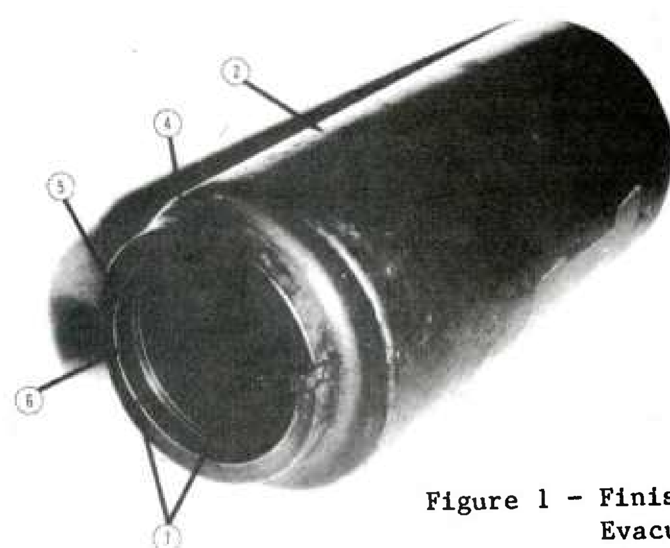


Figure 1 - Finish Machined Chamber Evacuator. Machined Surfaces (2), Face (4), Bore (5), Groove (6) Chamfers (7)

SUMMARY

Engineering specifications were formulated for a machine that would incorporate facing, boring, grooving, chamfering and machining to length into one setup. This would be accomplished by placing the component in a horizontal position, making both ends accessible to machining.

A search was initiated to determine if any machine tools capable of simultaneous machining were available; two Government-owned, single spindle planetary milling machines that could be refitted to a single base were located. The decision to use these two mills was based on several factors. Overall cost to the Government is lower by using some already owned equipment, instead of purchasing everything new. Purchasing lead time is reduce because much of the special purchase machine is already constructed. Finally, this approach uses equipment which is aleady proven to be reliable.

A machine specification was prepared to solicit manufacturers for the production of the special equipment required. Two technically acceptable replies were received and a contractor was selected.

BENEFITS

Upon completion of the fiscal year 1981 project, benefits are expected to include greater centerline accuracy, a reduced possibillty of error and a reduction in operation time from 2.4 hours to 0.6 hours per chamber evacuator. The new machining process is also applicable to other gun tube components having similar configurations.

IMPLEMENTATION

The simultaneous machining equipment will be purchased and installed using 1981 funds. Thus the project is self-implementing.

MORE INFORMATION

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

Summary report, June 84, was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **680 7926** titled **"Hot Isostatic Pressing (HIP) of Large Ordnance Components"** was completed by the US Army Armament Research and Development Command in September 1982 at a cost of $216,000.

BACKGROUND

Producing the complex final configuration required for step thread type breech blocks for large caliber weapons has continually been a manufacturing problem. Lengthy machining time is required to machine the breech block from the rough forging to the finished part. During machining, 25 percent or more of the rough forging becomes chips. With the high cost of alloy steels, this machining is costly both in terms of material and labor.

This project is the first of a two year effort. Project 682 7926 will complete the development of the manufacturing process.

SUMMARY

The objective of this effort is to produce rough formed components closer to final (net) shape in order to lower material and processing costs. By applying the process of hot isostatic pressing (HIP) to low alloy steel powder, breech blocks will be produced closer to the final desired configuration than the present forgings.

To accomplish this objective, the program will develop the processing parameters and related technical information to apply HIP to breech blocks. Several aspects of alloy steel powder production required resolution in addition to generating HIP parameters such as: optimum containerizing techniques, processing pressures, temperatures and times for producing a fully dense component, and shrinkage or consolidation factors. Full size breech blocks were produced by hipping for testing and evaluation.

Low alloy steel powder was produced by vacuum induction melting and was gas atomized with nitrogen. Sample billets 4 inches in diameter by 12 inches long were hipped to evaluate the powder and hipping process. Based upon the results of this phase, three 8-inch breech block preforms were produced; one with 0.150 inch envelope over the target shape, one with 0.050 inch envelope over the target shape, and one subsize block at final shape.

The components were produced using the ceramic mold process for producing near-net as-HIP shapes. A hipped breech block preform is shown in Figure 1.

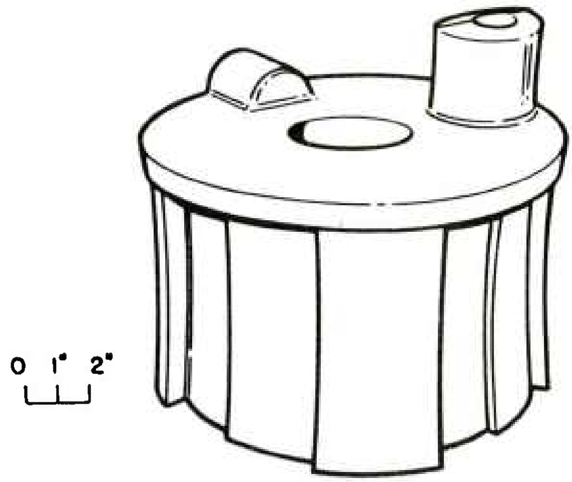


Figure 1 - Machined Breech Block

The results of this project demonstrated that hot isostatic pressing of alloy steel powder can be successfully applied to producing breech block preforms in near-net shape configurations. The processing information, optimum powder production methods and hipping temperature, pressure and time, necessary to produce these components was developed.

The mechanical properties of this material show the HIP process is capable of fully densifying the alloy steel powder and that the resultant product can be heat treated to satisfactory levels of strength and toughness.

BENEFITS

This project has demonstrated the feasibility of hipping large weapons components. Completion and implementation of this effort will result in an estimated savings of $432.00 per large breech block.

IMPLEMENTATION

The breech block preforms will be further analyzed for metallurgical characteristics and processing behavior in the follow-on HIP Project - 682 7926. Additional breech block preforms will be procured in support of the iterative process of obtaining the optimum preform shape. Upon successful completion and testing of the follow-on project, a complete production technique capable of producing a step thread type breech block using the HIP process will be established. Production HIP components will be purchased based upon a revised Technical Data Package.

MORE INFORMATION

To obtain additional information, contact the Project Officer, Mr. Peter A. Thornton, AUTOVON 974-4201 or Commercial (518) 266-4201.

Summary report, Jun 84, was prepared by J. Bruen, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **680 8035** titled **"Coating Tube Support Sleeves with Bearing Materials"** was completed by the US Army Armament, Munitions, and Chemical Command in June 1983 at a cost of $180,000.

BACKGROUND

Electric arc metallizing and flame spraying methods to coat tube support sleeves with bearing materials are inadequate. The coatings are porous and exhibit poor adhesion to the substrate. Sprayed castings are subject to brittle failure because of the formulation of oxide layers on metal particles. The oxide layers formed make surfaces hard and abrasive thereby reducing the bearing quality of the material. Rejection rates are high and considerable rework must be accomplished prior to field use. Consequently, low life cycle costs are not realized.

SUMMARY

The objective of this project was to develop cost effective manufacturing methods to coat weapon components with bearing materials for improved performance. Components fabricated from steel require the application of a bearing material to their surface since steel does not afford the built-in lubricity of nodular iron.

The use of Gas Metal Arc Welding (GMAW) methods to apply bronze bearing materials to inner and outer surfaces of the pistons was investigated. Bronze, deposited with this process, has a high bond strength and very low porosity and oxide contamination when compared to flame and arc sprays. Flame and arc spray coatings have low adhesive strengths and are subject to brittle failure because of the formation of oxide layers on metal particles. Welding the bearing material to the substrate eliminates the bonding interface problem inherent in the spraying process. Also, the welding operation may be automated which would reduce variability in the process. A low alloy steel plate was clad with al-bronze (Ampco-trode 46) for these evaluations. After coating, the plate was tempered for 2 hours at 1000°F. Various specimens were then machined for laboratory testing. Chemical, hardness, wear, friction, tensile and shear strength tests and metallographic analyses were conducted in the laboratory as a means of evaluating the properties of the bearing material and processes.

Several recoil pistons for the M174 gun mount were then coated with Ampco-trode 46 for further investigation (Figure 1).

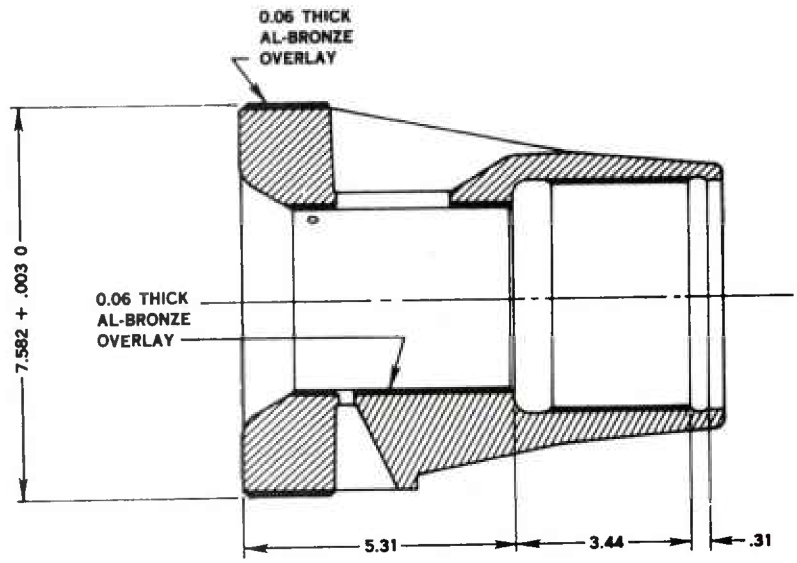


Figure 1 - Cross Sectional View of Recoil Piston for M174 Mount, Coated with Bearing Material

Live firing tests were conducted on a piston at Yuma Proving Ground. After a total of 518 rounds, the recoil mechanism was disassembled and the piston was examined. It was observed that no adverse degradation of the piston had occurred. Only a few scratches were evident and none of these scratches were of an appreciable depth.

Although GMAW procedures developed in this project are cost competitive, the rate of deposition, with attendant cost reduction, could be increased significantly by developing procedures to use larger diameter welding wire.

BENEFITS

The use of cast steel pistons clad with an aluminum - bronze bearing material will resolve prior failure problems experienced with nodular iron pistons currently used in the M174 recoil mechanism. GMAW of Ampco-trode 46 to cast steel pistons results in a competitively priced clad steel piston of better quality. The bond strength of the bearing material and its substrate is significantly stronger then the conventional electric arc metallized coatings. The aluminum - bronze coatings also have better wear resistance when compared to nodular iron.

IMPLEMENTATION

This was Phase I of a two-phase program. During the second phase, additional clad steel pistons will be manufactured for field tests. GMAW procedures using larger diameter wire will be investigated. Other cladding processes using strip welding and explosive bonding methods will be evaluated to determine the least-cost manufacturing methods. An Engineering Change Proposal will then be submitted to recommend implementation of the selected cladding process in production.

MORE INFORMATION

Additional information may be obtained from Mr. Mukesh Solanki, Rock Island Arsenal, AV 793-5965 or Commercial (309) 794-5965 and from Technical Report No. EN-80-01 titled "Coating of Weapon Components with Bearing Material (Phase I)", December 1980.

Summary report, June 84, was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Project **681 8113** titled **"Establishment of Ion Plating Process for Armament Parts"** was completed by the US Army Armament Research and Development Command in September 1982 at a cost of $141,600.

BACKGROUND

Cadmium electroplating has been the favored method for protecting steel on aircraft structures for many years. Obvious problems with its use were minimal prior to the use of high strength steel and aluminum alloys. Cadmium electroplating on high strength steel often caused hydrogen embrittlement. More recently, it has received further disfavor because it was found to cause solid metal embrittlement of the titanium structure and because of its toxicity and harmful effects on the environment.

Over 3,000 armament components are currently electroplated with cadmium. All DOD organizations are committed to replace toxic cadmium wherever feasible. There is an equal need to alleviate the potential for hydrogen embrittlement failures in armament components as well.

SUMMARY

The objective of this project was to establish and document the process parameters and coating requirements for aluminum ion plating of armament components. The basic equipment required for ion vapor deposition (IVD) is a steel chamber, a pumping station, an evaporation source, and a high voltage power supply. The process sequence consists of pumping the system down to about 10^{-4} Torr. The chamber is then backfilled with an inert gas to about 10 microns and a high negative potential is applied between the parts being coated and the evaporation source. The gas becomes ionized and creates a glow discharge around the parts being coated. The positively charged gas ions bombard the surface of the parts and perform final cleaning. The resulting clean surfaces are essential for good coating adhesion.

After the glow discharge cleaning process, commercially available aluminum wire (1100 alloy) is evaporated by continuously feeding it into resistance heated crucibles. As the aluminum vapor passes through the glow discharge, a portion of it becomes ionized. The ionized aluminum particles bombard the surface resulting in a denser coating and improved coating adhesion. The ionization also provides better throwing power and allows complex shapes to be more uniformly plated. The total coating cycle requires about 45 minutes.

The parts are generally chromate treated after being coated. This provides additional protection against corrosion. Chromate treatment also provides a good base for paint adhesion which is a common requirement for aluminum surfaces.

Thirty-six armament parts were selected and coated with IVD aluminum such as those shown in Figure 1. Initial effort on this project involved evaluations on coating thickness, distribution of deposit, adhesion, corrosion resistance, and faster qualification tests.

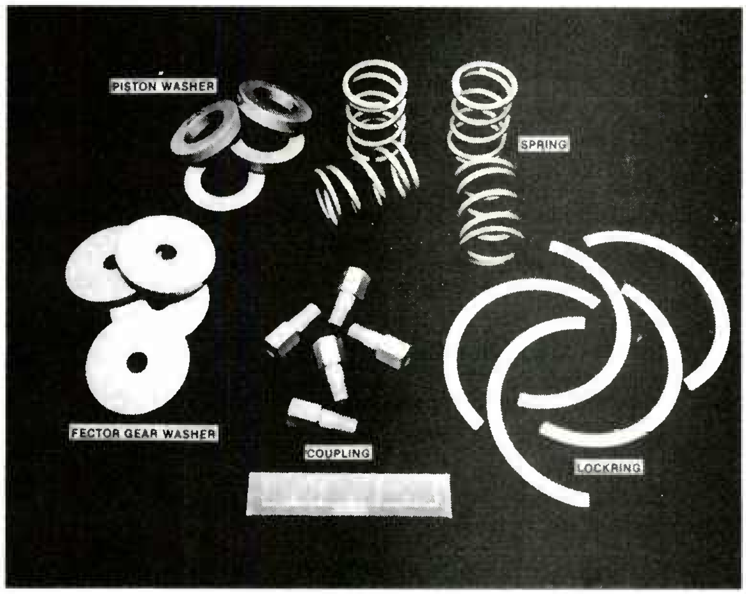


Figure 1 - Armament Parts Coated With IVD Aluminum

IVD aluminum coatings have several advantages over other coatings used to protect both steel and aluminum alloy parts. Some of these advantages include the ability to:

(1) Be used in a temperature range to 925°F (496°C). Cadmium is limited to 450°F (232°C).

(2) Replace diffused nickel-cadmium with better corrosion protection at all strength levels.

(3) Be used on titanium without causing solid metal embrittlement.

(4) Be used in contact with fuel.

(5) Provide galvanic protection to aluminum alloys without causing a reduction in fatigue strength.

(6) Be applied without creating toxic materials.

(7) Be used without producing any detrimental effects on the mechanical properties of the substrate.

BENEFITS

This program has established an IVD aluminum coating process and associated equipment suitable for coating armament components. The IVD process provides the best adhesion and most uniform coating thickness when compared with physical vapor deposition and chemical vapor deposition. The contractor's experience in production has shown the processing costs for IVD aluminum to be comparable to vacuum cadmium but slightly greater than electroplated cadmium. However, if polution abatement costs are included in the costs for electroplated cadmium, then the IVD process becomes even more cost effective.

IMPLEMENTATION

The work accomplished in this project to adapt an aluminum ion plating process to armament components will be continued. Several of the test specimens are still being evaluated and will be completed by the follow-on project No. 682 8113. Documentation of processing parameters including precleaning and post-coating processing will be completed. Optimization of coating parameters and fixturing to minimize coating costs will also be conducted.

MORE INFORMATION

Additional information may be obtained by contacting Mr. E. Silvestre, ARRADCOM, AV 880-3505 or Commercial (201) 328-3505.

Summary report, June 84, was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **681 8153** titled **"Increasing Tube Heat Treatment Capacity"** was completed by the US Army Armament, Munitions and Chemical Command in December 1983 at a cost of $335,000.

BACKGROUND

The current heat treat system, which processes gun tube forgings at Watervliet Arsenal, does not have sufficient capacity to keep up with increased rotary forge production or to meet mobilization requirements. It is estimated that the output of the heat treat line must be increased threefold to handle mobilization production.

SUMMARY

The objective of this project was to establish processing parameters and technical data which would direct mobilization modernization efforts. Two approaches were investigated for use with the existing system to insure that acceptable microstructure and mechanical properties would be attained. The approaches considered are the use of induction heating and utilizing the residual heat from forging to increase heat treat capacity.

Investigation was made into using the retained heat after forging was started by performing large-scale forging trials where special step cylinders were forged. These cylinders were forged into the breech and muzzle diameters of the 105mm M68 gun tubes. Temperatures were monitored throughout the entire heat treatment cycle. Mechanical testing was performed at the completion of each of seven separate heat treatments. Results showed no significant degradation of properties with all properties in the acceptable range.

The induction heating effort involved two contractors and an in-house induction heating experiment. Two basic approaches were investigated in the use of induction heating. One approach was to heat the gun tube so that the entire tube emerged at the completion of the cycle at the required temperature. In the other approach, the tube made one pass through an induction coil and only the area immediately exiting the coil was up to temperature. Both contractors were required to heat tube segments so that the temperature at the completion of the cycle was 1550°F $\pm$ 25° not to exceed 1600°F during the cycle, and not to exceed a 45 minute heating cycle. Basically, the same characteristics resulted from both approaches. Temperature distribution for the two contracts is shown in Table 1.

		PROGRESSIVE HEATING			FULL PC. AT TEMP		
			CROSS SECTION			CROSS SECTION	
TC#	LOCATION	TEMP	T	AVG TEMP	TEMP	T	AVG TEMP
1	1" from BR.	1430°F			1410°F		
2	"	1560			1430		
3	"	1515			1460		
4	"	1630			1300		
			200°	1534°		160°	1400°
5	35" from BR	1510			1570		
6	"	1550			1550		
7	"	1510			1510		
8	"	1550			1600		
			40°	1530°		90°	1558°
9	60" from BR	1520			1420		
10	"	1650			1480		
11	"	1500			1530		
12	"	1650			1780		
			130°	1580°		360°	1553°
13	38" from Muz	1460			1440		
14	"	1620			1490		
15	"	1580			1470		
16	"	1610			1500		
			160°	1568°		60°	1475°
17	1" from Muz	-			1290		
18	"	1660			1400		
19	"	1470			1330		
20	"	1710			1410		
			240°	1613°		120°	1358°

Table 1 - Temperature Distribution Induction Heating Contracts

The temperature uniformity requested is beyond the state-of-the-art and would require further testing for improved controlling techniques. The in-house induction heating test also used the full piece at temperature approach, and the results obtained basically agree with the contract results.

Project 684 8153 is the follow-on project and will investigate techniques to increase the existing tempering furnace capacity.

BENEFITS

The use of the retained heat in a forging appears to be a viable method of increasing heat treat capacity by reducing the time required in the existing austenitizing furnace. The use of induction heating techniques also shows potential for increasing heat treat capacity. Other benefits include reduced operating costs and savings in equipment installation to meet mobilization requirements.

IMPLEMENTATION

This was the completion of the first year of a two-year effort. The FY 84 project is the follow-on project and will complete the total effort. Therefore, the results of this effort are not ready for implementation.

MORE INFORMATION

Further information may be obtained from Mr. Charles Calderone, Watervliet Arsenal, AV 974-4179 or Commercial (518) 266-4179. Reference Watervliet Arsenal Interim Letter Technical Report dated 1 December 1983.

Summary report, June 84, was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **681 8341** titled **"Hollow Cylinder Cut Off Machine"** was completed by the US Army Armament, Munitions and Chemical Command in September 1983 at a cost of $84,000.

BACKGROUND

Gun tube length has been accomplished in one of two ways. The gun tube is either parted off in a lathe and faced to length; or it is rough sawed and then faced to length. Either method requires double measuring, double handling, and slow operating procedures.

SUMMARY

The objective of this project was to establish a new machining process designed to establish finish gun tube length in one setup. A rotary milling process was initially considered to be the most promising approach and was determined to be technically feasible. Further evaluation revealed, however, that the rotary milling process resulted in no noticeable advantage over existing practice.

The use of indexable inserted saw blades to replace brazed tip saw blades was then investigated. This approach was rejected because of premature tool insert and cartridge failure.

The last concept evaluated was a dual headed rotary abrasive saw, Figure 1.

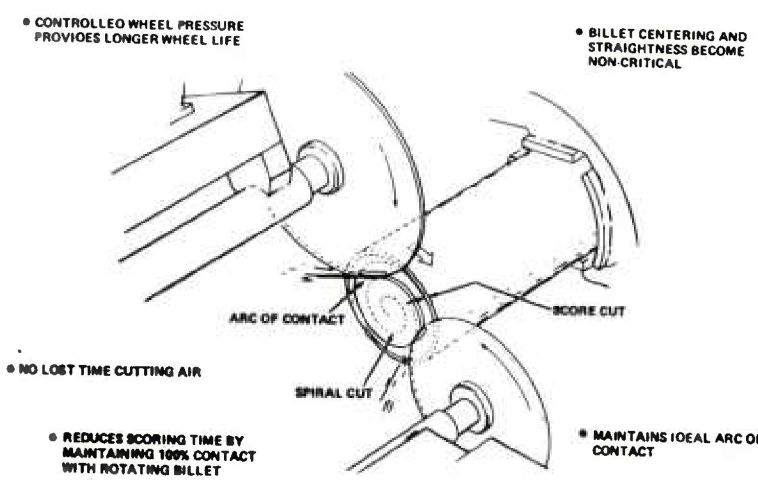


Figure 1 - Dual Headed Rotary Abrasive Saw

Tests were conducted via contract with a company possessing equipment considered to be potentially applicable to the production of gun tubes. Test discs were cut from the muzzle and breech end of the tube using various cutting feeds. Metallurgical tests confirmed that rotary abrasive sawing did not alter the mechanical properties of the gun tube. As a result of favorable test data, a performance specification was developed for the purchase of an automated dual head rotary abrasive saw.

BENEFITS

The execution of this project has resulted in the development of specifications for the purchase of a rotary abrasive saw. This equipment will provide for the establishment of finish gun tube length in one setup.

IMPLEMENTATION

This project is the first year of a two-year effort. Implementation will be addresed upon completion of MMT 682 8341.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Gary Conlon, Benet Weapons Laboratory, AV 974-5737 or Commerical (518) 266-5737.

Summary report, June 84, was prepared by Alan Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Project **680 8342** titled **"Keyway Milling Machine"** was terminated by the US Army Armament, Munitions and Chemical Command in March 1983 at a cost of $64,000.

BACKGROUND

The 155mm M185 Howitzer Tube (Figure 1) requires three keyways to be milled on the centerline to exacting size and location tolerances (±.002 inches). This procedure requires four machine tools to machine these slots, resulting in a large amount of material handling and requiring excessive floor space for work-in-process storage. In addition, each step requires the tube to be electronically repositioned to assure alignment with previous operations. Seven and one-half hours are required to machine a single tube.

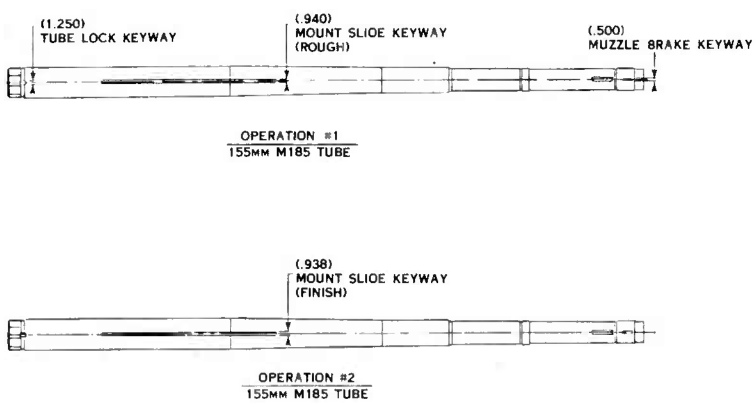


Figure 1 - 155mm M185 Howitzer Tube

A potential reduction in time, in-process storage and material handling, and therefore cost, can be realized through design and installation of a single machine to mill all three keyways simultaneously.

SUMMARY

The major thrust of this effort was on the engineering required to develop an engineering specification for a single special milling machine and on the evaluation of the technical proposals received from the contractors.

The specifications developed required a three-spindle, arbor supported, rise and fall, bed type traveling column milling machine capable of machining under control three different keyway slots independently and simultaneously. The machine would use steel arbor mounted cutters, but also would provide adequate rigidity, horsepower, and anti-backlash mechanisms required for carbide cutters. All fixturing, clamping, locating, and work holding devices were included with the specifications.

Three proposals were received by Watervliet. One was not in compliance with specifications and another was eliminated after a futile attempt by Watervliet to clarify certain items. The final proposal was technically acceptable but the price was in excess of the anticipated machine cost.

This project was terminated because the time and cost savings generated by the proposed keyway milling machine were not great enough to justify its purchase. The remaining funds were reassigned to another project.

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BENEFITS

None.

IMPLEMENTATION

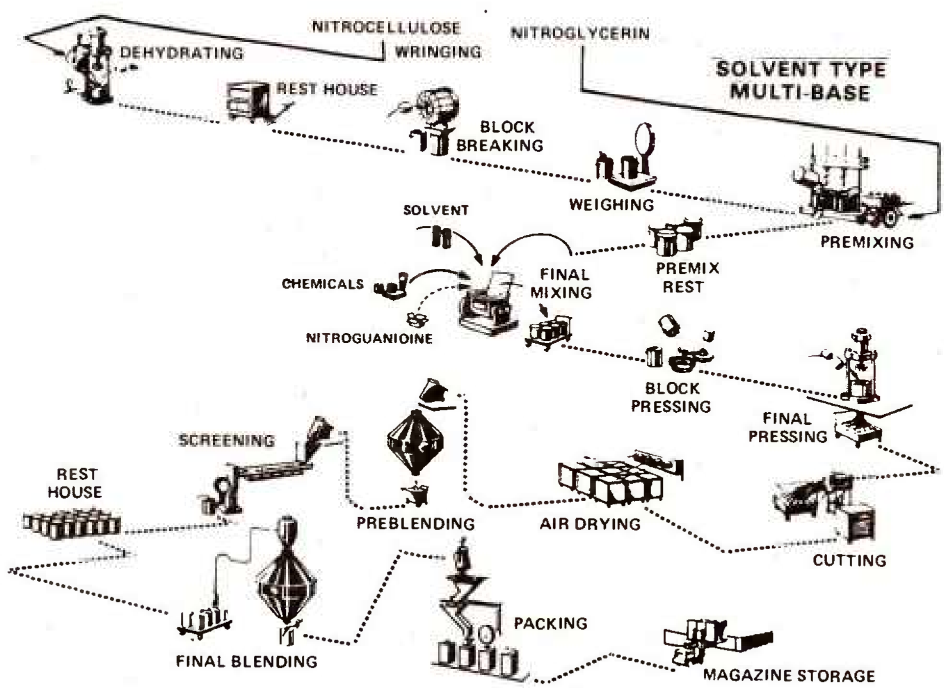
There is no planned implementation action of this project.

MORE INFORMATION

Additional information on this project is available from Mr. Brian C. Rose, Watervliet Arsenal, AV 974-5590 or Commercial (578) 266-5590.

Summary report, June 84, was prepared by Sandy Jackson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MUNITIONS



CONVENTIONAL PROPELLANT MANUFACTURE

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

MMT Project **579 4046** titled **"Development of Automated Method to Perform Quantitative Analysis of Blended Explosive Samples"** was completed by the US Army Armament, Munitions and Chemical Command in February 1984 at a cost of $307,000.

BACKGROUND

An explosive blend of five ingredients, NOL-130 primer mix, is used in the loading of detonators. The most popular of these detonators is the M55 with a monthly production in the millions. A sample of each newly synthesized batch of NOL-130 must be analyzed before the batch can be loaded. Currently, about seven analyses are required each day. Performing the test at Lone Star AAP requires the transport of each sample from the detonator production area to the Chemistry Lab, a distance of approximately 2 1/2 miles. The lab test requires four hours to determine if the composition is within specified tolerances. In addition to the extra cost and longer exposure to hazardous materials, the material can pick up moisture during the holdup time. As a result, a large incentive exists to reduce the analysis time.

SUMMARY

The purpose of this project was to provide equipment and procedures which would shorten the time required for the analysis of explosive compositions used in detonators and related items. The studies were confined to NOL-130 primer mix, which is nominally made up of lead styphnate (40%), lead azide (20%), barium nitrate (20%), antimony sulphide (15%) and tetracene (5%).

Since no commercial equipment was available to perform this analysis, it was necessary to first study various chemical analysis techniques. These included neutron activation, x-ray fluorescence, atomic absorption, combustion and polarography. It was concluded that the latter system was the optimum one to be developed.

Polarography is a branch of voltammetry that investigates solution composition by reducing or oxidizing metals, organics, and ions at a dropping mercury electrode (DME). A potential is applied between the DME and a reference electrode, and the resulting current versus the applied potential is plotted. The polarograph analyzer is connected to the analytical cell. It controls the potential of the electrode and measures the current at the electrode. The cell contains three electrodes (reference, working, and counter) which are immersed in the solution.

Work was then carried out to optimize the polarograph for the application at hand. The major components of the polarograph system developed are a Model 384 polarograph analyzer, a Model 303 static mercury drop electrode (SMDE), and a Model DMP-2 digital plotter. These are shown in Figure 1.

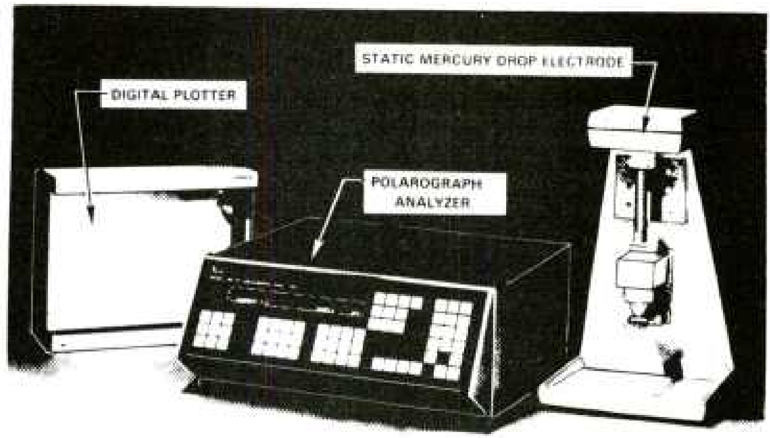


Figure 1 - Polarograph System

The process was optimized for analyzing all of the NOL-130 constituents. This included studies for determining the best dissolving techniques, optimum electrolytes, required times, conversion formulas, etc. Subsequently, it was tested at an operating plant using load plant personnel and another polarograph.

It was concluded that the polarograph can be used in production to analyze NOL-130. Its use will reduce analysis time from four hours to less than one hour. During the initial use of this new testing process, the allowable composition tolerance will be tightened until confidence is gained through successful experience. These new tolerances are shown in comparison with the chemical laboratory test tolerances in Table 1.

Table 1

	Polarograph Test Tolerances	Chemical Laboratory Test Tolerances
Lead Styphnate	+1.0%, - 1.3%	(+ 2.0%)
Lead Azide	+1.2%, - 1.0%	(+ 2.0%)
Barium Nitrate	+1.1%, - 1.8%	(+ 2.0%)
Antimony Sulfide	+1.0%, - 1.0%	(+ 1.5%)
Tetracene	+0.25%, - 0.25%	(+ 0.5%)

BENEFITS

On the basis of operating cost savings alone, the new technique is expected to save $130,000/year.

IMPLEMENTATION

Implementation of the polarograph test method is now in progress at Lone Star AAP and Iowa AAP.

MORE INFORMATION

To obtain more information, the project officer, P. Monteleone, can be contacted at ARDC, AV 880-4545 or Commercial (201) 724-4545. Also, further detailed information relative to development of the polarographic process can be found in the following two technical reports:

a. Stanley Semel, "A Rapid Chemical Analysis of the Ingredients of NOL-130 Primer Mix", Report ARLCD-TR-79041, ARRADCOM, Dover, NJ, December 1979.

b. Sanford Levat, "Polarographic Analysis of NOL-130 Primer Mix", Report ARLCD-TR-83037, ARDC, Dover, NJ., February, 1984.

Summary report, June 84, 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)

MMT Project **581 4059** titled **"Control of Nitroguanidine Crystallization"** was completed by the US Army Armament, Munitions and Chemical Command in March 1983 at a cost of $190,000.

SUMMARY

Nitroguanidine (NQ) is an ingredient used in several military propellant compositions. It has been found that during long term storage, NQ undergoes an agglomeration of the particles. This may cause difficulty in the manufacture of triple-base propellant. To preclude these difficulties, it would be necessary to determine parameters affecting NQ agglomeration and ways to minimize any increase in particle size during storage.

SUMMARY

The objective of this project was to investigate the effects of impurities, coatings, and additives on the agglomeration of NQ.

Experiments were performed to determine the rate of agglomeration of NQ as a function of time at various percent relative humidities. The particle size rate-of-change of an NQ standard and test samples were monitored by surface area measurements using Krypton gas as the adsorbate molecule in Brunauer, Emmet, and Teller (BET) apparatus. Surface areas were determined for NQ samples exposed in 25, 50, 75, 90, and 100% relative humidity (RH) chambers. There was no apparent loss in specific surface at 25 or 50% RH. At the higher humidities, the loss was rapid during the first three weeks and negligible thereafter to twenty weeks. The total loss in specific surface was about 25%. A sample of purified NQ was held at 0% RH for 10 months. Its specific surface remained virtually constant.

Samples of NQ made by Cyanamid of Canada, Ltd., were tested without recrystallization at 25 and 100% RH. The relative loss in specific surface after 10 weeks was about the same as for purified NQ, but occurred gradually. The specific surface then remained approximately constant for the next 10 weeks. Limited work was done with NQ made at Sunflower AAP. It appeared to agglomerate faster, but to about the same degree as other samples.

The results of exposing different particle sizes (the smaller particle sizes have the larger surface areas) to 100% RH are shown in Figure 1. This figure shows that the rate of agglomeration is proportional, at least in a qualitative way, to the surface area.

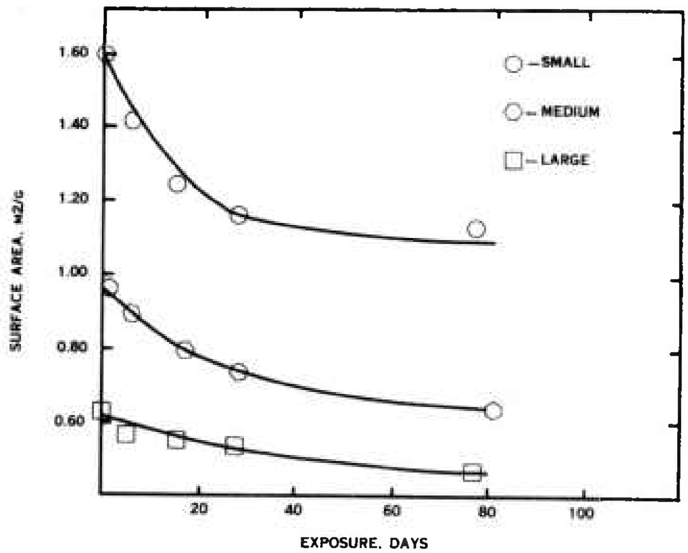


Figure 1 - Agglomeration of Nitroguanidine Exposed to 100% Relative Humidity as a Function of Particle Size

A Canadian plant sample of NQ was subjected to water adsorption/desorption measurements. An open hysteresis loop was observed on desorption which means that a certain amount of water becomes irreversibly absorbed into the crystal lattice. Also, the number of water molecules adsorbed per 100A°^{2} of NQ surface at monolayer coverage was calculated to be four, which classified NQ surface to be of intermediate hydrophilicity.

A number of potential inhibitors were tried. Two batches of NQ were crystallized using 0.05% ammelide as a crystal habit modifier. Three batches of NQ were recrystallized using 0.01% concentrations of cationic, anionic, and non-ionic surfactants, which may act as hydrophobing agents. The surfactants used were sodium lauryl sulfate, Malasperse and cetyl trimethylammonium bromide. NQ samples were recrystallized with various substances reported to be crystal habit modifiers. Substances tested were starch, polyvinyl alcohol, N-methyl pyrrolidinone, benezaldehyde, nitroguanyl hydrazone, melamine, formaldehyde, and methyl cellulose. None appeared to be adequately effective agglomeration inhibitors.

A coating agent tried was stearylammonium acetate. After treatment, the surface area of the sample was measured and then placed in storage at 100% RH. There was no significant agglomeration after 34 days. This approach has the advantage of minimizing handling, as it can be applied after the NQ has been precipitated in the plant and just prior to filtration. However, vacuum stability tests at 90°C produced excessive gas when M30 propellant was mixed with amines.

Conclusions drawn from these tests were that NQ in storage was prone to agglomerate in the presence of a high RH. Agglomeration can be prevented by controlling humidity. Attempts to modify the crystal habit to inhibit agglomeration were not successful, nor were attempts to alter surface properties with surfactants. Various experiments were made to hydrophobe the NQ surface. It has been shown that it is possible to hydrophobe the NQ surface, and thereby inhibit agglomeration in the presence of a high humidity. Further testing on a large scale and resolution of the possible compatibility problem remain to be accomplished. Work along these lines will depend upon experience with NQ produced at Sunflower and studies of the effects of NQ particle size in current gun systems.

BENEFITS

An improved crystallization process is expected. This improvement may reduce off-grade product rework by an estimated 7 percent. Avoiding this rework would result in savings of $300,000 per year at full production.

IMPLEMENTATION

The ultimate plan is to incorporate the results of this effort into the NQ production plant at Sunflower AAP.

MORE INFORMATION

Additional information may be obtained from the project engineer, Mr. A. Litty, AMCCOM (D), Dover, NJ, AV 880-3637 or (201) 724-3637. Details of this investigation are contained in Technical Report ARLCD-TR-83026, "Nitroguanidine Agglomerations", May 1983, LCWSL, Dover, NJ.

Summary report, June 84, was prepared by Andy Kource, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **580 4061, 581 4061,** and **582 4061** titled **"Nitroguanidine Process Optimization"** were completed by the US Army Armament, Munitions and Chemical Command in Feburary 1984 at a total cost of $2,550,000.

BACKGROUND

A nitroguanidine pre-production facility was constructed at Sunflower Army Ammunition Plant and proved out in 1981. It is the first nitroguanidine plant constructed in the United States. It utilizes processes not previously used commercially and it contains many recirculation and support loops, the operations of which are strongly interdependent. No optimization operations were conducted during prove out.

The Nitroguanidine Support Equipment (NSE) is a scaled down version, 1/18, of the main production plant. It was sized to provide correlation with the main plant. Operating the NSE would be more economical in terms of energy, manpower, and raw material consumption. Optimizing operating conditions in the NSE would be more efficient and expedient than in the main, full sized plant.

SUMMARY

The objective of this effort was to determine optimum operating criteria in the NSE plant and applying the information developed in the main production plant. In this regard, a program was developed which would systematically investigate and optimize the guanidine nitrate, nitroguanidine, sulfuric acid concentration, and recycle processes.

This report covers the first three years of a four-year effort. The first year (FY80) provided for the preparation and approval of a plan by which the equipment would be operated. The next two years of funding (FY81 and 82) provided for the operation of the equipment to determine equipment and process adequacy for retention time, temperature control, concentration, pressure control, and maintainability.

The physical condition, as well as the chemical content of many of the solutions and slurries were critical because of their effect on settling, filtering, and final particle size. The effects of the various recycle loops upon each other had to be established if the plant was to be run economically. In the first year, variables for optimization were established and their high and low values were set. The required analyses were determined and the order of the test runs was established. A finalized list of samples required for each optimization test and analyses for each sample was then completed.

The optimization efforts began with the guanidine nitrate (GN) process parameters. A two-level fractional factorial experiment was designed to evaluate the parameters selected for the reactors, crystallizer, neutralizer, dryer, and evaporator. Significant improvements in process parameter set points were established. Reducing the reaction temperature from 120 to 110°C was particularly effective in improving the conversion of calcium cyanamide to GN. Conversion to 83% of theoretical was obtained. The calcium cyanamide feed rate used was 250 pounds/hour, twice that obtained during prove out operations. During this time, a total of 60,500 pounds of GN were produced for use in the subsequent NQ optimization runs.

The nitroguanidine (NQ) optimization efforts were directed at the process parameters of the nitration system, Figure 1. The GN feed rate was 200 pounds/hour which resulted in an NQ output of 145 pounds/hour, a substantial improvement over the 75 pounds/hour production rate obtained during the prove-out operations. A total of 41,500 pounds of NQ was produced during a 5-week time period. The optimization efforts showed that the conversion of GN to NQ could be increased beyond the design level of 92% up to 96%. In view of the high conversion and relatively good operation that was achieved in the NQ section of the plant, it was decided to devote additional effort to the GN process.

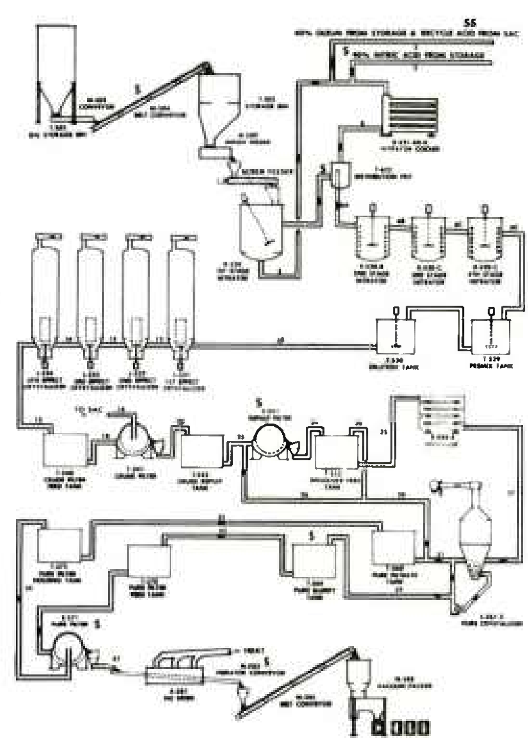


Figure 1 - Nitroguanidine Process Flow Diagram

During this next series of runs, it was found that the conversion of calcium cyanimide to GN could be increased from 83% to 96% by increasing the ammonium nitrate to calcium cyanimide ratio from 5.92 to 8.89. During this entire series of tests, the runs were allowed to run 24 hours to achieve equilibrium. However, during one of the tests, a sample was taken at the 38-hour point. This sample showed a 5% higher conversion than the 24-hour sample. After performing some residence time calculations, it was concluded that future GN system testing should use a stabilization period of at least 108 hours.

BENEFITS

Operating the NSE instead of the main plant to determine optimum operating conditions resulted in savings in manpower, energy and materials. Future savings are also expected when the main plant is operational as a result of the optimized conditions developed. Assuming a 5% increase in yield as a result of these optimal conditions, an annual savings of $800,000 will occur when the plant is operated at 28% of the full production rate.

IMPLEMENTATION

The information obtained will be applied and validated in the main plant in 1984. The information will also be applied to the design of a second plant which is currently scheduled for FY87 funding.

MORE INFORMATION

Additional information about this project may be obtained from M. A. Litty, AMCCOM(D), by calling AV 880-3637 or Commercial (201) 724-3637.

Summary report, June 84, was prepared by Andy Kource, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **580 4231** titled **"In-Plant Reuse of Pollution Abated Water"** was completed by the US Army Armament, Munitions and Chemical Command in April 1983 at a cost of $208,000.

BACKGROUND

The Federal Environmental Protection Agency has set 1985 as their goal for zero discharge of pollutants into U.S. waterways. There are essentially only two ways to accomplish this: reduce the pollutant level in the discharge water or reduce the volume of discharge water itself. In order to reduce plant effluent, some type of wastewater decontamination is followed by recycle and reuse of the abated wastewater within the plant. The abated effluent may be recirculated anywhere that it has been determined that the pollutant level will not adversely affect the manufacturing process.

SUMMARY

This project evaluated load/assemble/pack lines at both Louisiana AAP and Kansas AAP to determine potential processes which could use recycle/reuse water.

Louisiana AAP - The metal parts (Y-line) line at LAAP was identified as having potential use for recycle/reuse of pollution abated water. An analysis was conducted to determine the quality and quantity of process water required by the metal parts line, the minimum treatment required for the out-of-plant discharge, and the economics involved in recycling this discharge.

The results indicated that recycling pollution abated waters is not currently economically justifiable at LAAP. However, future stringent discharge limits will have criteria available for corrective measures to be implemented at the plant.

Kansas AAP - A previous project (579 4214) identified three areas of KAAP as potential users of recycle/reuse water. These are the 900 (81mm mortar line), 1000 (105mm line) and 1100 (CBU line) areas.

Two different effluent treatment systems were studied, ultraviolet-ozone treatment and filter adsorption. The ultraviolet-ozone system has variable UV light input and intensity, ozone introduction rates and mixing, and water flow rate (See Figure 1). This system was analyzed in five different operational modes by changing the UV wavelength, wastewater flow rate, and ozone dosage rate. These experiments indicated that RDX removal efficiency from 90.5% to 99.0% is obtainable.

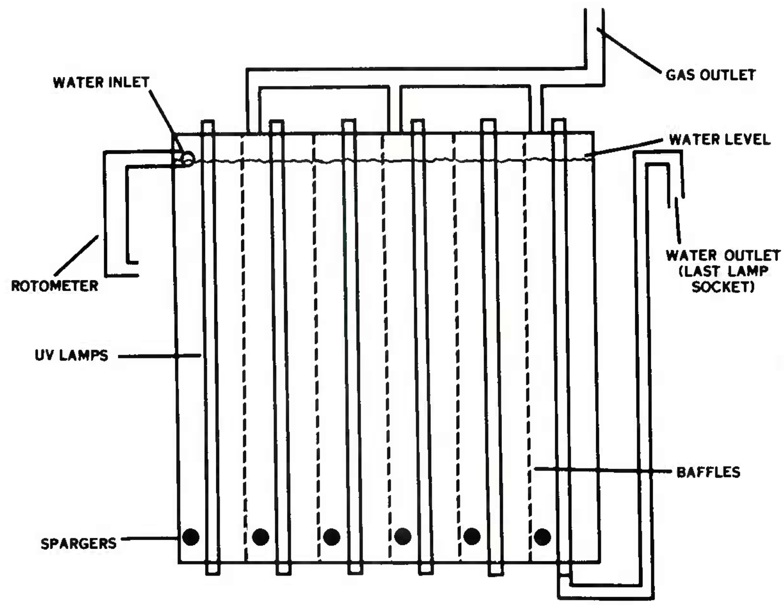


Figure 1 - View of UV Ozonation Reactor

The filter adsorption system consists of a single diatomaceous earth leaf filter and an activated carbon adsorption column. This system was analyzed in four operational modes. The wastewater retention time in the column and the number of carbon columns were the variables considered. Efficiency ranged from 65.6% to 99.3% for RDX removal and from 95.7% to 99.99+% for TNT removal.

An economic evaluation of the UV-ozone and charcoal adsorption treatments was conducted for six areas within the Kansas plant. Reuse of treated water was found to be economical in three of those areas. The projected payback periods for installing a UV-ozone recycle system in areas 900, 1000 and 1100 are 5.6, 4.5, and 3.4 years, respectively.

The water recirculation system at KAAP was also studied extensively. After a recirculation of nearly 15,000 gallons of abated water, there was no evidence of explosive buildup in the high-volume, high-pressure pipes. The same result was observed after recirculating 47,000 gallons through the low-volume, low pressure lines.

BENEFITS

Implementation of the UV-ozone system at Kansas AAP, areas 900, 1000 and 1100, would lower the pollutant level of the effluent while decreasing operating costs.

IMPLEMENTATION

The results of this project are currently available for implementation.

MORE INFORMATION

Additional information may be obtained from Mr. Larry Sotsky, ARDC, AV 880-3544 or Commercial (201) 328-3544.

Summary report, June 84, 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)

MMT Project 581 4285 titled **"TNT Equivalency Testing in Support of Safety Engineering for Ammunition Plants"** was completed by the US Army Armament, Munitions and Chemical Command in December 1983 at a cost of $441,000.

BACKGROUND

The US Army has been involved in a continuing program to upgrade the safety standards of new and existing ammunition plants. In support of this program, design standards are developed for hardening protective structures to withstand the effects of the detonation of high explosives. Design and safety engineers require data pertinent to the maximum strength of a blast wave that may originate from any of the explosive or deflagratable materials present in a plant. Since blast parameters were not available from the literature on certain explosives and propellants, efforts were needed to establish TNT equivalencies of these materials. By utilizing this data, significant cost savings could be achieved by avoiding over-design of structures and safety of personnel improved by the installation of adequate blast protection.

During the FY80 project, tests were conducted on DIGL-RP propellant, JA-2 propellant, Cyclotol 70/30, RDX ,and PBXC-203. TNT equivalencies were determined from this data.

SUMMARY

The objective of this project was to obtain TNT equivalency ratings for selected high energy materials. This was accomplished by determining the peak pressure and positive impulse data from blast measurements.

Tests were conducted on XM37 propellant, ammonium perchlorate, and bulk flake TNT. The tests resulted in the establishment of pressure and impulse curves from the materials detonated. The TNT equivalency was then computed based on comparison with TNT hemispherical surface bursts. In order to calculate the TNT equivalencies, appropriate scaling laws were applied. For example, the pressures which occur at a distance from an explosion are proportional to the cube root of the energy yield. The following paragraphs summarize the results on some of the materials evaluated:

XM37 Propellant

XM37 propellant is a double base propellant blended as a solventless slurry, manufactured into carpet rolls and extruded into propellant billets. The billets are extruded in two diameters for the production of the forward and aft grains for the RAP 549.

The XM37 propellant was detonated in configurations simulating the extruded billets, forward and aft grains, and the shipping container typical of a manufacturing facility. Blast output parameters were measured and compared with TNT to determine equivalency.

The pressure equivalencies were found to be greater than 100 percent for all configurations except at a scaled distance of 2.78 m/kg$^{1/3}$ (7.0 ft/lb $^{1/3}$) for the aft propellant grain. Impulse equivalencies were greater than 100 percent for all configurations except at a scaled distance of 7.14 m/kg $^{1/3}$ (18.0 ft/lb $^{1/3}$) for the forward propellant grain and at a scaled distance of 3.57 m/kg$^{1/3}$ (9.0 ft/lb $^{1/3}$) for the Ro Con shipping drum (aft grain). Test results indicate that pressure and impulse values were dependent upon geometry.

Ammonium Perchlorate

Ammonium perchlorate is an oxidizer ingredient used in the manufacture of composite solid propellants. The hazard classification of ammonium perchlorate was questioned by the UN Committee of Experts on the Transport of Dangerous Goods. To resolve this conflict, a series of tests was conducted.

The objective of this study was to determine the class and behavior of ammonium perchlorate, nominal 200-micron size, packaged and subjected to Test Series 6 of the INTEREG, Transport of Dangerous Goods.

A first series of tests was conducted on single drums of ammonium perchlorate, each confined in all directions by 1 m (3.28 ft) of sand bags and ignited by an S94 squib and 56.7 g (2 oz) of black powder. A typical test setup is shown in Figure 1. In all tests, the material thermally decomposed. There was no explosion, no overpressure detected, and no rupture, splitting or fragmenting of the drum.

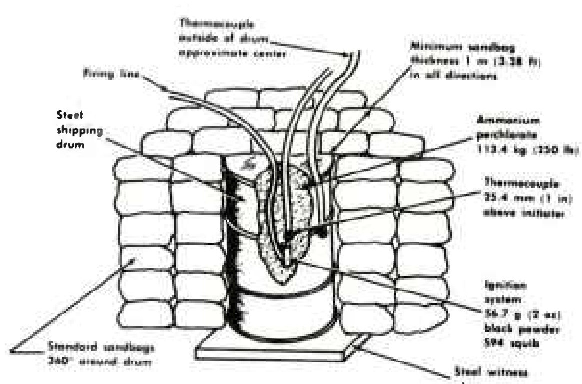


Figure 1 - Single Package Test Configuration

In a second series on single drums of ammonium perchlorate confined in the same manner as in the first series, the initiation source was a number 8 blasting cap. In this series, the ammonium perchlorate also thermally decomposed and there was no explosion, no overpressure detected, and no rupture, splitting, or fragmenting of the drums.

In the next series of tests, a single drum of ammonium perchlorate was tested unconfined using an S94 squib; 56.7 g (2 oz) of black powder was the ignition source. The ignition of the black powder caused the drum lid to pop off and ejected approximately one-third of the ammonium perchlorate from the drum. The ammonium perchlorate did not react or thermally decompose and there was no damage to the drum. Based upon interpretation of the series of tests, ammonium perchlorate, nominal 200-micron particle size, in 113.4 kg (250 lb) quantities in steel shipping drums is not a Class 1 material explosive but is classified as a 5.1 oxidizer.

Bulk Flaked TNT

Bulk flaked TNT is a high explosive. The TNT equivalency tests were performed covering those configurations which are encountered at sensitive locations in the explosive manufacturer's facility. These configurations were the hopper configuration at the end of the casting belt, the transfer box, and the cylindrical shipping container, typical of a manufacturing facility. The large weight generally contained in the hopper configuration and the transfer box configuration was scaled down for these tests. The pressure equivalencies were greater than 100 percent at the near-field scaled distances < 3.57 m/kg $^{1/3}$) (9.0 ft/lb $^{1/3}$) for all configurations, and varied above and below 100 percent at the far-field scaled distances > 7.14 m/kg $^{1/3}$ (18.0 ft/lb $^{1/3}$). Impulse equivalencies varied for each test series and were greater than 100 percent for all configurations at scaled distances <3.57 m/kg $^{1/3}$ (9.0 ft/lb $^{1/3}$) and varied above and below 100 percent at scaled distances > 3.57 m/kg $^{1/3}$ (9.0 ft/lb $^{1/3}$). Test results indicate that pressure and impulse values were dependent upon geometry and scaled according to the cube root of the charge weight.

BENEFITS

This project provided TNT equivalency data which, when used with DRMCR 385-100 and TMS-1300, enables the designer to design structures that will safely resist the blast effects of an accidental explosion. Cost savings can be realized through the use of the data developed.

IMPLEMENTATION

The results published in technical reports were distributed to AAP's, Corps of Engineers, other design agencies, and various other safety echelons for use in conjunction with TMS-1300. The equivalency results using TNT as a basis can be converted to overpressures and impulses since the design data in the manual is based upon TNT curves. This enables the designer to calculate the loads on protective structures.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary report, June 84, 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)

MMT Project **582 4298** titled "**Evaluation of DMN Disposal on Holston AAP B-Line**" was completed by the US Army Armament, Munitions, and Chemical Command in January 1984 at a cost of $390,000.

BACKGROUND

This project is a continuation of the prior year's effort to develop the technology for the abatement of dimethylnitrosamine (DMN), a carcinogen present in the wastewater stream at Holston AAP. The initial FY81 project studied advanced DMN treatment technologies and determined the most practical means was the catalytic hydrogenation of the final sludge stream. This treatment method chemically reduced both the DMN and explosives contained in the final sludge by reacting them with hydrogen gas in the presence of a catalyst. In order to proceed with construction of a disposal facility, a process design was required.

SUMMARY

The objective of this project was to obtain the complete process design for a DMN disposal system based on the recommended treatment method. As a result of this effort, the process design for the DMN disposal system to be used in HSAAP's B-Line (acetic acid recovery process) was generated. A drawing package and materials list of sufficient detail was prepared to permit procurement of the processing equipment, piping, instrumentation, and installation materials required to construct a functional DMN disposal facility at HSAAP.

The DMN disposal system design was prepared on the basis of installing and initially operating the disposal system as a pilot plant facility at Building B-3 in the B-Line at HSAAP. The pilot plant design permitted the catalytic hydrogenation process to be evaluated and, if necessary, modified without disrupting current B-Line operations. The system was sized to handle the total amount of final sludge currently being generated from the acetic acid recovery operation. The pilot plant design for the DMN disposal facility is readily adaptable to production usage once system proveout has been demonstrated and completed.

The DMN disposal system was designed to eliminate DMN and explosives from the final sludge stream at Building B-3. As a result, some of the existing equipment at Building B-3 was used to support the pilot plant evaluation. The existing equipment to be utilized includes the acetic acid stripping column, three final sludge storage tanks in the tank farm, the reactor feed pumps used to feed final sludge into the caustic reactors, one caustic reactor to be used as a finished sludge hold-up/transfer tank, and the transfer pump for the caustic reactor. New process equipment required for the DMN disposal system will include a final sludge feed tank, a two-stage centrifugal pump system, a catalytic hydrogenator reactor, a vapor/liquid separator, a finished sludge hold-up tank, and a finished sludge transfer pump.

A general process description is provided as follows and shown in Figure 1.

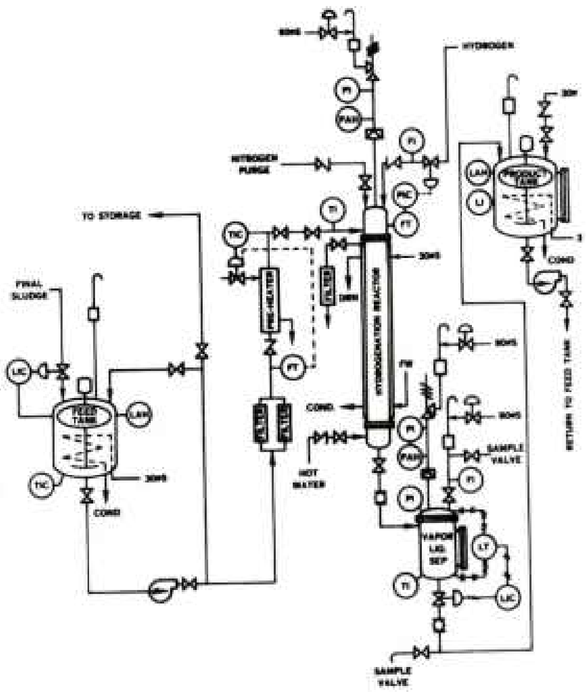


Figure 1 - Flowsheet of the Catalytic Hydrogenation Process to Dispose of Dimethylnitrosamine (DMN)

Final sludge feed for the DMN disposal process will be pumped into the feed tank from one of the final sludge storage tanks located in the tank farm at Building B-3. The transfer will be made using one of the reactor feed pumps. After the sludge has been transferred into the feed tank, it will be agitated and heated to 110-120°C (383-393K) to insure that all of the water soluble solids are in solution. Electrical heat tracing and an in-line filter will be used in the feed line to further insure that the final sludge feed to the reactor remains free of solids.

A special two-stage centrifugal pumping system will be used to feed final sludge into the pressurized hydrogenation reactor. The process design was based on a final sludge feed rate of 3.1 gal/min (2.0×10^{-4} m^3/sec). The balance of sludge flow from the discharge will be recirculated to the feed tank.

The catalytic hydrogenator reactor will operate at an interior hydrogen presssure of 150 psig using a final sludge feed rate of 3.1 gal/min. A "trickle-bed" operating mode, involving concurrent flow of hydrogen and final sludge down through a fixed catalyst bed of palladium coated carbon will be used to obtain the contact time required between the hydrogen and the final sludge contaminants (DMN, RDX, and HMX) at the catalyst sites that results in the complete destruction of DMN and explosives in a single pass through the catalyst bed. The "trickle-bed" operating mode has been shown to be effective in the current sized reactor with final sludge flow rates up to 4.5 gal/min (2.8×10^{-4} m^3/sec); however, excessive feed rates will stop the hydrogenation process by flooding the catalyst bed.

Collection of the hydrogenated, or finished, sludge is performed in two stages. The first stage involves a vapor/liquid separator equipped with a differential pressure level control system and an "off-gas" bleed/vent system to permit sludge drawoff while maintaining the reactor system pressure at 150 psig. Transfer of the finished sludge from the vapor/liquid separator into the finished sludge hold tank will utilize the system pressure to force flow through the separator discharge line when the automatic valve in the line is opened by a high level signal from the level controller. The second stage of finished sludge collection will be performed in the hold-up tank where residual hydrogen will be separated and removed from the treated sludge. Steam purge of this tank will be used to safely remove hydrogen through the atmospheric vent. A centrifugal pump will be used to transfer the finished sludge to storage.

A preliminary hazards analysis of the DMN disposal process was also prepared. The flammability of hydrogen was determined to be the most significant hazard associated with the system, and the constant venting of purge hydrogen from the vapor/liquid separator was identified as the most likely source for ignition. The recommended action for minimizing this hazard included locating the vent exit remotely from the process, steam snuffing of the vent exit, and installation of a positive shutoff of the hydrogen supply from a location outside the pilot plant facility. Implementation of the modified design recommended by the analysis is expected to result in the DMN disposal system operating with a Category IV (negligible) hazard classification.

The US Army Medical Bioengineering R&D Laboratory continued to investigate the use of a semi-continuous activated sludge treatment system for treating munitions wastewaters. The data indicated that continuously fed intermittently operated activated sludge systems appear to be highly suitable for the treatment munitions wastewaters.

BENEFITS

This project provided a system design for a process to reduce the DMN resulting from the B-Line at Holston AAP.

IMPLEMENTATION

The results generated from this project will be implemented at Holston AAP under a future MCA or MOD Expansion program.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. Swotinsky, AV 880-3544 or Commercial (201) 328-3544.

Summary report, June 84, 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)

MMT Project **580 4310** titled **"DMSO Recrystallization of HMX/RDX"** was completed by the US Army Armament, Munitions and Chemical Command in October 1983 at a cost of $349,000.

BACKGROUND

This effort is the continuation of the development of an improved continuous process for recrystallizing RDX and HMX from dimethylsulfoxide (DMSO) solvent. The use of this solvent, with an improved process, will allow more efficient crystallization of large quantities of RDX/HMX; thereby, yielding significantly greater throughput of product. During the FY75, FY76 and FY77 efforts, the design, procurement, and installation of the DMSO pilot plant was accomplished. In FY78 and FY79, the DMSO pilot plant was continuously operated and tested using first inert, then live material to establish process parameters. However, implementation of the DMSO process improvement was contingent upon interim qualification end item testing and toxicity testing.

SUMMARY

The purpose of this project was to complete the interim qualification testing of end items containing RDX/HMX recrystallized from DMSO. In addition, toxicity testing of selected in-process streams was conducted because of exposure to operating personnel.

The qualification and end item testing was performed on DMSO recrystallized RDX/HMX that was manufactured at Holston AAP (HSAAP). Seven explosive compositions, namely, Comp A-5, Comp A-3, Comp B, Comp C-4, Cyclotol 70/30, Octol 70/30, and Octol 75/25 were tested. The test results indicated no significant difference in sensitivity, stability, and compatibility for the DMSO-recrystallized explosives when compared to equivalent standard explosives.

End item tests were also conducted with the DMSO-recrystallized explosive compositions loaded into four items. They were the M55 detonator, M42 and M46 grenades, M112 demolition charge, and 105mm M1 projectiles. Visual inspection of the loadability of the DMSO explosives was determined to be equal to the standard explosive when loaded into the end items. When subjected to long term storage and environmental tests, the performance of the DMSO items was equal to the standard items. The overall testing effort concluded that the DMSO-recrystallized explosives were safe, stable, and functional as standard explosives now in use.

The toxicity study was conducted by US Army Medical Bioengineering R&D Laboratory (USAMBRDL) which, in turn, subcontracted major segments of the work to Oak Ridge National Laboratories (ORNL), the Letterman Army Institute of Research (LAIR) and the Laboratory for Energy-Related Health Research (LEHR), a Department of Energy Lab located at the University of California in Davis, CA. The overall study consisted of three phases: (1) Problem Definition Study, (2) Chemical/Physical Characterization and Site Evaluation for Hazards Exposure and (3) Acute Toxicology.

The Problem Definition Study conducted by ORNL involved a review of available scientific and biomedical data on DMSO and DMSO-contaminated solvent principal components.

Chemical characterization of the in-process samples used in the acute toxicology work was conducted at HSAAP, LAIR and USAMBRDL. In-process samples consisted of the bottoms product remaining after solvent recovery operations (evaporator sludge) and a recycle solvent obtained by combining samples taken over a number of runs for both HMX and RDX recrystallization. The results of the analysis using high performance liquid chromatography (HPLC) indicated that compounds detected were RDX, HMX, and other by-products. However, additional analysis using gas chromatography/mass spectrometry identified other compounds such as dimethyl-sulfone, benzothiazole, and diacetone alcohol.

Acute toxicology testing of the two pilot plant samples was conducted primarily at LAIR and consisted mainly of a battery of animal dosing studies including acute oral LD50 in mice and rats, primary dermal and primary eye irritation in rabbits and dermal sensitization in guinea pigs. Two mutagenicity assays were also carried out: Ames Salmonella at LAIR and a more sensitive Mouse Lymphoma Cell procedure at LEHR.

Results of the oral, dermal and ocular tests did not show any unusual levels of toxicity. In the dermal and ocular tests, samples of the evaporator sludge, recycle solvent and virgin DMSO were found to be essentially non-irritating. In the oral LD50 studies, only the recycle solvent exhibited a noticeable toxicity but even this was classified as moderate (level 3 out of a possible 6).

While the oral, dermal and ocular test gave little cause for concern, both the Ames Salmonella and mouse lymphoma cell tests for mutagenic activity gave strong positive results. It was already established that none of the identified components (RDX, HMX, DMSO plus by-products and water) were known mutagens. However, additional analysis, as stated earlier, led to the detection of three additional compounds: dimethyl sulfone, benzothiazole and diacetone alcohol. Both benzothiazole and diacetone alcohol were shown by other studies in the literature to result in mutagenic activity. The conclusion was thus reached that one of these agents,acting alone or synergistically with other materials present in the pilot plant samples, was the cause of the high mutagenic activity that was detected.

USAMBRDL recommended a continuing multi-task effort covering additional sample characterization, further mutagenicity studies on benzothiazole and diacetone alcohol, subchronic toxicology testing, teratogenicity and reproductive studies and possible carcenogenic and lifetime dermal toxicity investigations. It was also recommened that a water quality evaluation be conducted at HSAAP and that, until further data is amassed, precautions should be taken to protect workers in the DMSO pilot plant from exposure to in-process material.

Follow-on efforts will involve correcting deficiencies encountered during operation of the pilot plant under MMT project 5XX 4548. Omnibus funding will support additional toxicity and mutagenic studies.

BENEFITS

The use of a DMSO recrystallizing facility will increase the capacity to produce RDX/HMX. A ten-fold increase in throughput for Class 5 RDX and Classes 1, 3 and 4 HMX has been estimated while a 25-fold increase for Class 5 HMX is predicted. In addition to low cost and higher throughput, other benefits expected are better control of particle size and crystal shape, potential for continuous processing and lower residual solvent levels in the finished products.

IMPLEMENTATION

Implementation of DMSO recrystallization technology is planned as part of the HMX/PBX Facility Improvement Project 58X 2999. Plans call for conversion of a G-Building at Holston AAP. DMSO recrystallization could also be incorporated into an X-Facility or RDX Mini Plant design should those efforts once again be pursued.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. R. Goldstein, AV 880-4123, or Commercial (201) 328-4123.

Summary report, June 84, 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)

MMT Projects **578 4469, 579 4469,** and **580 4469** titled **"Automated Insertion of Grenade Layers"** were completed by the US Army Armament, Munitions and Chemical Command in June 1984 at costs of $495,200, $1,146,500 and $350,000, respectively.

BACKGROUND

The current procedure for filling M483 and M509 projectiles with M42/M46 grenades involves the manual placement of the grenades and filler components into cluster trays which are then transported to stacking stations where they are manually positioned and then pressed into the projectile. A visual inspection is then performed and the entire process repeated for each grenade layer. This procedure is labor intensive and results in unnecessary downloading to rectify errors. Therefore, the need for an automated system that would reduce labor requirements, reduce downloading, and increase product reliability was recognized.

SUMMARY

The objective of this effort was the design, fabrication and prove-out of an automated system to insert pre-packed grenade layers into the M483A1 projectile at a rate of six layers per minute. This system was to receive the pre-packed layers from a feed conveyor and after inspecting the layer, press it into the projectile with proper keyway/spline alignment. After removal of the metal spline from the first grenade layer, the following inspections would be performed:

(A) Identify the type of grenades (M42 or M46) in each layer.

(B) Verify that all fuze ribbons are wound correctly.

(C) Verify the number, type and positioning of the components in each layer.

(D) Verify that the fuze safety pins have been pulled.

(E) Verify the position of the fuze slide.

(F) Verify that no grenades had been withdrawn by the press head after insertion.

Additional system requirements were the capability to insert the adapter and any number of grenade layers while remaining compatible with existing units at the load plants. Also specified was the rotational alignment of the grenades in a concentric configuration in each pre-packed layer prior to introduction into the system to facilitate inspection operations.

The automatic grenade layer insertion system was designed, fabricated and assembled by the MRC Division of Chamberlain Manufacturing Corporation and consisted of three basic elements; the infeed system, the load insertion press, and the control cabinet (Figure 1).

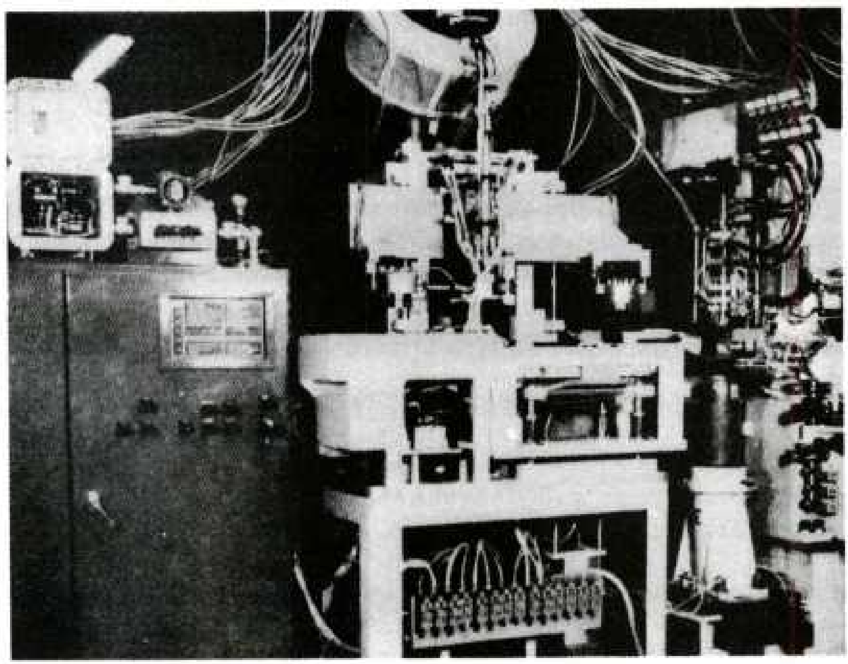


Figure 1 - Automatic Grenade Layer Insertion System

This system was configured to interface with a ring pack input conveyor and a pre-pack ring takeaway conveyor, which were to be furnished by the ammunition plant, and with the existing pallet transfer system. Provisions were also made to process pre-packed layers of grenades for M509E1 projectiles but inspection heads were not provided with the equipment.

Operationally, the machine system receives pre-packed grenade layers from an input conveyor, places the grenade layer on the projectile base with proper keyway/spline rotational alignment, presses the grenade layer into the projectile and removes the empty pre-pack ring at a rate of six layers per minute. In addition, a total of 118 inspections are performed on each grenade layer. The system assures that the correct type of grenades are present in each layer and verifies that all parts are present, the fuze ribbons are correctly wound, the fuze safety pins are pulled, and the fuze slide is still in a safe position after the safety pins are pulled.

The machine system is controlled by an Allen Bradley Programmable Logic Controller (PLC) in conjunction with Dynamco Air Logic. Air Logic is used to control all machine functions while the PLC is used to evaluate the condition of the inspections performed and to interrupt the air logic sequence as required. The machine controls can be programmed to insert any number of grenade layers into a projectile. Operation of the system is fully automatic and requires an operator's attention only when a fault is detected. Since rejects are not to be processed through the system, a detected fault will cause an interruption of the automatic sequence. The fault must be corrected or the entire ring pack must be replaced.

The machine control system is divided into two parts, the PLC and the air logic. The air logic system controls the machine functions while the PLC analyzes the inspections. In addition, the PLC interfaces with the air logic through pressure switches and solenoid valves to monitor and initiate machine motion. In this way, the PLC is the dominant control system for the machine.

The air logic system uses program modules to establish a sequential machine cycle. Six sequences are used, one for each major area on the machine, in order to provide flexibility in the system. Each sequence can be locked out, to a certain degree, by the PLC to alter the machine cycle. By using a sequential approach and limit valves as safety interlocks, the possibility of machine damage or personnel injury is greatly reduced. The PLC program starts and stops the air logic sequences and handles all of the inspections.

Provisions have been made on the machine system for future conversions to inspect and insert prepacked layers of grenades in the M509 projectile.

A test plan was implemented to test each subsystem independently for accuracy and repeatability of the inspections performed and for proper sequencing of operations during the machine cycle.

One hundred ring packs were cycled through each subsystem. Faults were introduced into each ring pack at specific locations so that all possible faults which could occur at each position within a ring pack were inspected a minimum of 12 times at each inspection station. Calibration standards were used to verify calibration of the inspection heads.

After a few modifications, the system was demonstrated again in early March 1982 and shipped to Kansas Army Ammunition Plant for installation.

BENEFITS

There are a number of benefits that will result from this effort. Cost reduction will occur because the number of operators required will be reduced. It is expected that the reject rate will be reduced and the reliability of the product produced will be increased. Also, the number of personnel exposed to hazardous operations will be reduced. Annual cost savings on a 1-8-5 basis are estimated to be $1,700,000.

IMPLEMENTATION

The equipment has been delivered to Kansas AAP. Its installation, scheduled for March 1984, is being phased to coincide with the availability of new M483 center sleeves required for automation. After on-line experience is obtained, additional automated systems will be obtained for other ammunition plants, possibly Mississippi, Lone Star and Milan.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. Lawrence Weiner, ARDC, AV 880-5538 or Commercial (201) 724-5538.

Summary report, June 84, was prepared by Andy Kource, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **579, 80 4498** titled **"Development of Methodology for Consolidation and Automated Assembly of Small Mines"** were completed in January 1984 by the US Army Armament, Munitions and Chemical Command at a cost of $1,059,000.

BACKGROUND

The Army has developed a family of systems to deliver scatterable mines. Many of the internal components among the family of systems are identical or very similar. During development, the Producibility Engineering and Planning effort established a manual method to assemble each system.

Numerous production problems were caused because operations were labor intensive, hazardous and lacked repeatability. Multiple handling, off-line operations, and in-process inspections were required for the predominantly manual load, assemble, and pack (LAP) operations. A four phase effort was undertaken to establish design requirements, prove out and install prototype equipment for mechanized or automated assembly. Initial analysis results were reported under MMT Project 578 4498. Mine systems addressed are part of the family of scatterable mines and include Ground Emplaced Mine Scattering System (GEMSS). Other mine systems include an Army artillery projectile named Remote Anti-Tank, Anti-Personnel Munition (RAAM) and an Air Force aircraft delivery system named GATOR.

SUMMARY

The objective of the effort was to increase the reliability, safety and quality of the manufacturing processes. Manufacturing costs were also to be reduced through the use of automation.

The approach was to determine the manufacturing system requirements, then establish prototype equipment for individual modules. The technical feasibility of each planned element was determined. The next phase was to design, build, prove out and install prototype equipment. Mechanized assembly, in-process electronic testing of lenses, automated soldering, and improved techniques for loading explosives were the individual modules. The prototype equipment was installed and proved out in actual production lines at Iowa Army Ammunition Plant (IAAP), Middletown, IA.

The engineering analysis indicated that a totally automated or mechanized system was not cost effective. Based on peacetime production rates, several individual operations were selected for mechanization. The results of work on each module are reported under four tasks.

Under Task I, the mechanized LAP equipment was designed and manufactured. Iowa AAP installed and conducted final prove out on the equipment. Four fixtures were designed and tested to rotate the main charge, disperse adhesive, bend a fragile lead of the Safety Arming (S&A) Assembly, and also rotate the mine case, disperse adhesive and cut the flexible cable.

Under Task II, an automatic soldering machine was designed and manufactured. Iowa AAP installed and debugged the equipment on the GEMSS line. Final prove out of the machine will be conducted after initial production. The machine can be adjusted to each of two mine types, GEMSS and GATOR. All points can be simultaneously soldered between the flexible cable of S&A assembly and the electronics assembly. The resistance of the S&A circuits and the magnetic coupling device of the electronics assembly can be automatically inspected. See Figure 1 for a photo of this equipment.

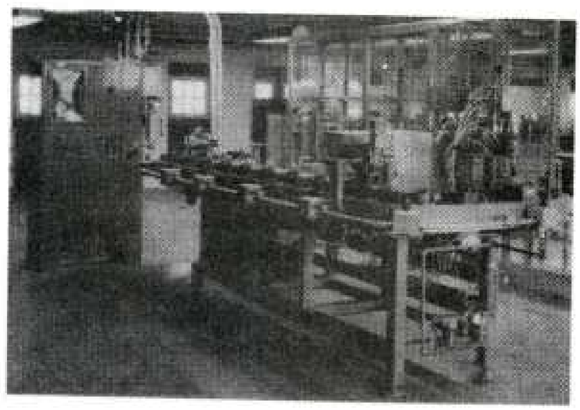


Figure 1 - GEMSS/GATOR
Automatic Soldering & Inspection Machine

Under Task III, an electronics tester was designed and manufactured. Iowa AAP debugged the equipment on the RAAM line and installed the equipment on the GEMSS line. The electronic test set can check individual non-activation cell voltage and verify shorts across the firing capacitor, in series with electronic battery primer and AP mine trip line continuity.

Under Task IV, procedures were established for loading explosive for AP mines. The procedure utilized a nylon funnel or riser and aluminum core pins to eliminate a preheating and a drilling operation.

BENEFITS

Prototype equipment was developed which will reduce human involvement and chances for error, and increase assembly safety and reliability. A faster manufacturing process will reduce manhours of direct labor and production cost.

IMPLEMENTATION

The results of this effort have been implemented at Iowa AAP. Benefits will be realized when production of GEMSS is initiated.

MORE INFORMATION

Additional information on this effort is available from the Project Officer, Mr. Joseph Chiappa, AMCCOM, Armament Research and Development Center, ATTN: DRSMC-LCV-CM (D), AUTOVON 880-6110 or Commercial (201) 724-6185. Point of Contact at Iowa AAP is Mr. Leon Baxter, AUTOVON 585-7101 and Commercial (319) 754-7101.

Summary report, Jun 84, was prepared by S. McGlone, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project **582 4548** titled **"Pyro Safety Enhancement"** was completed by the US Army Armament, Munitions and Chemical Command in March 1984 at a cost of $490,200.

BACKGROUND

Pyrotechnics are primarily solid chemicals or mixtures of solid chemicals which, when ignited, burn at relatively slow rates as compared to propellants or explosives. However, pyrotechnics are much more sensitive to friction, impact, and static discharge and are more prone to exhibit deflagration phenomena. Special techniques and methods are required to reduce the manufacturing hazards and risks to acceptable levels. Yet, the manufacture and transport of pyrotechnic materials and devices have been marked by accidents caused, at least in part, by the relative sensitivity of the materials. The day-to-day handling of pyrotechnic materials during their manufacturing stages greatly enhances the probability of an incident and potential fatalities. Efforts, therefore, are needed to review the pyrotechnic processes and improve the current manufacturing techniques from a personnel safety standpoint.

SUMMARY

The objective of this project was to survey all pyrotechnic manufacturing operations in order to systematically identify and compare procedures and equipment used for the various compositions made. Using these results, new concepts and procedural changes for improving the safety of present operations will be developed. High emphasis was placed on reducing operator exposure as much as possible.

To cover the various aspects of this effort, the project was divided into four tasks as follows: mixer safety, transport/conveying safety, fire suppression system, and bay design safety.

Task 1 - Mixer Safety

Preliminary surveys of procedures and techniques involving batch mix-muller operations were studied at Longhorn AAP, Lone Star AAP and Crane AAA. Lake City AAP and Pine Bluff Arsenal do not use mix mullers to manufacture pyrotechnics. Longhorn AAP uses Teflon blades on muller scraper arms to manufacture M206 flare composition. Stainless steel blades are used for all other production blending. The Teflon blades used at Longhorn AAP touched the sides and bottom of the mix muller bowls; whereas, the stainless steel blades were offset from the bowl surface. No manual scraping was necessary when Teflon blades were used since the sides of the muller bowl were tested relatively composition free. Cleanup of residual composition that collected on the metal support structures of the muller was done using pressurized water and solvents after the composition was dumped and manually carried away.

Lone Star AAP and Crane AAA do not use Teflon blades in any production operations. Scraping down of sensitive material using a spatula was common practice in the past at Lone Star AAP and is current practice at Crane AAA. Lone Star AAP uses a muller wheel reversing action to break up lumps of composition formed during pyrotechnic manufacture. This technique eliminates the hazardous operation of manually breaking down lumps of composition that could be formed when blending composition.

The Energetic Material Division at ARDC was given the task to verify that the use of Teflon blades on a Simpson batch mix muller would eliminate the necessity of manual scrape-down during composition manufacture. The mix muller was also equipped with a reversing action mechanism to remotely break down lumps of composition formed during blending operations if required.

Live pyrotechnic compositions were blended using this Teflon bladed mix muller. The results indicated no manual scrape-down was required for the compositions blended. The Teflon blades minimized buildup of composition on the walls of the muller and on the blades themselves.

Task 2 (Transporting and Conveying)

Southwest Research Institute (SWRI) performed a survey of pyrotechnic manufacturing plants to generate concepts and procedures with regard to remote loading, unloading, transport and conveying of materials. Based on these surveys, the following preliminary recommendations were made by SWRI:

a. A remote device for loading and unloading pyrotechnic ingredients be installed onto batch mix mullers.

b. A remote method for transferring composition to a transporting vehicle for removal from the mix muller area be implemented.

c. A remote device for loading and unloading the granulator be installed.

d. Remote transfer of materials from a granulator to a transporting vehicle be implemented.

e. Remote transfer system to and from drying ovens be implemented and modify drying bays such that the entire bay is used as an oven.

Task 3 (Fire Suppression Systems)

SWRI surveyed fire suppression systems in the manufacturing plants. As a result, it was concluded that Longhorn and Lone Star AAP's are equipped with remotely activated fire suppression/deluge systems using ultraviolet light (UV) detectors, and a nozzle or sprinkler manifold system to deliver water. The fire suppression system at Pine Bluff Arsenal consisted of only one or two nozzles per bay, which were manually activated. Crane AAA has no fire suppression/deluge systems installed in their process operations bays, but do have these systems in their loading facilities. Lake City AAP has limited fire suppression/deluge systems installed in their pyrotechnic manufacturing facilities.

A test program was undertaken at SWRI using a water deluge system similar to that used at Longhorn AAP. Eleven deluge tests were performed varying the quantity of pyrotechnic mix, the nozzle spray pattern, the ignition point and the water application rate. It was concluded that nozzles with a 15° full cone spray pattern and a flow rate capacity of 400 gal/min were most effective in controlling and extinquishing a fire.

Task 4 (Bay Design)

Ammann & Whitney Corporation analyzed pyrotechnic mixer bay design and preliminary designs of bays for the prevention of propagation from one bay to another in the event of a fire. It was concluded that for all pyrotechnic facilities surveyed, a pyrotechnic propagation can spread from one bay to another through corridors connecting the bays, through interconnected exhaust systems and sliding steel doors that may not adequately resist blast pressures. Also, these doors may not be sufficiently sealed to prevent fireball leakage through side corridors to main control areas.

A test plan was developed to determine the effects of a pyrotechnic incident and to test the methods and techniques for preventing propagation of a fire from one area to another. These tests will be accomplished in the follow-on project for FY83.

BENEFITS

A survey of five pyrotechnic facilities was completed and identified potentially hazardous areas. Recommendations were developed to eliminate or minimize human interaction in process areas.

IMPLEMENTATION

Mix muller modification designs (Task 1), remote materials handling system designs (Task 2), fire suppression system designs (Task 3), and bay design criteria (Task 4) developed under this program were made available for implementation at pyrotechnic manufacturing facilities (Longhorn AAP, Lone Star AAP, Lake City AAP, Pine Bluff Arsenal and Crane AAA) requiring these systems.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. R. Manno, AV 880-4122 or Commercial (201) 328-4122.

Summary report, June 84, 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)

MMT Projects **578 6760** and **579 6760** titled **"Drying of Low Density Ball Propellant"** were completed by the US Army Armament, Munitions and Chemical Command in January 1982 at costs of $118,000 and $95,200, respectively.

BACKGROUND

Low density ball propellant called ball propellant igniter (BPI) has been qualified for use as an igniter for the 155mm, M3A1 and M4A2 rounds. Because of its presumed cost advantage over presently used igniter material, clean burning igniter (CBI), it would be preferred. At present, there is no facility to produce BPI. An analysis of the product indicated that its very low density, 0.36g/cc., and high initial moisture content, greater than 40%, suggested it was incompatible with conventional drying techniques. Because of the hazards associated with this single base material and the relatively low production requirements, it is undesirable to jeopardize existing and proposed high volume dryers.

SUMMARY

The objective of this effort was to establish the design basis for a production scale drying process for low density ball propellant. It was to be safe, practical and economical.

The first step was to make a literature survey and contact dryer vendors. As a result, it was determined that fluid bed drying would be more feasible than micro-wave or super heated steam drying techniques for wet, low density ball propellant. A preliminary hazards analysis was then conducted. A scope of work for the purchase of a fluid bed drying system was prepared and a contract was awarded. The final accomplishment in the first year project was the acquisition of 160 pounds of low density propellant (0.36g/cc) for use in planned drying tests.

The batch fluid bed drying system was designed, fabricated, functionally tested, and shipped to AMCCOM-ARDC, Dover, NJ. for installation and testing. A schematic of the drying system is shown in Figure 1. Debugging operations consisted of calibration of all temperature sensors, familiarization with system operations, and establishment of a preliminary operating procedure. Initial tests established the minimum flow rate for fluidization at about 4.2 cubic feet per minute (cfm) at ambient conditions. All subsequent drying tests were conducted at about 12.5 cfm. This conforms to standard fluid bed drying practice which is to operate at about three times the minimum fluidization velocity.

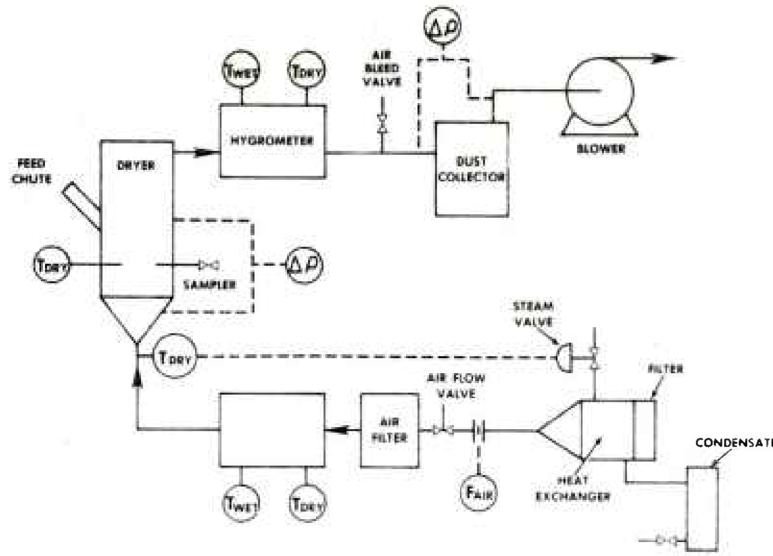


Figure 1 - Fluid Bed Drying System

A series of 21 tests were conducted at inlet air temperatures varying between 50° and 80°C and propellant weights between 1 and 3 kg having initial moisture contents varying between 11 and 97 percent on a dry basis. The results of these tests provided the basis for design of production scale drying equipment. The data developed is listed below.

Inlet air temperature:	75°C
Operating air velocity at 75°C:	0.17 meters per second
Average residence time:	17.5 minutes
Product carryover:	less than 0.5 percent of feed
Nominal propellant bed temperature:	46 - 52°C
Initial moisture, dry basis:	0.27 g/g
Final moisture, dry basis:	0.004 - 0.008 g/g
Specific hold up in dryer:	54.6 kg/m^2

As part of the data analysis, correlation of the product moisture content (X_p) with the quantity ln $(T_i-T_w)/(T_B-T_w)$ established the basis for on-line product control. The quantities are defined as follows:

T_i: Inlet air dry bulb temperature
T_B: Propellant bed dry bulb temperature
T_w: Inlet air wet bulb temperature

The ranges for the logarithmic term and the product moisture for good control are identified below:

X_p (g/g)	ln $(T_i-T_w)/(T_B-T_w)$
0.004	0.64
0.008	1.04

The equation which describes the relationship developed is
$X_p = -.0032 + .0108 \ln (T_i-T_w)/(T_B-T_w)$.

The correlation coefficient for this equation was 0.9753.

The above data was provided to a contractor for a budgetary estimate of a fluid bed dryer having a capacity of 500 pounds per hour. This equipment would cost $282,600. Factored for a completely new drying facility, including buildings, the total cost would range between $850,000 and $1,100,000.

BENEFITS

A series of drying tests provided the design basis for a production scale drying facility. An economic analysis based upon average production rates for igniter propellant of 300,000 pounds per year and a $1.00 per pound savings, and capital investments of $850,000 and $1,100,000 shows respective ROIs of 33.3 and 24.1 percent.

The large differential cost between CBI and BPI emanated from the facts that the ball propellant process generally used scrap artillery propellant as its source of cheap nitrocellulose and is a much simpler manufacturing process.

IMPLEMENTATION

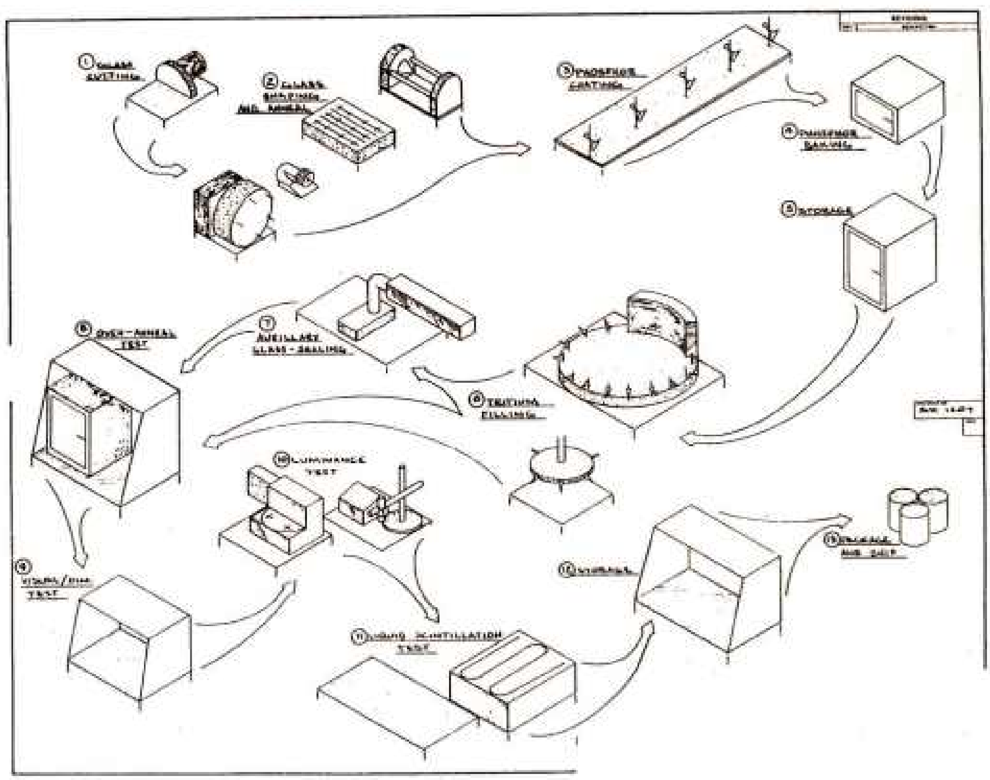
The assumption that cheap scrap artillery propellant would continue to be available for ball propellant manufacture has become unrealistic. In fact, recently the interested contractor has been forced to buy virgin nitrocellulose (NC) from their competition. Hence, temporarily at least, the gap between BPI and CBI cost has been narrowed considerably. For the moment, procurement is continuing to use CBI. This situation could change if Badger AAP were re-opened or if NC production at Radford AAP were interrupted.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Joel Goldman at the Armament Research and Development Center, AV 880-6930 or Commercial (201) 328-6930.

Summary report, June 84, was prepared by Wayne 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)

MMT Project **178 7091** titled **"Processing of Aircraft Components Using Pultruded Materials"** was completed by the US Army Aviation Research and Development Command in February 1982 at a cost of $380,000.

BACKGROUND

Advances in the performance of reinforced plastics have enabled these materials to be used in applications long thought to be the exclusive domain of metals. In the helicopter industry, the application of these materials in a development program has progressed to the point where the entire airframe is now being constructed from reinforced plastics. Although feasibility has been demonstrated, the economical production of helicopter airframes from reinforced plastics is not attractive due to the lack of mass production processes. The current hand layup method is laborious, expensive, and encumbered with the possibility of human error. Where possible, the industry has incorporated automated processes such as tape laying, filament winding, compression molding, injection molding, extrusion, and thermoforming, but these processes have not been fully adaptable to airframe component fabrication.

Another process is available which produces straight parts with almost any cross sectional configuration. This process, called pultrusion, is derived from the metal fabrication industry's extrusion process in which metal is pushed through a die to form constant cross section metallic parts. Since fiber reinforced plastic resins cannot be pushed through a die like metals, they are mechanically pulled through a die, thus the term pultrusion. Most pultrusions are either of fiberglass/polyester or fiberglass/epoxy and are cured in the die. The result is a cross section of almost any degree of complexity but always straight due to the nature of the die. However, the pultrusion process has found only limited applications in the aerospace field because of small demand for constant section straight parts.

SUMMARY

The purpose of this project was to establish a production technique for forming constant cross sectional components that are nonlinear. The approach followed was to postform a pultruded shape into a curved configuration. In this process, the pultrusion machine would align and shape the material to the desired form while advancing the state of cure. The pultruded part would not be fully cured and would result in an advanced cure stage sometimes called the B-stage. In this condition, it could be postformed while retaining the pultruded cross sectional shape and dimensions.

Selection of the component to demonstrate the process was restricted to an Army helicopter component that is currently being produced. Candidate components were the UH-1 control tube, tailboom elevator spar, and the upper cargo door track. These components were eliminated because they were primary components and would introduce too much risk for the process, materials, and future implementation. The component finally selected was the UH-1 lower aft cargo door track (Figures 1 and 2). The part describes an arc 83 inches long with a 240-inch radius and a twist in the final 5-inches. The upper cargo track carries the weight of the door; therefore, the only significant flight load on the lower track was found to be 80 pounds in an outward direction perpendicular to the track face. This loading is well within the limits of composite capabilities.

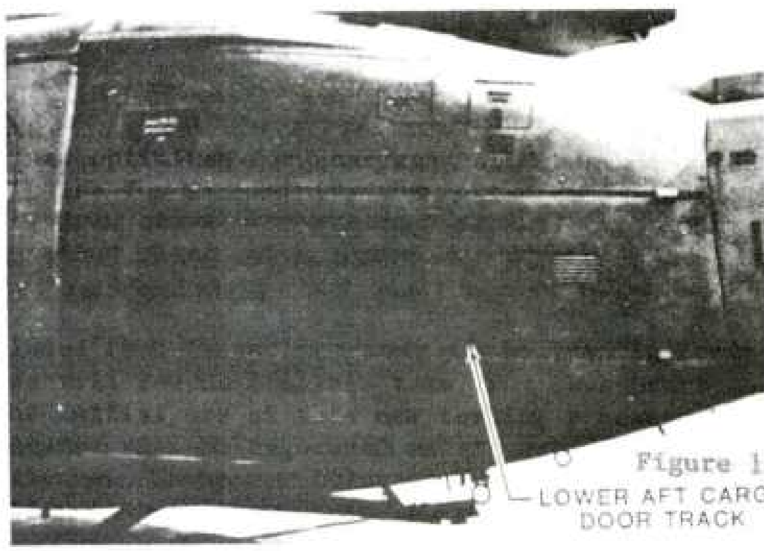


Figure 1 - LOWER AFT CARGO DOOR TRACK

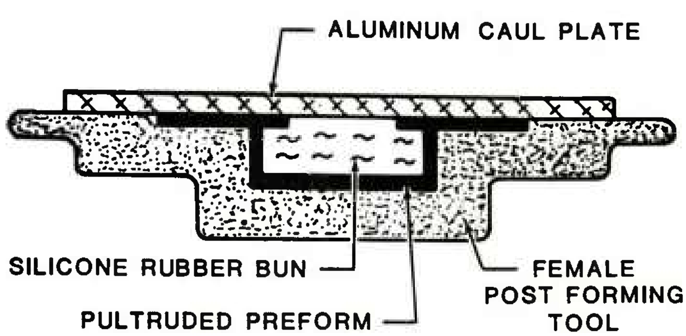


Figure 2 - Cross Section of Part and Postforming Tool

Material selection was critical since the matrix material would govern the ability to pultrude and postform the preform. Several resin and fabric combinations, including a vinyl ester that appeared to be the most promising in respect to pultrusion rate and requisite pultrusion tooling variations, were tried. Unfortunately, the vinyl ester tested was not successful. The successful result is illustrated in Figure 3. The track is formed by pulling E773, 60 end count, US Polymeric epoxy prepreg roving through two dies heated to 150°F at a rate of 3 to 10 inches per minute. The first die forms and debulks the prepreg rovings. The second die wraps a fiberglass cloth prepreg around and onto the roving shaped in the first die and forms it into the final door track cross-sectional shape. The cross section was uniform and stable. The fabric and rovings bonded sufficiently to enable handling without separation and were malleable enough at room temperature to allow for easy conformation to the postforming tool.

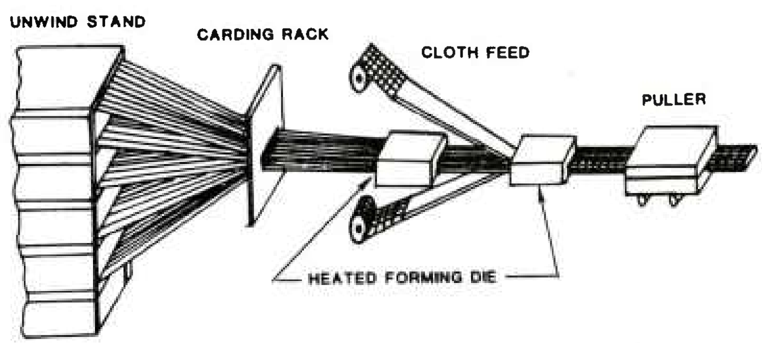


Figure 3 - Door Track Pultrusion Operation

Post forming of the pultrusion was performed in a tool which consists of a fiberglass/epoxy female mold with a removable support, an aluminum caul plate, and a rubber bun, (Figure 2). The female tool was fabricated by laying up alternating layers of fiberglass fabric and Hexcel Epolite 2354 epoxy tooling compound. This was followed by debulking with the metal track serving as the mold internal pattern. The tool was then cured with the metal track still inserted by holding temperature for 72-hours at 75°F, and then heating at 200°F for two hours and at 325°F for three hours.

The first step in the postforming process was to insert the rubber bun into the preform. This was performed easily by raising the inner flange of the preform and then tucking it down into the recessed edge of the bun after insertion. The next step was to fit the preform and bun into the female postforming tool. After performing this step, which posed no problems, Teflon coated fiberglass was placed over the preform and the 0.125-inch-thick aluminum caul plate was taped in place. The tool was then vacuum bagged, placed on the support base, and placed in a 4x9-foot autoclave. The preform was cured for 75 minutes between 240° and 280°F at 50 psi. The heat-up from the ambiant temperature of 70°F was linear and took 90 minutes to accomplish.

After cooling to 120°F, the part was debagged and the caul plate removed. The part was detached from the female tool with little difficulty in spite of the curve and twist formed into the door track. The bun was dislodged by pulling on one end until the stretch was taken up at which point it slid out easily. The formed track exhibited a minimum of flash which made it easy to trim.

Trimming was accomplished with conventional routers, and cutting of the track was conducted with a diamond saw. A total of 17 door tracks were fabricated. Six of these were submitted to destructive tests and 11 were trimmed and cut to the final, finished configuration. The destructive test program consisted of tensile and flexural tests. The dynamic tests were conducted with resin content determination specimens under ambiant conditions, specimens water soaked for two days at 125°F, and specimens exposed for 21 days at 125°F and 95% relative humidity. Five specimens were tested for each condition. The test results showed excellent consistency and performance. Static load and wear cycle testing were also performed. The static load test yielded a mean failure load at 237 $\pm$ 19 lbs. The maximum load the track experiences is 89 lbs. The wear test was conducted with an ultra-high-molecular weight polyethylene slide which was cycled at two hertz under a five pound load over a three inch length for 200,000 cycles. No wear was discernable on the track or slider.

BENEFITS

Production of composite door tracks in excess of 1000 units would yield material costs equivalent to aluminum; however, the labor cost for composite tracks cannot compete with that for aluminum. The economic benefit of the lighter weight for the door track equals $140 per ship. However, this process could yield an economic advantage against aluminum tracks in other weapon systems if extensive machining or other operations were involved, if weight savings were a primary factor, and if corrosion resistance was required. In addition, the excellent potential of other resin systems, such as the vinyl esters, would allow significantly reduced processing times that would make the process more attractive. Unfortunately, the currently available vinyl esters are not optimized for the door track type of application.

IMPLEMENTATION

Components from both of the Army ACAP designs have been reviewed for application of this process. The most likely candidates are composite stiffeners for use in composite airframe helicopters.

MORE INFORMATION

Additional information is available in a report titled "Adaptation of Pultrusion to the Manufacture of Helicopter Components" dated May 1981, Contract DAAG 46-79-C-0089. The project officer is Mr. Noel Tessier, Army Materials and Mechanics Research Center, AV 955-5172 or Commercial (617) 923-5179.

Summary report, June 84, 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)

MMT Project **177 7281** titled **"Survey of Composite Manufacturing Technology for Army Aircraft Structures"** was completed by the US Army Aviation Research and Development Command in May 1979 at a cost of $135,000.

BACKGROUND

In the fifteen years preceding this project, the Department of Defense (DOD) expended millions of dollars to advance the state-of-the-art in composite materials and manufacturing technology. Much of this work has been summarized in composite fabrication/design guides but has dealt primarily with fixed wing aircraft applications. In order to expand the range of application to rotary wing aircraft, the Army funded this project and designed it to be incorporated in the Second Edition of the DOD/NASA Structural Composites Fabrication Guide.

This guide provides the aerospace design/fabrication/quality control community with accurate and timely fabrication and producibility data, and the methodology necessary for the production of low-cost, high-quality, structural composite primary structures. It is aimed primarily at manufacturing, quality, and tooling engineers who have some experience in composite materials and fabrication techniques. It also includes the specific information and data required to fabricate composite structures. The guide can help the designer maintain an effective design/manufacturing interface by keeping him informed of current trends in structural composite manufacturing concepts and their impact on the design function.

SUMMARY

The objectives of this project were (1) to identify structures and structural shapes typical of Army helicopters; (2) to prepare a summary comparing composite fabrication processes for helicopter structures as a function of part geometry, production rate, process cost, and the basic nature of the process itself; and (3) to determine areas where manufacturing technology for helicopter structures needs to be advanced.

These objectives were achieved by conducting a survey of composite manufacturing technology developed and being applied in Army installations and contractor plants. The installations and plants surveyed were the Army Material and Mechanics Research Center (AMMRC), Bell Helicopter, Boeing Vertol, Hughes Helicopters, Kaman Corporation, and Sikorsky. The manufacturing technology surveyed, which included composite rotor hub, pitchbeam tail rotor, tail section and main rotor blade applications, was summarized in a preliminary report and in survey reports formatted for inclusion in the computerated data base of the guide. The Army's reports, along with those submitted by the Air Force, Navy, and NASA, were collated and published in the Fabrication Guide.

The guide was published in two volumes (Figure 1). Volume I includes an introduction; a generalized section on composites manufacturing which includes discussions on materials, fabrication techniques, tooling, quality assurance, cost systems, producibility planning, equipment, and specific fabrication experience; a glossary; and an appendix which describes the computerized data base and presents the statistical results of the guide survey.

Volume II consists of a short section on cost estimating and machining, and an extensive section in which specifications used for the fabrication of the examples discussed in the specific fabrication experience section in Volume I are presented in their entirety.

Figure 1 - Volumes I and II of Fabrication Guide

The guide, in addition to serving its principle functions as a fabrication guide for practicing engineers, provides an excellent introduction for anyone seeking to learn of composites and their application to specific designs and uses.

BENEFITS

Direct cost savings cannot be quantified, but the guide will benefit the Army by providing information to Army contractors that will save time and money, provide designers with manufacturing data, eliminate redundant work, and designate areas in manufacturing that need additional development. The guide has also aided the Army in the identification and selection of future MMT projects. Projects proposed and funded as a result of this effort will be able to claim direct savings which can be considered as indirect savings attributable to this project.

IMPLEMENTATION

The guide was published and distributed to aircraft manufacturers and government agencies. The report identified and recommended several Army MMT projects for future funding. Three of these projects have been funded.

MORE INFORMATION

Additional information is available from Mr. Dana Granville, AMMRC, AV 755-5172 or Commercial (617) 923-5172.

Summary report, June 84, 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)

MMT Project **179 7315** titled **"Stabilized Line of Sight Gimbal Production"** was completed by the US Army Aviation R&D Command, US Army Avionics R&D Activity, Fort Monmouth, NJ in December 1981 at a cost of $302,000.

BACKGROUND

Stabilized line of sight gimbals used in airborne vehicles must ameliorate vibrational and maneuvering g's to reduce jitter in the sight to a level that will allow acceptable image quality. This is accomplished in the gimbal design by forcing the lowest natural frequency to as high a level as possible. Since the gimbal mass reduces the natural frequency while the gimbal rigidity increases it, it is desirable to obtain the highest possible stiffness to weight ratio. This is what makes the gimbal structure such a logical application for high modulus composite materials. A lesser known but equally important reason is damping, or diminished amplitude of the oscillations because each of the resonances within the spring mass system is perturbed by the vibrational input. Since more damping causes less response at each of the resonances, the jitter is reduced.

The basic problem was to redesign and fabricate a gimbal structure using advanced composite materials and low cost tooling. The objective was to achieve a weight less than the current aluminum gimbal, with resonant frequencies equal to or greater than those associated with the aluminum version while staying within envelope constraints determined by the prior design. Specific problem areas included determining optimum filament orientation, developing subelement fabrication techniques, maintaining alignment during bonding, and achieving good metal insert bonds.

SUMMARY

The fabrication and test program was divided into three phases. Material samples were initially fabricated and tested to help establish the materials base line for the gimbals. A thermal sample was designed and tested for adequacy. Finally, two complete gimbals were manufactured and subjected to vibration and thermal tests. The second gimbal sample represented a design change from the first and provided a test of the adaptability of the process to changes in component design.

The composite gimbal design is shown in Figure 1. In application, the arms of the gimbal support a mirror which directs the image desired to optics that are located through and under the four-inch hole in the base plate. The optical assembly is not attached to the gimbal.

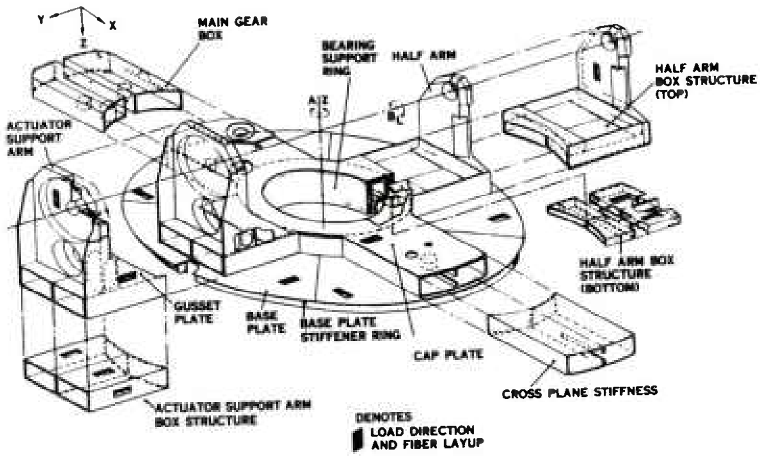


Figure 1 - Isometric of Composite Gimbal

Graphite epoxy was selected as the composite material. This selection was based upon the following advantages in comparison to aluminum:

- ° Stiffness to weight - greater than aluminum.
- ° Modulus - greater or equal to aluminum.
- ° Damping coefficient - greater than aluminum.
- ° Coefficient of thermal expansion - closer to titanium than aluminum.

Other composite candidate materials considered (glass, Kevlar and metal matrix) did not offer all of these advantages.

A crucial consideration in the composite design was the thermal expansion compatability of the titanium inner ring with the composite component of the bearing support ring, and the attachment of the bearing support ring to the composite gimbal base plate. A thermal test structure, which consisted of the bearing support ring, the base plate, and the cross plane stiffener, was fabricated and tested. Test results determined that the design successfully passed the thermal conditions.

The fabrication and assembly of the gimbal involved 33 parts which can be classified into five categories:

1. Box sections, which required good external surface finish, were formed in female metal tools and expandable internal mandrels. The mandrels were wrapped with Courtauld 10K HY-E 1248-1A graphite prepreg, placed in the tool and expanded. After curing at 100 psi and 250°F, the parts were removed and machined.

2. Plates were fabricated from twelve plies of Courtauld HMS 10K HY-E 1248-1A graphic oriented at ± 25° and Fiberite 984A1 epoxy resin. They were cured at 100 psi and 250°F. Plates thicker than 0.063 were fabricated by stacking 0.063, 0.030 or 0.100 plates to the desired thickness and bonding with FM73 adhesive.

3. Bearing support and base-plate stiffener rings were fabricated by filament winding and manual layup techniques. The support ring consists of composite and titanium construction. The graphite/epoxy outer ring was fabricated in three parts, two flange rings and a hoop ring, and then bonded together using Hysol EA 9320 adhesive to form a circular channel section. The ring and flanges were wet filament wound on a mandrel with 60% of the fibers in the 90° direction and 40% of the fibers in the 45° direction.

Prior to bonding, the titanium parts were pretreated with PASA JELL SOLUTION. The parts were bonded with CIBA Geigy adhesive XU 235/205/.

4. Base plate stiffener ring was fabricated in alternating layers from carbon fiber mat (Stackpole Panex CFP) and wound AS4 Hercules graphite fiber in 90° fiber orientation. Two finished rings were machined from the as wound ring with a diamond cut off wheel. The rings were milled and drilled with carbide tipped tools. This ring represents one of the most complicated machined composite items ever attempted.

5. Metal parts consisting of threaded stainless steel inserts and titanium washers and the titanium inner support ring were bonded to the mating composite structures with CIBA-Geigy XU235/XU215 adhesive with outstanding results.

Gimbal assembly was performed by adhesive bonding in metallic fixtures. The majority of the bonds were formed with FM 73 adhesive and were cured at 250°F for one hour at 40 psi pressure. Less critical bonds were formed at room temperature with adhesive EA 9320.

The two fabricated gimbals were tested for bearing bore coefficient of thermal expansion, stiffness, natural frequency/mode shapes and thermally induced strain. The results of these tests demonstrated that within the required temperature range of -65°F to +160°F, composite materials are fully acceptable for gimbal applications and offer the following significant advantages: weight was reduced by one-third, the stiffness to weight ratio was increased by a factor of 2, and the damping ratio was improved by a factor of 4.

A cost analysis, based upon a production plan for 1000 gimbals, resulted in a total cost for each composite gimbal of $3,467. The cost drivers were determined to be raw material and machining labor costs. By using lower priced pitch based graphite material and reducing machining operations by designing an all-composite gimbal which is not an exact duplicate of the aluminum gimbal, a cost of $3157 could have been obtained. The cost of the current aluminum gimbal is $2,368.

In considering this cost comparison, there is one additional and very important factor that needs to be discussed. This factor is the ease with which design changes can be incorporated into a composite design that employs low cost tooling. In this program, the second gimbal sample was different from the first with respect to the length of the arms and corresponding bearing bore locations. To incorporate these changes, all that was required was a few drafting hours to change a set of drawings. Fabrication of the second set of detail parts was based on the revised drawings. No expensive tooling had to be scrapped or changed. New tool try-outs were not needed. This would not have been the case if the design were based on a metal casting. These savings plus the added performance capability of advanced composites in electro-optical systems greatly reduce or eliminate the significance of the cost edge of the aluminum gimbal.

BENEFITS

The composite gimbal cost factor, when compared to an aluminum gimbal, came out at 1.5X. However, the fact that the sample gimbal had to be designed to fit within a previously designed aluminum system represented a cost driver. The project results indicate that with an entirely new all composite design using pitch base material, the cost factor could be reduced to 1.3.

Also in the area of cost, this program demonstrated that the use of low cost tooling allowed design changes to be incorporated without experiencing high cost impacts. In a typical system where design improvement changes are incorporated on a fairly regular basis, the savings in the tooling area could more than offset the premium associated with the use of graphite epoxy.

In addition, the composite gimbal design resulted in lower weight, improved damping, and a higher natural frequency.

IMPLEMENTATION

Implementation is being sought on current and future weapon systems. An end-of-project demonstration has been conducted, and a detailed technical report describing the process is available.

MORE INFORMATION

For additional information, contact Mr. Alfred Kleider, ERADCOM, Fort Monmouth, NJ, AV 995-4776 or Commercial (201) 544-4776.

Summary report, June 84, 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)

MMT Projects **179 7338**, **180 7338** and **181 7338** titled **"Composite Tail Section"** were completed by the US Army Aviation Research and Development Command in October 1981 at a total cost of $2,014,000.

BACKGROUND

The replacement of metals with composite materials in helicopter primary structural applications has been accomplished with the adoption of composite main or tail rotor blades on the CH-47D, Black Hawk, and Cobra aircraft. The adoption of composites in a primary structural fuselage component was the purpose of this project. The component selected was the tail section of the Advanced Attack Helicopter (AAH). Anticipated benefits were reduced cost and weight and improved survivability, reliability and maintainability. Feasibility of composites in this application was demonstrated in a previously conducted R&D effort in which an AH-1G aircraft tail assembly was fabricated and tested successfully.

SUMMARY

The purpose of this effort was to design, test, establish and validate fabrication processes for a full-scale, composite, Advanced Attack Helicopter (AAH) tail section. The principle composite fabrication approaches followed were wet filament winding and co-curing.

Initiation of work was delayed because of events outside of this effort. Immediately after project funds were made available, the contractor redesigned the prototype AAH tail section to meet newly determined flight requirements. The design of the composite tail section for this effort could only proceed in parallel with the design effort for the metal section in the 6.3 RDT&E program. The entire tail section (station 370 and beyond) as indicated in Figure 1, was the target of this effort.

Figure 1 - AH-64A Final CTS Configuration

A trade-off study was conducted to determine the best design for the three major subassemblies of the tail section: the tail boom, vertical tail spar, and the stabilator. A design-to-unit production cost approach was followed. The resulting tail boom and spar designs are of monocoque honeycomb sandwich shell construction with frames located at high load points. The skins are filament wound and consist of graphite/Kevlar/epoxy materials. The stabilator is of skin/spar/rib construction. The spars and central rib materials are graphite/epoxy and the skin, nose, and tail portion of the ribs are composed of Kevlar/epoxy. Galvanic corrosion protection between aluminum fittings and graphite epoxy laminates is provided by covering the graphite laminate with E-glass/epoxy laminate skins. Structural verification tests were conducted with test specimens in typical configurations found in the Composite tail section (CTS) to verify strength, elasticity, and strain allowables. The materials used were Kevlar-49 and Thornel 300 graphite fibers, and APCO 2434 epoxy resin. The two resin hardeners used were APCO 2347 (300°F cure temperature) for all major structural elements, and APCO 2340 (room temperature cure) for small, non-critical parts. The filament volume/resin ratio was 0.50. Additional tests to determine ballistic vulnerability and VHF antenna performance were conducted by the contractor with company funds.

This work was followed by a manufacturing technology refinement study in which detail design and winding approach were established. The production fabrication process and sequence for the three major subcomponents resulting from this study are shown in Figures 2, 3 and 4. The tailboom and vertical tail spar tooling are aluminum monocoque stiffened with bulkhead and longeron construction. Tooling for the spar details consists of matched metal molds with trapped silicone rubber to provide molding pressure for the frames, a female metal mold for the tip cap, and a closed cavity metal mold with a silicone rubber pressure block for the T bars. The frames are assembled to form the tail rotor gearbox in a three-part washout mold over which a prepreg

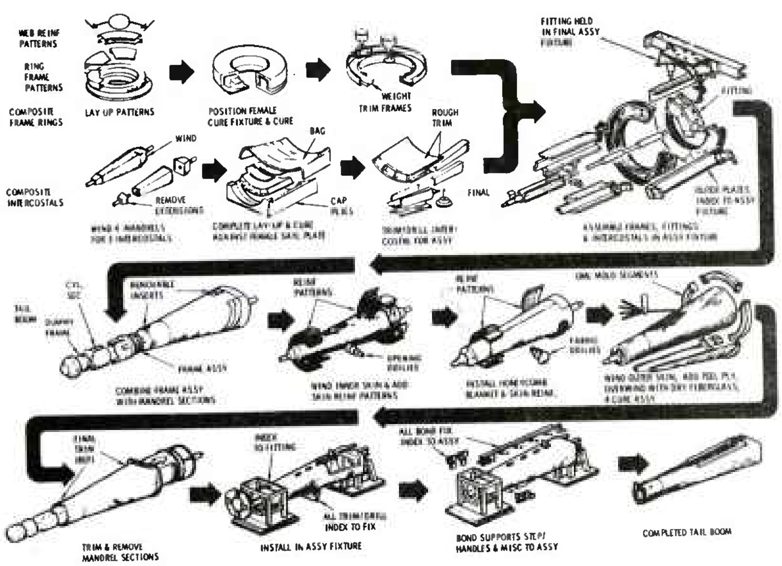


Figure 2 - Tailboon Fabrication Sequence

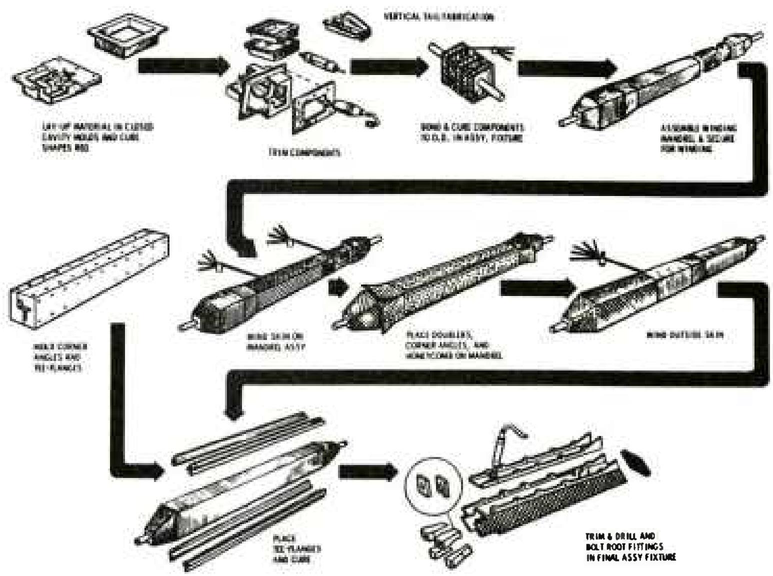


Figure 3 - Vertical Tail Fabrication Sequence

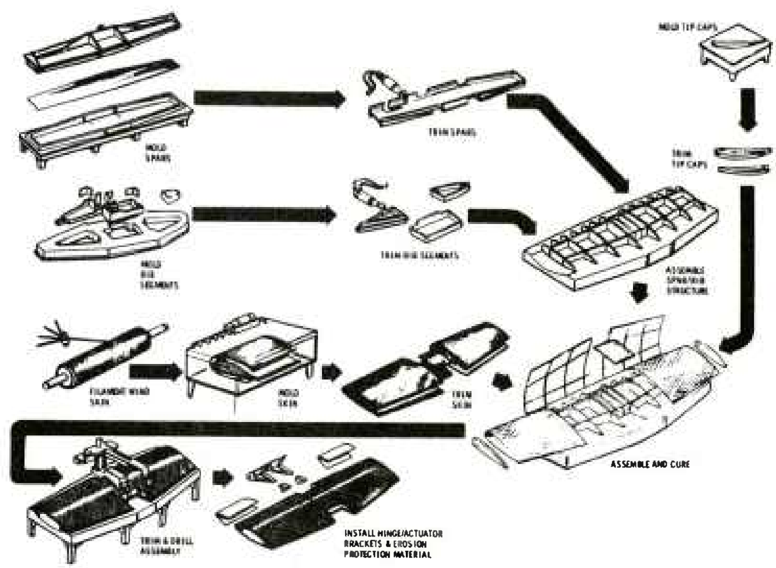


Figure 4 - Stabilator Fabrication Sequence

shell is wrapped and cured in place. The stabilator is wet filament wound on a cylindrical mandrel, cut off, and cured on an aluminum male mold shaped to the airfoil contour. The spars and ribs are formed in the same manner as the spar frames.

Final assembly of the tail section would be accomplished in a fixture. The planned operations for the final assembly are identifying the location of parts for attachment, machining (drilling and milling) and aligning the parts for installation. After removal of the CTS from the fixture, it would be ready for mounting on the helicopter.

This effort was carried through the design of the tail section, the manufacturing processes and sequencing, and the design of the tooling. At this point in the work, the effort was reviewed to assess implementation potential. It was determined that because of the delays in the program, the results of this effort, even if successfully completed, could not be implemented soon enough to result in a significant return on investment. In view of this determination, it was decided to terminate the effort.

BENEFITS

No benefits are possible since the effort was terminated before implementable results were achieved.

IMPLEMENTATION

No implementation is possible until the MMT effort is completed through successful component fabrication and testing. Since funding has not been provided, this will not be accomplished.

MORE INFORMATION

A detailed technical report is available (AVRADCOM TR-82-F-1, contract no. DAAKSO-78-G004 DO 0002) from Mr. James Tutka, US Army Aviation and Systems Command, St. Louis, MO, AV 693-3079 or Commercial (314) 268-3079.

Summary report, June 84, 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)

MMT Projects **180 7341** and **181 7341** titled "**Structural Composites Fabrication Guide**" were completed by the US Army Aviation Research and Development Command in September 1982 at a total cost of $123,000.

BACKGROUND

These projects (efforts) are a follow-on to MMT project 177 7281 titled "Survey of Composite Manufacturing Technology for Army Aircraft Structures." This project surveyed the state-of-the art of composite materials and manufacturing technology applied to Army helicopter structures. The survey results were included in the Second Edition of the DOD/NASA Structural Composites Fabrication Guide. The subject effort continued and expanded upon this survey, and the results were planned for inclusion in the third edition of the guide.

The guide provides the aerospace design/fabrication/quality control community with accurate and timely fabrication and producibility data, and the methodology necessary for the production of low-cost, high-quality, structural composite primary structures. It is aimed primarily at manufacturing, quality, and tooling engineers who have some experience in composite materials and fabrication techniques. It also includes the specific information and data required to fabricate composite structure. The guide can help the designer maintain an effective design/manufacturing interface by keeping him informed of current trends in structural composite manufacturing concepts and their impact on the design function. Specific objectives of the third edition of the guide are to provide production analysis, provide process/cost interrelationships, provide cost estimating techniques, and promote a thorough manufacturing/engineering interface in the application of structural composites.

SUMMARY

The objectives of this project were (1) to identify structures and structural shapes typical of Army helicopters; (2) to prepare a summary comparing composite fabrication processes for helicopter structures as a function of part geometry, production rate, process cost, and the basic nature of the process itself, and (3) to determine areas where manufacturing technology for helicopter structures needs to be advanced.

These objectives were achieved by conducting a survey of composite manufacturing technology developed and being applied in Army installations and contractor plants. The installations and plants surveyed were the Army Material and Mechanics Research Center (AMMRC), Bell Helicopter, Boeing Vertol, Hughes Helicopters, Kaman Corporation, and Sikorsky. The manufacturing technologies surveyed, which included technologies used to produce composite rotor hubs, pitchbeam tail rotors, multi-tubular spar main

rotor blades, tail sections and other composite rotor blades, were summarized in a preliminary report and in survey reports formatted for inclusion in the computerized data base of the guide. The Army's reports, along with those submitted by the Air Force, Navy and NASA, were collated and published in the Fabrication Guide.

The guide was published in two volumes (Figure 1). Volume I, 311 pages in length, includes an introduction and a generalized section on composites manufacturing which includes discussions on materials, fabrication techniques, tooling, quality assurance, cost systems, producibility planning, equipment, and specific fabrication experience. Examples of the data presented in Volume I are shown in Table 1 and Figures 1 and 2. Volume II, 555 pages in length, consists of an extensive section on cost estimating, an extensive section in which the specifications used for fabricating the examples given in the specific fabrication experience section of Volume I are presented, and a short section on drilling and machining composites.

The guide, in addition to serving its principle functions as a fabrication guide for practicing engineers, provides an excellent introduction for anyone seeking to learn of composites and their application to specific designs and uses.

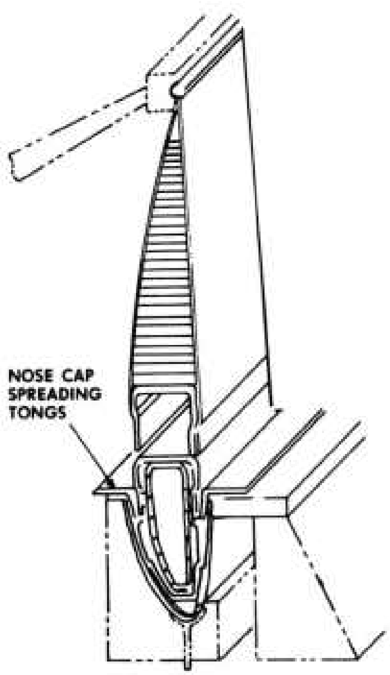


Figure 1 - Assembly of all Elements

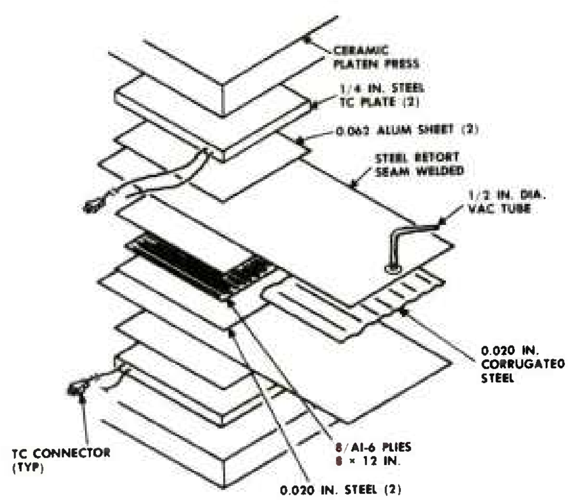


Figure 2 - Preparation of Metal Matrix Monolayers

Table 1 - Resin-Matrix Composite Processing Materials

Application	Material Type	Comments
Peel Ply	Miltrex 3921 heat-set and scoured nylon Style 112 or 116 glass release fabric	Low cost: little markoff More expensive: higher markoff
Separator Ply	104 Glass impregnated with 50% Teflon by weight	Standard
Blender Ply	Style 116 or 120 dry glass Air Weave Mochburg 1850 paper Kaycel 6910 W paper Barl Flo 4819 (1.9oz/yd^2mat.)	Original material 2X absorbency 1X absorbency 2X absorbency
Sealer Ply	Non-permeable Teflon impregnated Style 104 glass cloth Tedlar or nylon film	Standard: easily removable from part May tear: hard to pull off
Breather Plies	Style 181 dry glass Air Weave 162 glass	Standard Standard
Vacuum Bag	0.002 - 0.003" nylon film 0.005" PVA Glass fabric reinforced silicone rubber	Standard Satisfactory for 250°F cures Reusable, very difficult to puncture repairable: high initial cost
Mold Release	Fluorocarbon Silicone	Standard Limited to parts not being structurally bonded or painted
Bag Sealing	Various Types	Standard shop materials

BENEFITS

Direct cost savings cannot be quantified, but the guide will benefit the Army by providing information to Army contractors that will save time and money, provide designers with manufacturing data, will eliminate redundant work, and will designate areas in manufacturing that need additional development. The guide has also aided the Army in the identification and selection of MMT projects.

IMPLEMENTATION

The guide was published and distributed to aircraft manufacturers and government agencies.

MORE INFORMATION

Additional information is available from Mr. Dana Granville, AMMRC, AV 755-5172 or Commercial (617) 923-5172.

Summary report, June 84, 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)

MMT Projects **180 7342, 181 7342,** and **182 7342** titled **"Pultrusion of Honeycomb Sandwich Structures"** were terminated in January 1984 by the US Army Aviation Research and Development Command at a cost of $233,000.

SUMMARY

The purpose of this effort was to establish a manufacturing process for producing composite skin and honeycomb core sandwich flooring and floor beams by the pultrusion technique. The process was to be demonstrated by fabricating these items for the CH47D Helicopter. The composite flooring would replace the currently used magnesium flooring which corrodes and is heavier than composites. The project was to be performed by the contractor currently producing the CH47D helicopter with a pultrusion machine that the parent company had purchased for the production of composite, honeycomb flooring for their line of commercial aircraft. Shortly before project work was to be initiated with this machine, and before the parent company was to begin production of commercial composite flooring, the subcontractor, who had supplied aluminum flooring for the commercial aircraft, lowered their price dramatically. The new price was significantly lower than the cost of composite flooring. As a result, the parent company decided to continue with aluminum flooring and abandoned their plans to use composite flooring. A short time later, the composite pultrusion machine was sold. This development was appraised by the contractor with respect to flooring for the CH47D Helicopter. The contractor subsequently decided to replace the magnesium flooring in the CH47D Helicopter with aluminum flooring. The decision process included composite flooring as an alternative approach, but composite flooring, as in the commercial aircraft situation, was determined to be a more expensive approach.

In view of these developments, this project could not be justified economically and was subsequently terminated. Project work had proceeded through the redesign of the floor beams for composite materials but was stopped short of the fabrication of components. A technical report was prepared which summarizes the limited work that was accomplished and contains a detailed economic analysis.

MORE INFORMATION

Additional information can be obtained from Mr. Noel Tessier, AMMRC, AV 955-5172 or Commercial (617) 923-5172.

Summary report, June 84, 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)

MMT Project **178 7348** titled **"Lightweight Composite Fastening System for Composite Helicopter Components"** was completed by the US Army Aviation Research and Development Command in March 1981 at a cost of $216,000.

BACKGROUND

Aircraft design and performance are compromised because of inherent problems associated with mechanical assembly of graphite composite structures using conventional metallic fasteners. Problem areas are that aluminum fasteners in contact with graphite composites deteriorate due to galvanic corrosion, that stainless steel fasteners resist corrosion but impose a substantial weight penalty, and that titanium fasteners do not corrode under normal conditions but a premium for their use is paid in both cost and weight.

A potential solution to this dilemma is the use of composite fasteners. The advantages of composite fasteners, such as a fiberglass reinforced epoxy fastener, are lower weight, reduced radar cross section, and elimination of the corrosion problem. To explore the use of composite fasteners, the Air Force funded a two-phase manufacturing technology effort which is reported in AFML-TR-79-4044, "Manufacturing Technology for Low Cost Composite Fasteners" (June 1979). This effort demonstrated and validated manufacturing methods for producing and installing composite fasteners. In addition, cost analyses and projections were made which substantiated potentially competitive costs.

SUMMARY

The purpose of this project was to determine the applicability of composite fastener technology to helicopter structures. To accomplish this, three full-scale test articles (Figure 1), representative of a section of the UH-60A tail boom, were fabricated with graphite/epoxy materials and joined with glass/epoxy composite fasteners.

The test article (Figure 1) was a modified 40- x 40-inch area of the tail cone structure. This area of the tail cone is a conical section with a radius of curvature that varies from 29 to 111 inches. To simplify manufacturing and test procedures, the component specimen was fabricated as a flat panel.

Component specimens were fabricated from Hercules AS/3501-6 graphite/epoxy (unidirectional tape) with a basic skin thickness of 0.035 inch. The 1/4-inch (6.35-mm) diameter protruding head composite fastener was selected for use in this design (Figure 2) and a standard rivet spacing of approximately 4 times the fastener diameter (4D) was used.

Fastener selection was limited to the protruding head type which is installed in two pieces (see Figure 2) and bonded with adhesive 207-8-416 Type II (EC 3445) at 240-260°F under clamp pressure for 60 minutes. Fastener

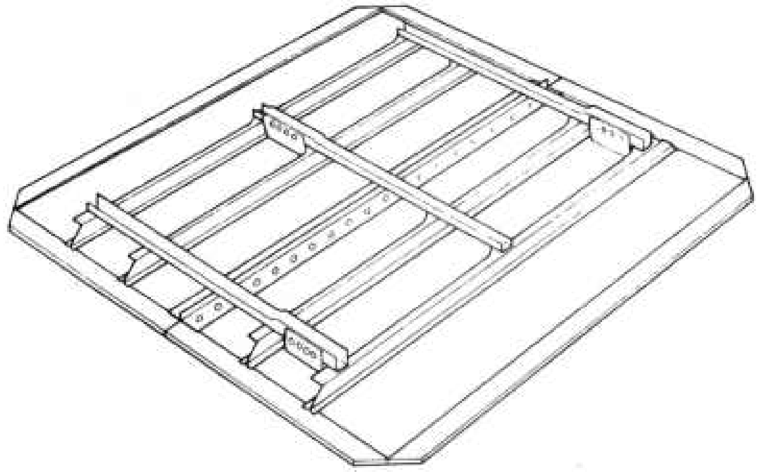


Figure 1 - Demonstration Component

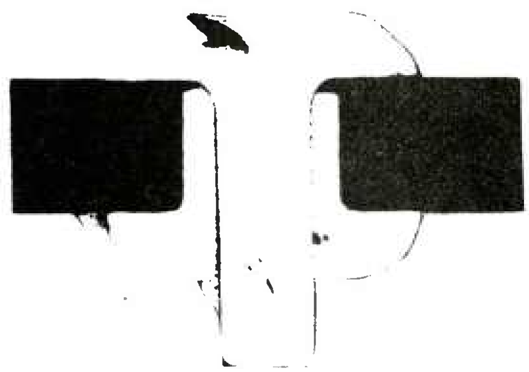


Figure 2 - Composite Fastener Assembly Cross Section

diameter, grip length, and fastening technique were determined in coupon tests. The results demonstrated that the fastener pin to sleeve bond was critical for consistency, and that the 1/4-inch diameter fastener (as opposed to the 5/16-inch fastener) demonstrated better properties.

The element specimens were selected to represent critical areas of high stress in the demonstration article area. The three critical areas were (1) the tension joint; (2) the shear joint; and (3) the frame/cap joint. Multiple fasteners and/or complex load situations were imposed on joint types, and both static and fatigue tests were performed. The fatigue tests were conducted at 3.5, 4.4 and 5.3 ksi stress in the fasteners. All of the 3.5 ksi stressed specimens survived 360,000 cycles.

The coupon and element tests were successful in determining baseline data for the design, fabrication and testing of the full-scale component (Figure 1).

Three demonstration components (40 x 40 inches) were fabricated and tested. These components were redesigned in flat condition to simulate the skin-stringer construction in the UH 60A helicopter tail cone and were fabricated from composite materials. All graphite/epoxy components (skins, stiffeners, shear clips, and spliceplates) were fabricated from Hercules 3501 AS-1 prepreg unidirectional tape in 90°, 0°, -45°, +45°. 0° and 90° ply orientations. The T-section and U channels were layed up and cured separately from the skin/stiffener cocured assembly. Tedlar release film was positioned between the graphite/epoxy contacting surfaces to prevent bonding between the surfaces exclusive to the rivet attachments.

One panel was statically tested dry at room temperature. Another panel was environmentally conditioned to 1% moisture content in the fasteners and then fatigue tested for 360,000 cycles. It was then statically tested to failure. The third panel was subjected to a vibroacoustic environment. The static test resulted in failure at 147% of DUL. The fatigue test was based on an estimated fatigue life of 180,000 cycles of limit load. The specimen was tested to two lives (360,000 cycles) at a maximum load of 143 lbs shear flow (limit load) with a stress ratio (min stress/max stress) of 0.10. At the end of the test, no damage was detected. The panel was then statically tested and failed at 206% DUL and 442 lbs/in shear flow. The vibroacoustic test was conducted to determine the acoustical fatigue resistance of the component in a simulated but accelerated helicopter environment. The panel passed this test with no detectable damage.

It is concluded that: 1) Composite structures joined with glass composite fasteners are structurally sound for light and medium loaded helicopter components, 2) Longer helicopter service life is projected (based on accelerated fatigue and vibroacoustical environment test results), 3) Some detrimental effects from humidity conditioning occur as evidenced by comparing wet and dry test results of the current fastener material, and 4) Application of composite fastener technology to certain helicopter composite components is cost-effective.

BENEFITS

A cost analysis was conducted in earlier work performed by the Air Force. In this analysis, composite fasteners demonstrated a cost advantage against titanium fasteners but not against aluminum and stainless steel fasteners. Composite fasteners can be used at an advantage where lightweight, corrosion resistance, and low radar cross section requirements are critical or where large quantities of titanium fasteners are part of the design.

IMPLEMENTATION

The results of this project have not been implemented for lack of an application. Current helicopters do not feature composite fuselages. Implementation will be pursued on the follow-on helicopter to the ACAP program.

MORE INFORMATION

Additional information on this project is available from Mr. Joseph Pratcher, AVRADCOM, AV 693-1625 or Commercial (314) 263-1625.

Summary report, June 84, 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)

MMT Projects **175 8045, 176 8045** and **178 8045** titled **"Fiber Reinforced Plastic Helicopter Tail Rotor Assembly"** were completed by the US Army Aviation Research and Development Command in January 1980 at a total cost of $624,000

BACKGROUND

One of the most significant helicopter design concepts developed in the past decade has been composite bearingless rotors. A composite bearingless rotor was designed and used in the prototype BLACKHAWK aircraft and is currently incorporated in the production version (Figure 1).

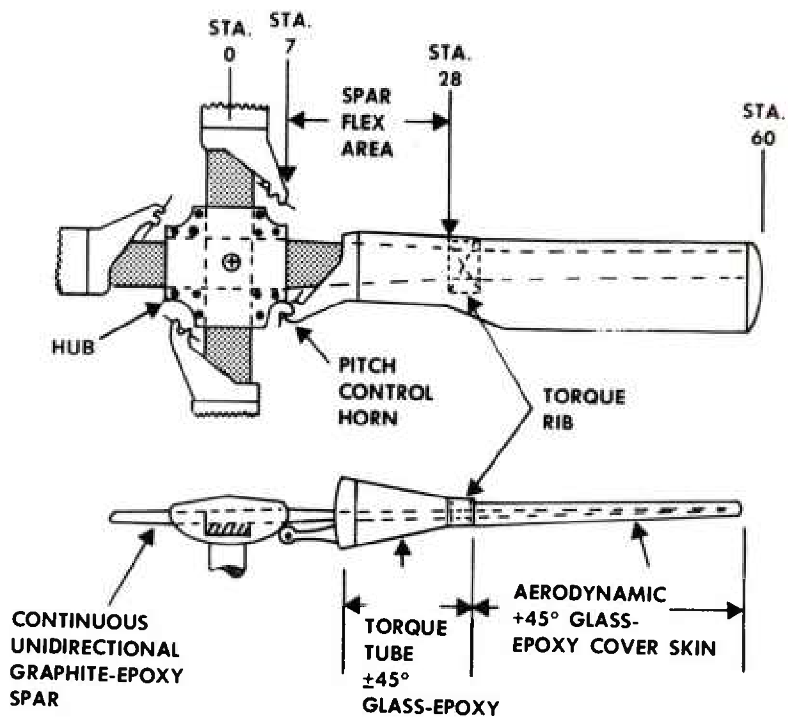


Figure 1 - UTTAS Bearingless Tail Rotor Design

The heart of the bearingless rotor system is the advanced composite flexbeam spar, which is light in weight, stiff in bending, and very flexible in torsion. The flexbeam consists primarily of a 0° unidirectional rectangular-shaped graphite-epoxy spar, which is continuous from one blade tip to the other blade tip. The spar is approximately 10 feet long, 5 inches wide by 0.6 inches thick at the inboard hub region, tapering to 3 inches wide by 0.3 inches thick at the outboard tip end. Currently, the tail rotor blade spar for the UH-60A BLACKHAWK helicopter is fabricated by laying precut individual plies of 0.012-inch thick preimpregnated material into a mold to obtain the required thickness dimension (approximately 250 individual plies) and curing the assembly in an autoclave to produce a homogeneous composite spar. Because the cost of cutting prepreg into various lengths and of using hand layup techniques to form the preform is high, this method of fabrication is costly. Use of pultrusion to replace the cutting and hand layup processes appeared particularly amenable to this configuration, and was, therefore, selected to demonstrate reduced manufacturing cost for a future production application.

SUMMARY

The primary aim of the MM&T effort was to demonstrate the applicability of the pultrusion fabrication process for the manufacture of flexbeam-type tail rotors for use on the US Army BLACKHAWK helicopter. The scope of work included the determination of the producibility and cost effectiveness of pultrusion technology in this application without sacrificing structural performance, and keeping design changes to a minimum. The method recommended to demonstrate the pultrusion capability was to design, fabricate, and test a complete tail rotor assembly. The prototype BLACKHAWK tail rotor design was used as a baseline for comparison of manufacturing cost, producibility, and structural test results.

The program was planned originally in five phases: Phase I - Design and Manufacturing Concepts, Phase II - Small-scale Specimen Testing, Phase III - Full-size Static and Fatigue Specimen Fabrication, Phase IV - Full-scale Static and Fatigue Specimen Testing and Evaluation and a 50-hour whirl test, and Phase V - Documentation of the data obtained. During the final phases of this program, however, the design of the tail rotor was changed to meet increased performance requirements that were identified in the prototype BLACKHAWK flight testing program. This modification resulted in deletion of the original plan for a full-scale whirl test and incorporated a new Phase V item termed "Final Design Manufacturing Method Assessment". This new Phase V effort was directed at redesigning the prototype pultruded spar for the new tail rotor design which was adopted for production.

The planned work was completed through Phase IV less the whirl tower test, and was sufficient to determine the generic feasibility and manufacturability of a pultruded spar rotor blade.

The approach followed was to investigate two manufacturing techniques. The first concept was to fabricate a full blade and then bore the center hole. This concept represented a high performance risk approach because 80% of the pultruded spar fiber would be severed leaving only 20% of the fiber continuous from blade tip to tip. The second concept is shown in Figure 2.

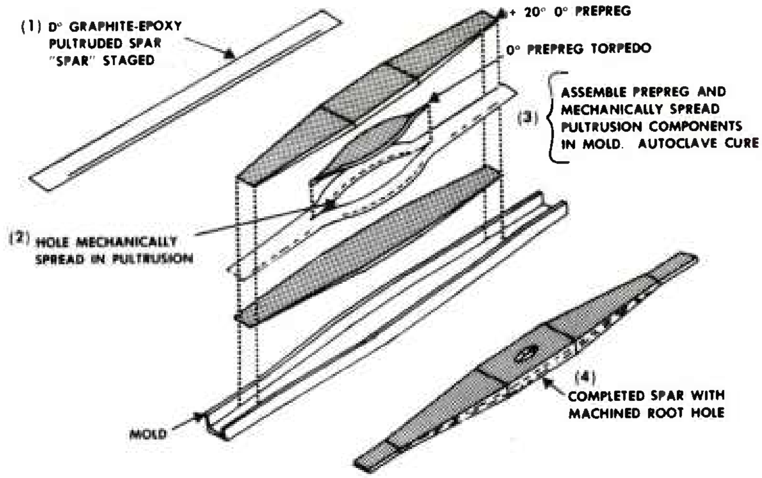


Figure 2 - Concept II - Partially Cured or "B" Staged Pultruded Spar Design Layout and Manufacturing Approach

In this approach, none of the pultruded spar fibers are severed, but the manufacturing risks are high because the pultruded spar is "B" staged and then spread in the center to accommodate a hub attachment torpedo. Both concepts were investigated and were pursued through the fabrication and static testing of subscale and full-scale blades. The pultrusion process facility used in this project is shown in Figure 3.

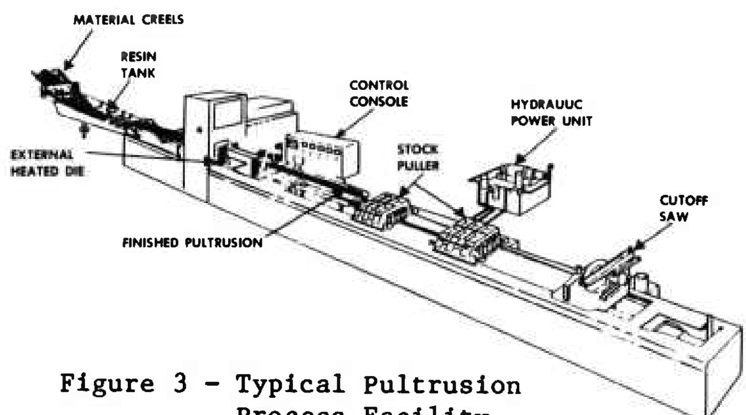


Figure 3 - Typical Pultrusion Process Facility

The resin system used, Epon826/MPD/DMFJ, was specified by the Army and is defined by MIL-R-9300, Type I, as the approved resin system for pultrudable epoxy resin systems. The process was designed to yield a fiber to resin ratio of 60/40. The materials used were Hercules AS fiber (10,000 filament/tow) and a EPON 826/MPD/DMF resin part-by-weight count of 100/14/5, respectively. The viscosity of the resin bath was kept at 500 cps by maintaining a bath temperature of 100°F. The concept I spar was pultruded using processing parameters of 390°F die temperature and 12-inches per minute feed rate. It was then oven cured at 200°F for 1 hour plus 350°F for 2 hours. The concept II spar was pultruded using processing parameters of 300°F die temperatures and 96-inches per minute feed rate, and subjected to a risk reduction parameter study in which the pultrudability of uncured "B" stage material, the feasibility of mechanically spreading the "B" staged spar, and the effect of the "B" stage on dimensional relaxation were determined. The result of this study showed that the concept II approach was feasible.

Specimen tests, subscale spar, and full-scale spar tests showed that the concept II approach was the preferred manufacturing process for the pultruded spar.

Subsequent testing and fabrication (static and fatigue) of full-scale blades determined that this manufacturing approach was successful in producing a blade which exceeded the requirements (short of whirl tower and flight requirements) of the prototype BLACKHAWK blade but not of the production blade design. Phase V of this project explored design, material, and processing changes necessary to qualify the pultrusion process for the production blade. Design changes were required in the torque rib/spar joint area of the blade. This situation ultimately reduced the potential for implementation and significant cost savings.

BENEFITS

The results indicate that a cost savings of $1,576 per aircraft would be obtained by incorporation of either pultruded design concept in place of the existing production prepreg design. This would be a total cost savings of $1,960,000 if the pultruded spar design was substantiated and incorporated as originally planned.

IMPLEMENTATION

Implementation can be accomplished on future helicopters in which the pultrusion process can be addressed in the design process.

MORE INFORMATION

Additional information can be obtained from Mr. Fred Reed, AVSCOM, AV 693-3079 or Commercial (314) 268-3079. A detailed report is also available which covers the work conducted under contract DAA-102-76-C-0001. The report number is USAAVRADCOM TR 79-45 and is dated January 1980.

Summary report, June 84, 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)

MMT Project **382 1050** titled **"Low Cost Braided Rocket Motor Components"** was completed by the US Army Missile Command (MICOM) in June 1983 at a cost of $475,000.

BACKGROUND

Army production goals have dictated a reevaluation of current rocket motor component materials and fabrication processes. A manufacturing technology effort was considered essential for establishing cost effective production for tactical rocket motor cases which comprise up to fifty percent of the propulsion system costs. Prior research led to the concept of braiding a fiberglass/resin composite onto an accurately dimensioned mandrel. The overall purpose of the two-year manufacturing technology effort was to optimize the conceptual process for an integrally braided case/nozzle configuration.

During the first year, the contractor was required: (1) to evaluate braiding materials and braiding mandrel designs and establish preparation procedures for both, (2) to establish automatic braiding and resin application techniques, (3) to establish optimum end closure and integral hardware attachment methods, and (4) to apply nondestructive test methods for screening critical braiding and bonding defects. Each of these requirements was achieved. The first-year project demonstrated a useful technique for the automated manufacture of braided motor cases which met all performance requirements.

This project, the second and final year of the effort, was conducted to demonstrate the technique on full scale motors, to deliver them for test firing and to establish and document final manufacturing procedures. Project work was accomplished by in-house effort at MICOM and contractual effort at McDonnell Douglas Astronautics Company, Titusville, Florida.

SUMMARY

Thirty braided rocket motor cases were fabricated, utilizing the techniques established previously. All cases successfully passed the 2390 psig Hydrostatic Proof Pressure Test. Five of these were burst tested. The failure points ranged from 3810 to 4522 psig. All cases were fabricated with three plies of S-glass yarn. Each ply consisted of 144 helical and 72 longitudinal strands of yarn. The helical braid angle was 32° measured from a plane perpendicular to the longitudinal axis of the case. A photograph of the braiding operation is shown below. The nozzle, at left, is positioned at the aft end of the mandrel and has already been "braided over."

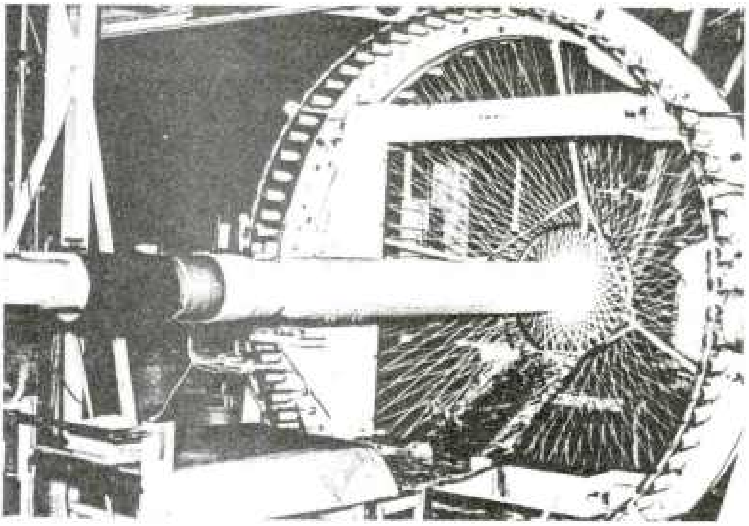


Figure 1 - Overbraiding Mandrel and Nozzle

Epoxy resin was sprayed onto the yarn immediately before it contacted the mandrel. The head end, at right, was left open to permit mandrel extraction. The head end closure retainer was adhesively bonded to the braided tube after final curing. Likewise, a fin body was bonded to the aft end. The overall size of the finished case assembly was 64 inches long by 5 1/4 inches outside diameter.

BENEFITS

Automatic braiding and resin application methods were established and then demonstrated by the fabrication of thirty prototype motor cases for a free-flight rocket, the MLRS. The cases were subjected to a series of materials properties tests. The test results proved that these cases were, in terms of performance, ideally suited for the MLRS and other applications as well.

IMPLEMENTATION

The systems developer for MLRS decided against the use of the braided case, choosing a monolithic steel structure instead. However, the fabrication method could be readily adapted to the production of future systems. Instead of using a mandrel, the overbraiding could be applied to a precast propellant grain. This integral case/grain concept is being considered for the Navy's Improved Zuni motor case. In addition, McDonnell Douglas, under contract to the Marine Corps, is developing an advanced shoulder-fired rocket. The launch tube for that rocket is a braided design.

MORE INFORMATION

Additional information on this project is available from Mr. William Crownover, MICOM, AUTOVON 946-5821 or Commercial (205) 876-5821. The technical report from the contractor is RK-CR-83-11, "Manufacturing Methods and Technology for Low Cost Braided Rocket Motor Components."

Summary report, Jun 84, was prepared by G. Fischer, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **577 1295** and **579 1295** titled **"Modernization of Charcoal Filter Test Equipment"** was completed by the US Army Armament, Munitions, and Chemical Command in July 1983 at costs of $245,000 and $360,000, respectively.

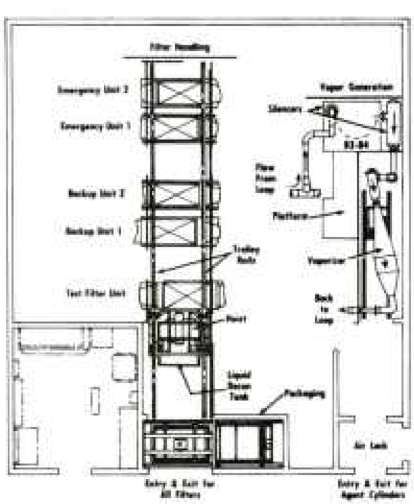
BACKGROUND

Performance testing is a critical step in the production of collective protective filters. This involves the determination of the gas life of the filters. The requirement for this testing has been established to insure compliance with the Training and Doctrine Command (TRADOC) gas life requirements for those filters. The equipment needed to provide the capability for gas life testing of end item filters does not currently exist. The only gas life testing which can currently be performed are laboratory tests of basic charcoal prior to production. Therefore, a testing procedure was needed which would challenge filters in the 60-1200 CFM range with toxic agents. This system would support the developmental, first article, production acceptance, and surveillance testing.

SUMMARY

The objective of this project was to design a modern, fully automated toxic agent test system to safely evaluate charcoal gas filters. The system would be designed to test full-size filters. The factors stressed in the design were safety and a minimum of operator attention during testing.

A diagram of the layout of the major equipment and facilities is shown in Figure 1.



The major components of the designed system were the agent vapor generator, filter test/changing station, hoist-trolley system, decontamination tank, spent filter packaging, and control room. All of the components were housed in a metal chamber with dimensions of 41 x 36 x 9 1/2 feet high. The chamber was all welded construction and designed to withstand 5 inches of water pressure. It was mounted on 3 foot piers to provide clearance for decon solution piping and waste solution drain lines and other services.

Figure 1 - Layout for Chemical Agent Filter Test Facility

The typical procedure for testing a filter was as follows: The test filter was brought into the metal containment chamber by a tranportation cart. The chamber was sealed and the temperature and humidity was brought to the proper level. Air flow was diverted through the test filter to be equilibrated before introduction of a chemical agent. While the test filter was being equilibrated, the agent tank was brought in and connected to the agent generation unit. When equilibration was complete, the agent was ready for introduction.

The test filter was then moved into position using a remote semi-automatic hoist system. The filter was automatically picked up and placed in the test rig. The operator from the control verified that the filter was in the proper orientation and position using video monitors. The chucks were activated to close the assembly to the testing configuration. The chemical agent was fed by spraying it into a heated air stream. This reduced the possibility of condensation and allowed a more accurate control of concentration. From that point, the operation of the system was automatic and the various operating parameters were automatically adjusted as necessary. When instrumentation downstream of the test filter indicated a breakthrough, the test was completed. The agent feed system was secured and clean air was passed through the test filter.

The contaminated filter was then removed by the hoist and put into the decontamination tank (Na_2CO_3 solution) and allowed to soak. After approximately one hour, it was removed, allowed to drain and taken by the hoist through a closure to the packaging system. Two separate nesting boxes were prelocated so that the filter could be put into the inner box. After the hoist moved away, the box lids were pressed on the boxes by an overhead cylinder. Self closing latches secured the inner lid and the outer lid separately. After checking for the presence of the chemical agent, a port in the chamber was opened and the boxes were removed and taken to a disposal site. The atmosphere of the chamber was monitored at a number of places. In some cases, interlocks were inserted to prevent certain actions from being taken if the chemical agent is found to be present.

The chamber will be housed in a Butler building 60 x 60 x 20 feet. Decon and waste decon solution tanks will be situated on the roof of the chamber along with compressors for the air conditioners.

The design of the charcoal filter test facility has been completed and Level I drawings have been prepared. Materials have been chosen and standard items such as motors, blowers, valves and instruments have been identified. Additional detailed drawings and upgrading of the drawing package will be accomplished in a FY83 project.

BENEFITS

An automated toxic agent filter test facility was designed to insure compliance with TRADOC requirements. This new facility design will allow the surveillance testing of filters in use, storage and under development.

IMPLEMENTATION

The drawings and specifications prepared will be used in the final design of the test facility and for imput to the technical data package (FY83 MMT project).

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. G. Lattin, AV 584-3510 or Commercial (301) 671-3510.

Summary report, June 84, 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)

MMT Project **578 1353** titled "**Smoke Mix Facility (Glatt-Colored CS)**" was completed by the US Army Munitions Command in October 1983 at a cost of $416,000.

BACKGROUND

The current facilities for the production of colored smoke blends at Pine Bluff Arsenal (PBA) are labor intensive and reflect equipment design established during World War II. Current equipment produces a heavy dust atmosphere which is hazardous to the operators by causing dermatitis and suspicion of carcinogen exposure. Dust-type detonations have also occurred resulting in personnel and equipment losses. The use of acetone in the current mix process introduces harmful vapors which must be removed by ventilating and scrubbing. In addition, particle size control has not been attainable which is a prerequisite for automated volumetric filling operations. Automated blending, drying and processing equipment was demonstrated under MMT 575 1249 that eliminated the problems previously described. The equipment is manufactured by Glatt and was successfully used to agglomerate M18 organic dyes for manufacturing smoke mixtures. Limited tests under MMT 1249 indicated that the Glatt was adaptable to the preparation of colored smoke and CS pyrotechnic mixtures.

SUMMARY

The objective of this project was to provide a modern colored smoke mixing facility at PBA capable of reducing dusting to OSHA standards, reducing operating costs, reducing mixing loss, and increasing the safety of personnel.

The approach was to select, procure, install and operate the fluidized bed spray granulation process using the Glatt equipment. This included auxilliary equipment installation, study of improved weighing and handling methods, optimizing the process parameters, and developing standard operating procedures.

The fluidized bed spray granulation process equipment used in this project were 15 kg/33 lb and 300 kg/660 lb (nominal batch sizes) units manufactured by the Glatt Company West Germany and distributed in the United States by Glatt Air Techniques, Inc., Ramsay, New Jersey. These units were capable of mixing, granulating, and drying batches of M18 smoke mix. A diagrammatic view of the Glatt fluid bed spray granulator is shown in Figure 1. The equipment consisted of a filter chamber, mixing chamber and/or product container/hopper. The mixing chamber contained the two fluid (binder solution and air) spray nozzle. The dust particles were agglomerated by spraying solvent based binder solution on top of the dust cloud created. On top of the mixing chamber, a conductive cloth was used to trap fumes and return them to the mixing chamber. The agglomerated particles were then dried by driving off the solvent by heated air that was used to fluidize the material. The end product was a dry (<0.1% volatiles), uniform, free flowing material which was collected into the product hopper. The hopper could then be removed by a dolly for further processing to form tablets.

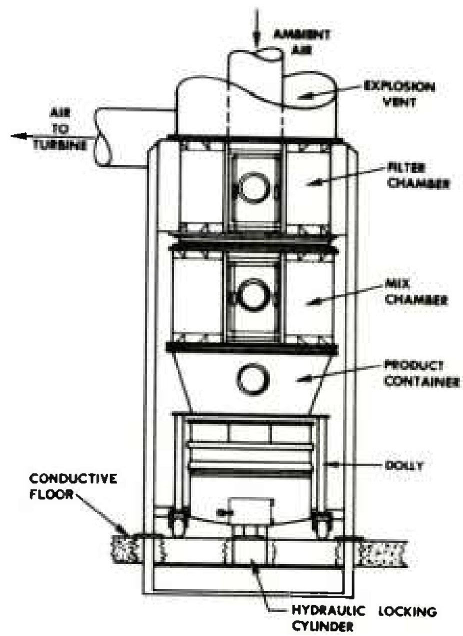


Figure 1 - Fluid Bed Mixer, Granulator, & Dryer (Glatt)

A pilot facility containing a full-scale Glatt WSG 300 fluidized bed mixer, granulator, dryer unit with a programmable control system, and required auxillary equipment was designed and equipped. The Glatt unit was equipped with a solvent pump and tank which supplied the binder liquid or solvent at a controllable rate to the atomizing nozzle. Auxilliary equipment included a vibrating screen sifter for raw material processing and a control console. Other safeguards designed into the installation were hinged vent covers on the filter chamber to prevent pressure buildup and deluge system with automatic sensor systems.

Safety certification studies were performed on the smoke mix, equipment, and the process. Approval to increase the batch size from 125 lb. to 1000 lb. resulted from these studies.

Process parameters for the remote production of colored smoke mix were successfully developed for the PBA Glatt unit. The PBA fluid bed granulator represented the first known application of fluid bed granulation of pyrotechnic mixtures and the first facility requiring remote operation of the fluid bed mixer, granulator, dryer unit. A series of test batches of smoke mixes containing different binders such as polyvinylpyrolidone (PVP), dextrin, and starch were produced. Optimal parameters were developed that would produce acceptable granulated mixes over the widest range of ambient conditions. Results showed that M18 colored smoke grenades could be processed with any of the binder materials. Standard Operating Procedures (SOP) were developed and proven for the colored smoke mixes in the full-scale Glatt WSG 300 unit.

A positive pressure, dense (two) phase pneumatic transfer system was installed and successfully used in transfer of smoke mix raw materials and the completed smoke mixes. Safe operation of this equipment for these materials was accomplished through hazards testing.

Engineering Change Proposals were submitted for the production of colored smoke mix by the Fluid Bed Spray Granulation Process in the PBA Glatt units.

BENEFITS

The equipment that will be purchased as a result of this project will significantly reduce the dusting problem and will satisfy OSHA requirements. This project corrected air pollution problems. The new smoke mix production facility also resulted in reduction of material and labor costs. The mix facility is projected to reduce the number of personnel required to operate from 18 to 10. This results in a savings of $.077 per grenade. The elimination of the acetone from the mixing process results in a savings of $.0738 per grenade. Based on an annual average production rate of 750,000 for the years 1984-89, annual savings are projected to be $113,000.

IMPLEMENTATION

A smoke mix facility project, 581 0283, has been funded and is now in progress at Pine Bluff Arsenal utilizing the results of this project.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. D. Garcia, AV 966-3589 or Commercial (501) 966-3589.

Summary report, June 84, 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)

MMT Project **581 4364** titled **"On-Line Bio-Sensors to Monitor Mixed Waste Streams"** was completed by the US Army Armament, Munitions and Chemical Command in August 1983 at a cost of $258,000.

BACKGROUND

A public law requires that waste discharge be monitored to assure that aquatic life in the receiving waters are protected from toxic/hazardous substances. In order to meet this requirement, the Army is attempting to develop a real time, foolproof system to monitor discharges from Army facilities, particularly Army ammunition plants.

SUMMARY

This project was to establish an operating, fully calibrated biological fish monitoring facility at the Radford Army Ammunition Plant (RAAP). The project will include on-line, continuous monitoring of several waste streams at RAAP. During Phase I (FY81), the ventilatory responses of the fish in the system will be evaluated for various pollutants, and modifications to the software will be made to increase the sensitivity and reliability of the proposed system. During Phase II (FY82), protocols will be developed for the operation of the system, the Central Wastewater Treatment Facility (CWTF) will be evaluated, and a technical data package prepared.

Changes in the ventilatory rate of bluegill, when exposed to a toxic effluent, was chosen as the response to be calibrated during the project. A contract was awarded for the calibration of the biological monitoring facility to the wastewater streams from the collected Wastewater System and the Central Wastewater Treatment Facility. The contractor initiated reference toxicant bioassays to determine acclimation effects of wastestreams on the fish. Ventilatory monitoring and the attending chemical analyses of the collected Wastewater System were also initiated.

BENEFITS

An inexpensive method was being developed that would detect toxic conditions and be in compliance with Public Law 95-217. The availability of a bio-monitoring system in continuous operation would quickly indicate toxic contaminants in plant effluents.

IMPLEMENTATION

The system will become an integral part of RAAP's wastewater management program. It will also serve as a model for duplication and use at other government industrial sites.

MORE INFORMATION

Additional information may be obtained by contacting the project officer, Mr. Dennis W. Johnson, AMCCOM(A), by calling AV 584-2586 or Commercial (301) 671-2586.

Summary report, June 84, was prepared by Andy Kource, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **580 4417** and **581 4417** titled "**Process Technology for Blending RP Smoke Compositions**" were completed by the US Army Armament, Munitions and Chemical Command in October 1983 at costs of $115,000 and $165,000, respectively.

BACKGROUND

The Chemical Research Development Center (CRDC) at Aberdeen, MD, conducted a product improvement program (PIP) to replace hexachloroethane (HC) smoke mix in the M8 grenades. The HC was suspected of being a carcinogen and a health hazard when burning. A substitute red phosphorous (RP) smoke mix was developed which solved the problems associated with HC use. However, no facility existed to produce the new RP smoke mix. Therefore, a project was initiated to establish the process technology needed to produce this new RP smoke mix.

SUMMARY

The objectives of this project were to perform pilot blending studies, evaluate the handling characteristics of the materials used in the RP mix, select the material handling equipment, and conduct material handling safety tests. The pilot blending studies were performed by CRDC, the materials handling studies by Pine Bluff Arsenal (PBA) and the safety tests by Computer Sciences Corporation.

The purpose of the blending studies was to optimize the operating parameters for the 3.5 cubic feet pilot model airmix mixer and identify operational and maintenance problems. The mixing system consisted of an air compressor, aftercooler, dryer, blender and dust collector. The approach was to alter the order of addition of the materials, the mixer control settings, and to determine the effect on the smoke mix homogeneity. The basic materials in the RP smoke mix were red phosphorous, manganese dioxide, microcrystalline wax, magnesium, and magnesium oxide.

Various batch sizes of the RP mix were prepared and samples were collected for grenade testing. Based on the results, the selected order of addition of the materials was based on convenience and safety factors. It was recommended that RP be placed in the blender first, followed by the magnesium, magnesium oxide, wax composite, and lastly, the manganese dioxide. One of the most important lessons learned was the need to keep the air supply to the blender both clean and dry. In addition, prescreening of all ingredients prior to loading into the blender was recommended.

The objectives of the material handling study were to evaluate the material handling characteristics of the chemicals in the RP mix, select appropriate methods and equipment, and conduct evaluation tests.

Selection of pneumatic transfer systems for the RP and manganese dioxide were made based on an equipment survey. A pneumatic system had the advantage of being the most cost effective since this type of equipment was available at PBA and had been used for a variety of materials, including HC mix components. Because no vendors were interested in conducting tests with RP, a building had to be established at PBA for these tests. Dynamic air transfer system equipment was installed in building 33-730. A waste water collection system for RP had to be constructed prior to beginning tests. The transfer trials were conducted according to the flow chart as shown in Figure 1. The RP was initially manually weighed and loaded into the transporter. The RP was then pneumatically transferred to the receiver. The excess dust produced was collected in a wet stage followed by a dry dust collector. The final RP material was dumped into a velostat bag and weighed to determine transfer efficiency.

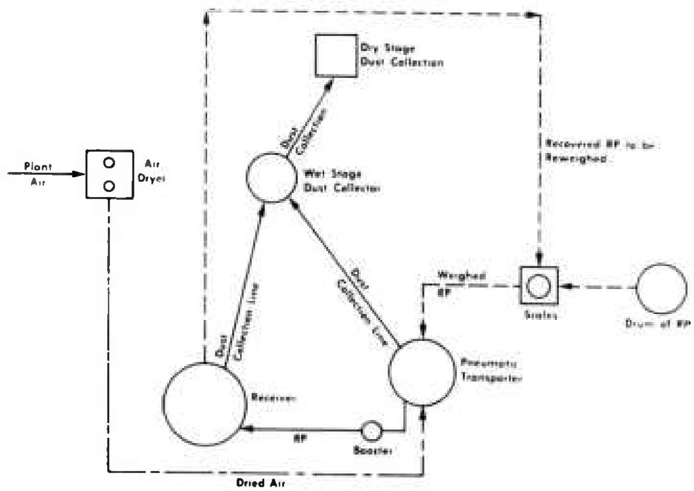


Figure 1 - RP Transfer Flow Chart

The initial attempt to transfer RP through this equipment resulted in a fire. This was attributed to corroded transfer piping. After disassembly and cleanup of the equipment, 22 successful RP transport operations were conducted. Further corrosion of the tubing was prevented by purging dry air through the system when not in use.

The transfer of manganese dioxide through the same positive pressure, 2-phase pneumatic transfer system, was demonstrated to be an effective and efficient material handling method in vendor conducted tasks. Because the remaining three ingredients, magnesium, magnesium oxide, and microcrystalline wax, are in much lower quantities, manual weighing, transfer, and dumping will be used. The results of the above studies will be incorporated into the RP blending facility at PBA.

The results of the safety tests are summarized as follows: Quantities of 100, 250, 500, and 1,000 pounds were tested in a mock-up of a full-scale (35 cu ft capacity) Airmix mixer. The 250 pound quantity ignited unintentionally during mixing. The cause was attributed to a foreign object in the mixer. The 1,000 pound quantity was ignited purposefully to determine the worst-case consequences of a fire in the blender. The test results showed that: 1) electrostatic charge generation during mixing is minimal, 2) the Airmix can be used to blend the RP smoke mix, 3) the worst-case initiation showed no explosive hazard, 4) the primary hazard is mass fire, and 5) extreme care should be taken so that no foreign object is introduced into the blender.

BENEFITS

The project demonstrated that the candidate replacement RP smoke mix can be handled and blended safety, effectively, and in essentially the same manner as that used for HC smoke mix. This will result in lower facilitization costs.

IMPLEMENTATION

The process data from this project will be used to design and equip an interim blending facility at PBA. Additionally, the data will be used to design any required modifications to PBA's existing production blending facility.

MORE INFORMATION

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

Summary report, June 84, 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)

MMT Project **678 7710** titled **"Injection Molding of Rubber Obturator Pads"** was completed by the US Army Armament, Munitions and Chemical Command in August 1982 at a cost of $77,000.

BACKGROUND

Rock Island Arsenal (RIA) has been manufacturing rubber obturator pads by conventional compression molding for over 20 years. Compression molding of obturator pads involves milling the mixed stock to slab form, extruding the rubber, accurately weighing the rubber, and forming the rubber into preforms in the form of a donut. The preform is then loaded into a hot mold and manually placed onto a steam heated platen of a hydraulic press. Pressure is applied to close the mold for final forming and excess rubber is forced out of the mold as flash during the curing process. For thick items such as obturator pads, lengthy cure times are required because of the low thermal conductivity of rubber. Compression molding time of 2 hours is specified for 155mm obturator pads. When using the compression molding process, only 3 molds can be used simultaneously at RIA; consequently, production is limited to 12 pads per 8-hour shift.

Conversely, the injection molding process requires no weighing or preform preparation. In this process, extruded rubber is fed directly into the heated injection cylinder where it is preheated and then forced through runners and gates where additional heat is generated by friction prior to entry into a preheated closed mold. A much shorter cure time is required because all of the rubber is at an elevated temperature when it enters the mold. In addition, virtually no flash is produced. Some items, depending on their volume and configuration, can be cured in three minutes or less.

SUMMARY

The purpose of this effort was to increase productivity and reduce production costs for fabricating rubber obturator pads for 155mm weapon systems by use of the ram injection molding technique. This technique has been used at RIA for the production of barrier bags for 152mm caseless ammunition, various shaped bellows, grommets, retaining straps, gaskets and numerous other items. However, none of these items have the bulk or the rigid dimensional requirements of the 155mm obturator pad. The configuration and dimensions of the pad are shown in Figure 1.

Molding was performed with the Lewis ram-type vertical injection molding machine. This machine is a Model 200V-Ram that has a filling capacity of 48 ounces, a 200-ton clamping capacity, a 2.5" diameter ram, and an effective plunger displacement of 65.4 cubic inches per shot. The machine is controlled with limit switches, timing relays and hydraulic valves. Valves, pressure and temperature regulators were operated manually to adjust injection temperature, pressure and speed. Mold temperature and clamping times were also varied to find the best conditions for injecting and curing the rubber.

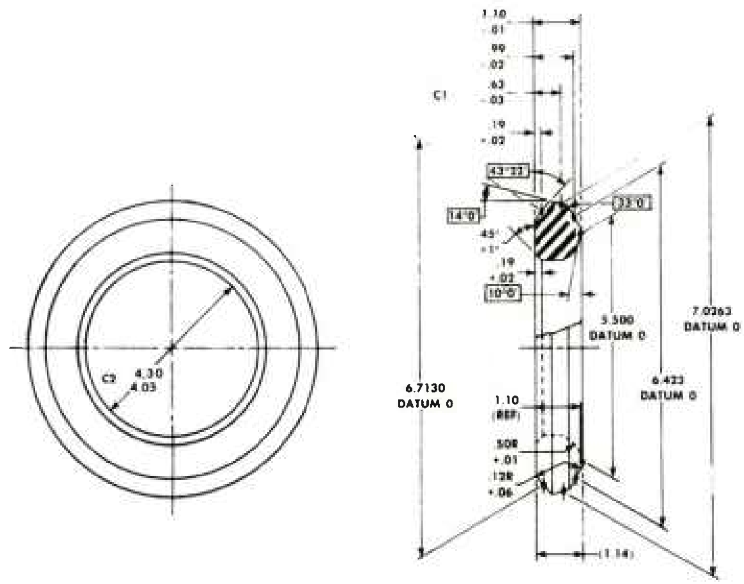


Figure 1 - 155mm Obturator Pad

Initial molding efforts consisted of forming a T142 track pad which measures 6" x 8" x 1.5" and a filler ring measuring 5.8"in O.D. and 0.43" thick. Under the conditions of cylinder temperature ranging from 140 to 180°, (curing occurred at 200°F) injection pressure of 1000 psi, injection time of 30-60 seconds, dwell time of 2.5-10 minutes, mold temperature of 350°F and dwell time of 2.5 to 20 minutes (lesser conditions applied to the ring component), the components met the required tensile strength, elongation and hardness. Conformance of the ring to drawing tolerances was also confirmed. These tests determined the feasibility of injection molding thick sectioned and round items with the specified rubber compound. With feasibility established, the next step was to mold the 155mm obturator pad (Figure 1). This step was initiated by fabricating an injection mold (15.245" x 15.245" x a stack height of 4.375") with a two-runner system having two gates and two vents of 0.125" diameter. Pads formed in this mold displayed less than ideal filling and part dimensions in the vent areas. This problem was resolved by changing the mold to a four-runner system, reducing the vent diameter to 0.0625", and optimizing the processing conditions. Improvement in the variation of the obturator pad 7.0263" diameter datum measurement from the initial runs to the final runs with the above changes was from a maximum of 0.013 to a consistent 0.0000 inches. The final parameters were an injection cylinder temperature of 160°F, an injection time of 30 seconds at 1800 psi injection pressure, and a cure time of 8 minutes at 320°F. The physical properties of the final injection molded pads are presented in Table 1 along with typical properties of compression molded pads and test pads.

Table 1

Physical Properties of
Injection and Compression Molded Pads

Property Measured	Injection Molded Obturator Pad	Compression Molded Obturator Pad	Compression Molded Test Pad	Requirements of Dwg. No. 11578863
Tensile strength, psi	2250	2100	2200	1500 Min
Modulus @ 100%E, psi	530	480	630	--
Elongation, %	250	210	220	200 Min
Hardness, Shore A	69	67	68	70 + 5
Brittleness at low temperature	Pass	Pass	Pass	5 specimens shall pass @-50°F or colder

A series of 12 obturator pads were subsequently fabricated using the same conditions. Three of these 12 pads were inspected using optical inspection procedures. All three pads met the drawing requirements. One obturator pad was installed in a M109 Self Propelled Howitzer. Sixty-five rounds were fired using zone 8 charges without any problems. Another pad was installed in a M198 Howitzer. Subsequently, 430 rounds were test fired using zone 8 charges. The pad was found to be in normal condition as compared to a compression molded pad. Additional rounds could have been fired using either pad.

BENEFITS

Molding time of obturator pads was substantially reduced using the injection molding technique. Forty-eight obturator pads can be injection molded as compared to 12 compression molded pads during an 8-hour shift. Although productivity was increased by four times, savings are not so dramatic since the injection molding operation requires a full-time operator and the compression molding operation requires only a part-time operator. This project also demonstrated that the injection molding process is applicable for thick sectioned parts with improvement in physical properties.

IMPLEMENTATION

Implementation is planned at Rock Island Arsenal when orders reach a level where the increased production rate gained with the injection molding process is required.

MORE INFORMATION

Additional information is available from Mr. Frank Testroet, Rock Island Arsenal, Rock Island, IL, AV 793-5039 or Commercial (309) 794-5039.

Summary report, June 84, was prepared by F. Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **681 7966** and **682 7966** titled **"Manufacture of Tritium Powered Radioluminous Lamps"** were completed by the US Army Armament, Munitions and Chemical Command in January 1984 at costs of $125,000 and $253,000, respectively.

SUMMARY

A tritium lamp is a phosphorescent light source. It is composed of a sealed glass vial in which the inner walls are coated with phosphor and the interior is filled with tritium, a radioactive gas. As the tritium decays, it releases beta particles which strike and excite the phosphors, Figure 1, causing them to glow. Tritium has a relatively long radiological half-life of 12.3 years and a short biological half-life of about 12 days. Thus, tritium activated lamps can last several years while accidental exposure to the body presents a very low biological safety hazard.

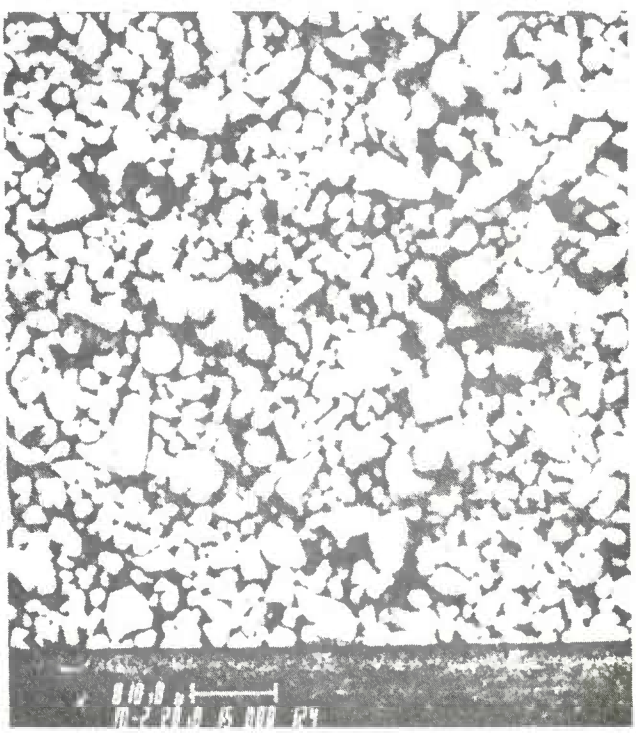


Figure 1 - Secondary Electron Photomicrograph of the ZnS Phosphor Container.

Tritium lamps being purchased by the Army for use in fire control instruments were exhibiting broad variations in the rate of brightness decay. Life, varying from two to four years, for decay of 50% of initial brightness had been experienced. There was considerable evidence that it should be possible to consistently produce tritium lamps so that the one-half brightness life would be six years.

SUMMARY

The objective of this effort was to improve the method of manufacturing radioluminous lamps by establishing new process controls which would prevent accelerated brightness decay. During the first year, the current manufacturing processes would be evaluated. During the second year, the project would validate new process controls which would improve the reliability of the radioluminous, tritium lamps.

A review of the tritium lamp manufacturing methods was conducted. It was found that the materials used (glass, paint and fill gas) by manufacturers were similar because they were specified in the government's technical data package (TDP). Also, the manufacturing sequences were the same, but there were differences in process parameters, manufacturing equipment, and in the selection of binder and phosphor compositions.

In order to obtain a representative cross-section of samples from manufacturers, four contracts were awarded. These contractors provided a total of 686 samples which reflected the condition of the lamps and their constituents at seven different stages of completion in the manufacturing cycle. These samples represented four different fire control lamp configurations and were fabricated using each contractor's processes, materials and equipment normally used in production. Groupings of illuminating lamps (phosphor-coated, tritium-filled) were furnished to ARRADCOM for brightness monitoring, and the balance of the samples was sent to an independent laboratory for internal analysis. The internal analysis was accomplished by breaking open the sealed vials and determining the composition of the fill gas using a mass spectrometer.

In determining performance factors for these lamps, it was concluded that the key indicator was illumination. Lamp brightness (illumination) was considered to be a function of three parameters; i.e., the efficiency of the phosphor/electron reaction, the rate of reaction, and the amount of internal light transmission, reflection, and absorption. Based upon the information obtained, it was apparent that high initial brightness was the key parameter in assuring a long useful lamp life. Measurement of brightness values was preceded by a conditioning procedure. This procedure consisted of holding the lamps in a darkened area at room temperature for 24 hours prior to testing. On the day of the test, three brightness readings were obtained at four-hour intervals and then averaged to obtain a "brightness value." The controls on brightness measurements, and associated test equipment, are currently part of the Quality Assurance provisions specified in the US Army Fire Control tritium lamp TDP.

Results obtained from the gas sampling and initial brightness tests indicated that there was basically a high quality of manufacturing. In addition, the results imply that quality lamps can be produced using similar materials and a variety of manufacturing procedures.

BENEFITS

Prior to this MMT effort, the lifespan of the tritium lamps ranged from two to four years. By improving the production methods and controls, the lifespan was increased to six and possibly eight to ten years. The long range monetary effect of this increased lifespan is that the Army will be able to reduce the quantity of lamps purchased in the future or reduce the frequency of these purchases.

IMPLEMENTATION

Improved process controls and manufacturing procedures were implemented by the contractors as they were identified during this investigative effort. A formal method of implementation will occur by the preparation of a new specification for the manufacture of tritium lamps. The new specification is expected to be released during the fourth quarter of FY84.

MORE INFORMATION

Additional information about this project can be obtained by contacting the project officer, Mr. Harvey Goldman, AMCCOM (D), AV 880-7983 or Commercial (201) 724-7983.

Summary report, June 84, was prepared by Andrew Kource Jr., Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

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

MMT Project **E80 3708** titled **"Coated Fabric Collapsible Fuel Tank Program - Circular Seamless Weaving"** was completed by the US Army Mobility Equipment Research and Development Command in October 1983 at a cost of $107,500.

BACKGROUND

Pillow tanks have been used by the military since the mid 50's for storing fuel in isolated locations or as an auxiliary to more permanent installations. These tanks are self-supporting, i.e., capable of supporting the fuel contents by the peripheral hoop stress of the coated fabric. No earth embankments are made to support the weight of the fuel. Panels of fabric are coated with an elastomeric compound, then seamed together to form a tank envelope.

An earlier project established the feasibility of producing a seamless fabric of a quality suitable for the production of collapsible fuel tanks. Since seams are the weakest element in collapsible tank construction, this was a positive step forward. However, coating of this seamless fabric with a compatible polymer remained to be demonstrated.

SUMMARY

The objective of this project was to perfect a technique for coating the large seamless fabric tube produced earlier so that it would be suitable for collapsible fuel tank production. The coating selected was a two-part urethane produced by DuPont. The prepolymer was Adiprene L-300 and the curative was Caytur 21 (methylene dianiline-sodium chloride complex in dioctyl phthalate). Methylene chloride was used as a cleaning solvent.

Three narrow width seamless fabrics were used for trial coatings. The first sample run resulted in excessive debris building up in the coating. This was attributed to the coating accumulating around the many broken filaments in the fabric. Another coating trial was singed and vacuumed prior to coating. This resulted in a fairly uniform coating, although it took four coats on each side to complete the process.

Although many problems were encountered in this effort, most were or could be resolved without too much difficulty. Special equipment, such as a bowed roller to relieve the fabric puckering tendency, would be required. Some of the problems encountered in coating were traced back to the weaving of the seamless fabrics. Notably, non-uniform tension in the filling picks contributed to the puckering problem, and filament breakage in the warp yarns resulting in debris buildup in the coating.

The coated sleeves were fabricated into tanks at the contractor's facility. The mounting of patches for the hardware and sealing of the end closures proceeded slowly but satisfactorily. The Adiprene L-300 urethane coating formulation was used as the bonding agent, and heat was supplied by using heated metal plates. Good bonds were obtained at the end closures, hardware reinforcing fabric and handle patches.

The two seamless tanks produced were received at Yuma Proving Ground in early December 1982. One tank was filled only with water because several leaks were reported through the coated fabric and one at the filler fitting. The second tank was filled with water and no leaks were detected. In January, 1,000 gallons of diesel fuel were added to this tank. (See Figure 1).

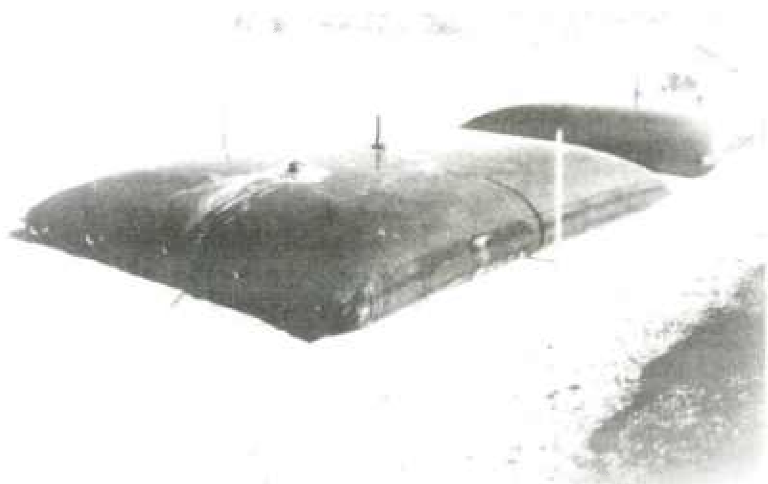


Figure 1 - Seamless Tanks on Test at Yuma Proving Ground

After 9 months exposure to the desert environment, inspection revealed that the leaks in the "water" tank had sealed. There was no evidence of damp spots in the coated fabric or fittings. The coating compound was still hard and could not be scratched with a coin. The tank appeared to be in excellent condition.

The "fuel" tank showed the effects of the 1,000 gallons of diesel fuel. The top portion was darker than the remainder. In all, there were about 35 darker spots on the top ranging in size from 1-inch to 5-inches in diameter. Some of these spots were damp with fuel but there was no fuel run-off. The older the spot, the drier it became. There was also a light sulfur colored residue on top of the tank. The coating could be scratched with a coin indicating some deterioration.

In some respects, the excessive deterioration of the "fuel" tank was expected because the compounds available for this project were not up to the standards for conventional tanks. The sulfur colored residue on the fuel tank is a result of the high diffusion rate of the coated fabric and some oxidation of the coating. The test program was terminated in September 1983.

BENEFITS

The practicality of making a seamless fuel tank has been demonstrated. Facilities exist which are capable of weaving and coating very wide fabric, either in flat or tubular form. Although problems were encountered, they appear to have relatively simple solutions, and the prospects of producing a superior product on a commercial scale are excellent.

IMPLEMENTATION

The technology has developed to the point where the tanks could be used for water and possibly other liquids. However, a better polymer coating, compatible with the special equipment required, must be developed before it can be applied to storing petroleum fuels.

MORE INFORMATION

Additional information may be obtained from the project officer, Mr. Charles Browne, MERADCOM, AV 354-5781 or Commercial (703) 664-5781. Also, a contractors report titled "Seamless Collapsible Fuel Tanks," July 1983, is available on the subject.

Summary report, June 84, 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)

MMT Project **E81 3759** titled **"Composite Material Reinforcement for Military Bridges"** was completed by the US Army Troop Support Command (TROSCOM) Belvoir Research and Development Center (BRDC) in July 1983 at a cost of $223,800.

BACKGROUND

This MMT project was preceded by a two-phase RDTE effort. Phase I consisted of analysis and subscale testing of design concepts for lightweight graphite/epoxy tensile elements for modular bridges. In Phase II, the full-scale designs were verified under static and cyclic loads. Both phases consisted of the following primary efforts:

(1) Fiber Selection - the reinforcing fibers that were evaluated included high strength carbon (T300), high modulus carbon (VSB), and KEVLAR 49. Subscale tests were made on these fibers separately and in combination. High strength carbon was selected as offering the best combination of strength, stiffness and production consistency.

(2) Configuration Selection - two basic configurations were evaluated. One concept used one element per set and consisted of a continuously wound link on four legs, twisted so that the end fittings were rotated 90°. Although this design only required one element per set, the manufacturing process was complex and costly. The other concept used two identical elements per set. Each element had two straight legs without twist and resembled a race track or rubber band in shape. Due to the production and assembly simplicity, this design concept was selected.

The MMT project was conducted to establish a pilot production line and demonstrate that the race track tensile elements could be produced economically. Project work was accomplished by in-house effort at US Army Belvoir Research and Development Center and contractual effort at Fiber Materials Inc. (FMI), Biddeford, Maine.

SUMMARY

A continuous filament winding process was selected per the contract statement of work. The processing method was based on rotating the mold (mandrel) about its transverse axis, thus drawing the fibers through a resin impregnator and onto the mold as shown below.

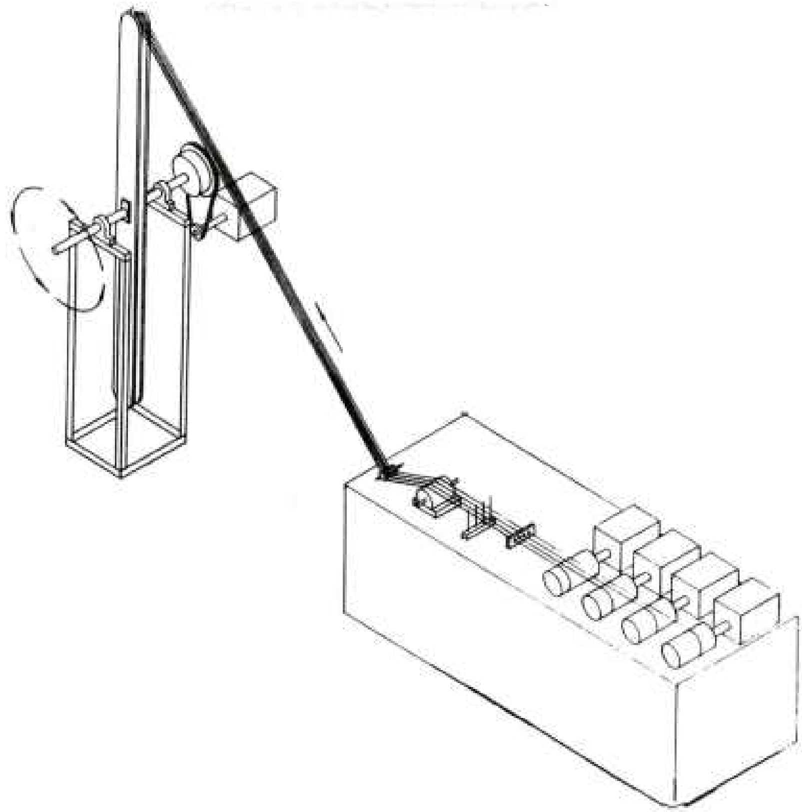


Figure 1 - Tensioning Creels, Impregnator and Mold

The process was relatively simple and had the advantage that it could be expanded by adding more stations rather than investing in expensive winding machinery. The controlling factor on production rate was the speed that material could be drawn through the impregnator. The degree of fiber wetting was controlled by an adjustable impregnator which passed the strands over a resin coated drum. The drum's lower portion picked up a thick layer of resin as it rotated through a bath. The coating was controlled by a carefully adjusted blade which removed excess resin leaving a film thickness equal to the clearance between the blade and the drum. Although the impregnator was relatively insensitive to fiber speed, it required constant attention to avoid reducing the gap between the blade and the drum caused by a build-up of fuzz from the fiber.

Two men were required to wind an element. The first man maintained the impregnator and the second man compacted the composite on the mold. After the element was wound, the molds were removed from the winding stand, and caul plates were placed on top of the composite. The plates maintained compaction during the curing process. After oven curing, the race track element was pried from the mold. Installation of the end fittings was accomplished by first applying a silicone sealant to a stainless steel half shell and then attaching the cover plates with screws. The remaining void was filled with styrofoam. Finally, the element was wrapped spirally with glass tape by hand. The tape was applied dry, then impregnated with a room temperature epoxy and set aside to cure. The finished element, as depicted in the figure below, weighed about 24 pounds. Forty elements, or 20 sets, were produced for further evaluation by the Army.

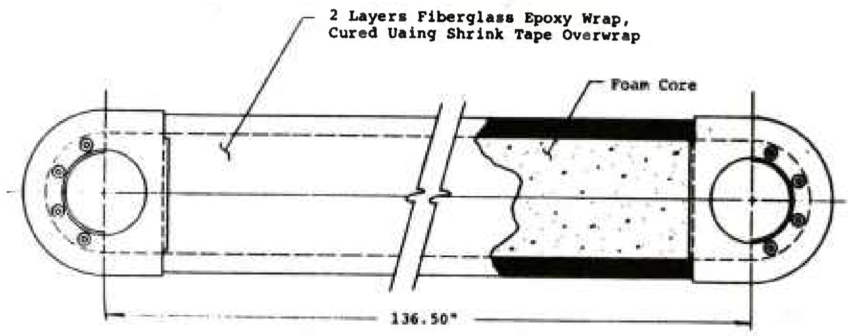


Figure 2 - Race Track Tensile Element with Steel/Al End Fittings

BENEFITS

The machine layup of graphite/epoxy is a marked improvement over previous methods of hand layup. The structural integrity of these tensile elements will be a significant improvement over metallic links currently used for pre-stressing military bridges. Based on a projected production run of 10,000 elements, the estimated cost per unit is $560. This is somewhat less than the cost of an aluminum tensile element.

IMPLEMENTATION

The technology established during this program will be incorporated in developmental models of the Light and Heavy Assault Bridge. During DT/OT the composite elements will be evaluated against their aluminum counterparts. Therefore, the prospect for implementing this technology in future full-scale production depends, in part, on the outcome of this evaluation.

MORE INFORMATION

Additional information on this project is available from Mr. Donald W. Bauersfeld, BRDC, AUTOVON 354-5176 or Commercial (703) XXX-5176. The technical report from the contractor is "Bridge Reinforcement System," dated 14 October 1983.

Summary report, Jun 84, was prepared by G. Fischer, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **Q79 8066** and **Q80 8066** titled **"Continuous Filament Helmet Preform"** were completed by the US Army Natick Research and Development Laboratories in September 1983 at costs of $232,300 and $38,400, respectively.

BACKGROUND

The conventional method for molding helmets is from preforms consisting of layers of resin impregnated fabric patterns. Such a method is an inefficient application of the fiber and is, in the case of Kevlar fabric, very wasteful and costly. It would be much simpler if it were possible to lay up the Kevlar filament in a random fashion while the resin is simultaneously applied to the filament preform. It may be possible to design a computer assisted method to adapt a dynamic programmable helmet preform mold. This would require synchronizing the application of the continuous filament to that mold through an air gun, while applying a predetermined amount of resin uniformly to the preform. It was believed that this process had the potential of saving the Government up to $50 per helmet.

SUMMARY

The objective of this effort was to investigate continuous filament lay up methods for helmet manufacture. The molding, solvents and aqueous solutions were all to be investigated.

A contract was awarded to produce Parachutist Standard Ground Troop (PASGT) helmets using a continuous filament process. After a number of delays, the contract produced several prototype helmets. These helmets were then sent to the Naval Research Center where a casualty reduction evaluation was conducted. The helmets tested met the V50 requirements of 2000 ft/sec. However, based upon a casualty reduction potential analysis, they did not compare favorably to the standard PASGT helmet molded with Kevlar fabric.

Furthermore, based upon the contractor's latest projected production cost, the savings hoped for through use of the continuous yarn method would not be realized. Therefore, this method of fabricating the helmet will not be recommended for incorporation into the helmet specification.

Consequently, it was decided to cancel the remainder of the MMT effort. No final technical report will be published due to the proprietary nature of the contractor's work.

MORE INFORMATION

Additional information may be obtained by contacting the Natick Labs project officer, Mr. Lawrence R. McManus, AV 256-5447 or Commercial (617) 651-5447.

Summary report, June 84, 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)

MMT Projects **R79 3142** and **R80 3142** titled **"Production Methods for Low Cost Paper Motor Components"** were completed by the US Army Missile Command in February 1981 and September 1983 at costs of $275,000 and $200,000, respectively.

BACKGROUND

The cost of a typical missile case has frequently been as much as 50% of the cost of the total rocket propulsion system. As a result, it was felt that ways should be found to bring this element of cost down. Recent R&D results suggest that this can be done by adapting the design to use commercially available tubular products and adding an end closure. Further, a highly promising concept is to use the paper/matrix tube process. This consists of laminating binder-coated strip paper on an accurately dimensioned mandrel, curing the laminate and cutting tubes to the desired length. Mill fabrication procedures would have to be optimized to obtain the lowest cost consistent with desired reliability.

SUMMARY

The objective of this effort was to establish the appropriate manufacturing methodology for producing low cost paper motor components. This included optimizing raw materials, strip preparation, head end and nozzle closure attachments and application of realistic nondestructive test methods for screening out critical defects.

In the prior work, a special Kraft Paper impregnated with a US Polymeric low cost phenolic resin was determined to provide the best combination of properties and cost. Tube preparation by special tape wrapping was shown to produce the best properties.

This program consisted of two phases: (1) A demonstration that solid propellant rocket motors could be fabricated from the spiral wrapped, Kraft-phenolic tubes, and (2) A demonstration that improvements could be made to the materials and processing choices to further improve the case performance. Conclusions of the first phase were that special wrapping techniques can be used to make high quality rocket motor cases. The maximum paper thickness for impregnation and wrapping was found to be 0.01 in. Also, it was determined that low cost reinforced phenolics are feasible for injection/compression molded closures and nozzles. Burst tests showed pressure capability in excess of 2,500 psi. Two motors were fired by the contractor and ten by MICOM. All were found to be structurally and thermally acceptable. Chamber pressure, total impulse and burn time were all very consistent. Also in Phase I, a new low cost phenolic resin (RS7384) provided properties equivalent to those of the baseline resin (F555Y).

In Phase II, the convolute wrapping method using raw paper resin product widths equivalent to the motor case length was found to be most practical. This process is amenable to various paper cloth products and resin systems, i.e., Kraft, Kevlar and fiberglass with phenolic, medium and epoxy resins. Also, there are several manufacturers in the U.S. with the capabilities to produce 5 to 6 foot long cases. Kevlar paper, however, has only been produced on pilot plant equipment up to 36 inches in width. (See Figure 1)

Figure 1 - Kevlar Case Flight Motor

An adhesive bonded tapered joint was determined to be the best attachment method for paper-resin cases. Pin joints, serrated surfaces, snap rings and riveted connections induce a high stress concentration in the low strain material, and thus result in greatly reduced burst strengths. The use of tapered adhesive joints requires additional work to realize the full strength potential of the case material.

Another 30 rocket motors were produced in Phase II and delivered to MICOM. Both the Kraft-phenolic and Kevlar-epoxy composite motors produced performed satisfactorily in a series of static firing. The performance characteristics were reproducible and met or exceeded expectations. There was no evidence of deterioration of the case material even though no insulation was used between the propellant and the case wall.

BENEFITS

Motor cases fabricated of Kevlar-epoxy composite have the potential of hoop tensile strengths nearly twice that of Kraft-phenolic (30 ksi vs. 16 ksi). This higher strength in Kevlar produces significant weight savings and improved mass fraction. However, the Kevlar case is 50% more expensive. For motor cases of equivalent performance characteristics, the Kevlar-epoxy case weighs 6.0 pounds and cost $90.00. The Kraft-phenolic case weighs 12 pounds but costs only $60.00. The present metal case unit cost is in excess of $160.00.

IMPLEMENTATION

Kevlar paper is the preferred material for the usage planned. Implementation must, therefore, wait for the development of a commercial source of Kevlar paper in widths of 72 to 100 inches.

MORE INFORMATION

Additional information can be obtained by contacting the project officer at MICOM, Mr. William S. Crownover, AV 746-5821 or Commercial (205) 876-5821.

Summary report, June 84, 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)

MMT Project **R78 3218** titled **"Reduce Finishing Cost of Slip Cast Fused Silica Radomes"** was completed by the US Army Missile Command in June 1983 at a cost of $300,000.

BACKGROUND

The current process for producing PATRIOT radomes (Radar Dome) is a conventional drain casting technique that results in an unnecessarily thick casting with significant wall thickness variations. As a result the casting blanks require extensive diamond grinding operations to provide the required wall thickness and shape contour both inside and out. The proposed matched die precision casting results in a close toleranced part that greatly reduces or eliminates the post-cast machining operations.

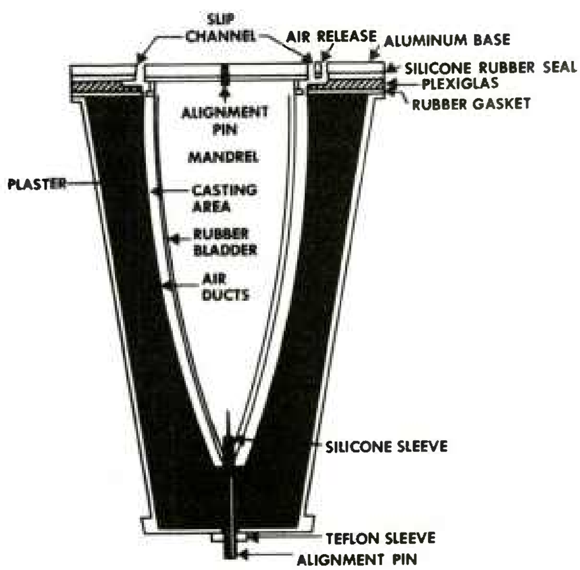


Figure 1 - Radome Mold Details

SUMMARY

The casting method developed by this project results in a radome that requires little or no final machining. A plaster mold is prepared by locating a polished aluminum mandrel in the center of an aluminum housing. A lightweight cage structure is used to support hollow mold duct rope approximately one inch from this center mandrel. Commercial Plaster of Paris is then poured in to form the mold. When the plaster reaches its maximum exotherm, the mold rope is pressurized to 15 psi causing the unreacted water to migrate to the surface. This results in a small uniform hydrostatic pressure on the mandrel which releases it from the mold. The mold is evenly dried by applying 3-5 psi to the mold duct for 2-3 hours then air drying for 24 hours. After drying, the center mandrel that forms the inner surface is positioned. This mandrel is covered with a thin (0.05 inch) rubber bladder to minimize shrinkage stresses and to facilitate mandrel removal. Alignment pins are utilized at the base and nose to assure alignment. The nose alignment pin also required a silicone rubber sleeve to prevent cracking and to facilitate removal.

The radome is cast, nose down, by forcing the casting slip out of a container and into the mold with 20-30 psi pressure. The mold vent hole is left open to allow air to escape until the slip first appears. The vent is then sealed and filling continues until 1/2 lb. or less of slip is added in a 15 minute period. The mold is then tipped nose up and the center mandrel is immediately removed. The mold duct material is again pressurized to free the cast from the plaster mold and it is removed. The cast drying operation was started at a temperature of 200 degrees for 24 hours with the part under the kiln to initiate drying. The part is then raised approximately 6 in. per 30 minutes until fully in place and then is rotated for 8 hours to complete the drying. After drying, the kiln temperature is raised 150°C per hour to a temperature of 1250-1300°C for a 1-1/2 hour soak. The kiln is then allowed to cool for a minimum of 12 hours and the radome is removed and inspected.

During the execution of this project, 15 castings were made with several mandrel and casting fixture modifications. These iterations were required to accurately compensate for the shrinkage of cast parts during drying and sintering operations and for the surface changes that occur due to slumping at the peak sintering temperatures. The maximum dimensional changes which occur during these processes are less than 3 percent and are repeatable from part to part thereby allowing compensation to be built into the dies. The resulting radome is at or very near its final required configuration.

BENEFITS

The ability to cast fused silica into near net shape was demonstrated. This reduces or eliminates the final diamond grinding operation that is required on drain cast radomes.

IMPLEMENTATION

There are presently no plans to implement the results of this project.

MORE INFORMATION

Additional information for this project is contained in MICOM Technical Report RL-83-3 titled "Reduction of Finishing Costs for Slip-Cast Fused Silicon Radomes." The project engineer for this investigation was Mr. P. A. Ormsby, AUTOVON 746-4933 or Commercial (205) 876-4933.

Summary report, Jun 84, was prepared by H. Weidner, Manufacturing Technology Div, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Projects **T78 5064** and **T79 5064** titled **"Light Weight Saddle Tank"** were completed by the US Army Tank-Automotive Command in March 1983 at costs of $90,000 and $179,400, respectively.

BACKGROUND

Fuel tanks for military vehicles, as well as commercial cars and trucks, generally are made of metal. However, military and passenger/commercial vehicles are used quite differently. Passenger/commercial vehicles are used on a daily basis and the fuel tank is usually filled weekly. On the other hand, military vehicles are used very infrequently and, in fact, often remain on standby in storage for as long as two to three years. During lengthy storage periods, water buildup due to environmental conditions (humidity cycling) and fuel degradation (chemical-microbial) can occur which leads to corrosion. Non-metallic fuel tanks would alleviate this problem.

SUMMARY

A previous MMT project established the feasibility of rotational molding of large capacity, complex geometry plastic fuel tanks. The objective of this effort was to provide plastic fuel tanks for 2 1/2 and 5-ton military vehicles and to evaluate them by field testing. The ultimate intent would be to have them replace existing metal fuel tanks.

Phase I covered the design and fabrication of the plastic fuel tanks. They were generally designed with dimensions identical to those of the current metal tanks so that transition would be easy. However, several minor modifications were made. One of these changes involved the method of securing the plastic tank to the vehicle. First, grooves were provided for the existing mounting straps. Tank slippage caused by sudden movement was thereby reduced. In addition, to compensate for the difference in strap location on the sides of the chassis, the groove width was made wider than the strap. A more significant modification was made in the filler assembly and fill cap. The design for the 1/4-ton truck tank was adopted for use on the 2 1/2 and 5 ton truck tanks because it provided a cap that is more easily removed in all climates. Also, this would standardize parts among all these vehicles. The filler-neck assembly was modified to provide a flange for the stud mounting on the plastic tank, and the fitting hardware was designed so that the plastic would only be subjected to compressive loads since it exhibits "cold-flow" characteristics.

After evaluating numerous types of rotational-mold polyethylene materials and discovering that nylon materials were inclined to be brittle, it was decided to use cross-linked polyethylene. The tanks were thus molded using Marlex CL-100, dark green. Due to time restraints, molds were made from fabricated and welded steel. To reduce fuel permeation, the exteriors of the tanks were flame treated and coated with epoxy. (See Figure 1).

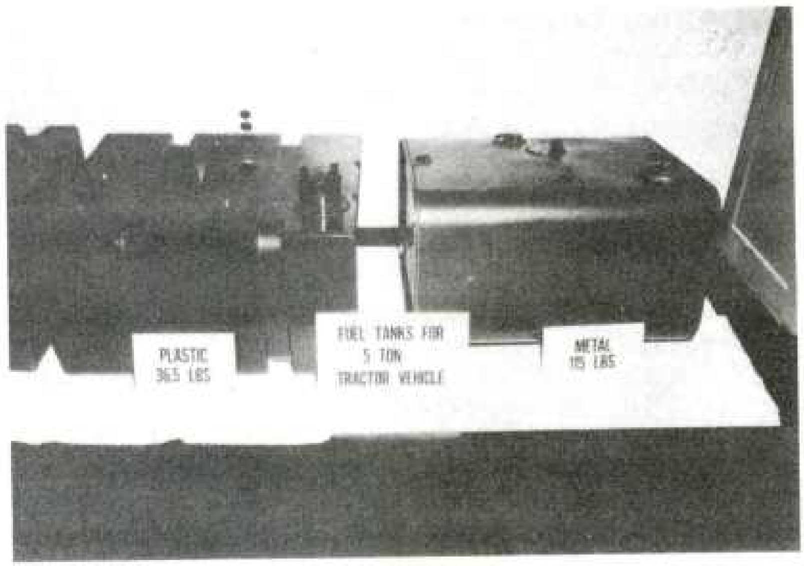


Figure 1

The tanks produced were then tested for impact resistance, heat resistance and fuel retention. The test results were all quite favorable.

Phase II covered the field testing of the tanks prepared in Phase I. Although no vehicle was available for the 2 1/2-ton tank, fuel tanks for the 5-ton vehicle underwent feasibility testing at Yuma Proving Grounds, Cold Region and Tropical Test sites. While no major failures occurred, a number of deficiencies were noted in the new plastic tanks. First, there was a tendency for the tank to distort when filled with fuel. Second, the fittings leaked and last, the epoxy coating peeled and was ineffective.

It is believed that all of these deficiencies can be overcome without too much difficulty. Reinforcing ribs or gussets could be incorporated to straighten the tank walls. The mold could be made of cast aluminum to produce greater radius corners and fillets which are structurally better for the part. This would also allow shot peening the mold interior which produces a textured surface on the part. This would eliminate the high gloss finish on the prototypes and more closely match the typical military satin forest green finish. Also, instead of epoxy coating, perhaps, the cleaned tank could be sulfonated. Finally, the fittings could be redesigned to permit them to be tightened more.

BENEFITS

1. Corrosion Resistance - Corrosion, both external and internal, is minimized with a plastic product.

2. Impact Resistance - Documented tests indicate plastic tanks will not rupture under impact. Metal tanks will instantly rupture under the same test conditions.

3. Safety - In a fire situation, a metal tank will occasionally explode while the plastic version will gradually melt.

4. Design Flexibility - Odd configurations in molded plastic allow the designer to maximize vehicle space availability for the tank. Similar shapes would be very costly with fabricated metal tanks.

5. Weight Reduction - Typical savings of 50-70% will result in greater fuel economy.

6. Cost Savings - For complex shapes, there will be a decided cost advantage of plastic tanks over their metal counterpart. Also, they will not have to be replaced as often. The current quote for the plastic replacement for the 5-ton truck, which is not the most complex, is about breakeven with the cost of a metal tank.

IMPLEMENTATION

This effort is being continued with FY82 and FY83 funding. Following the aforementioned changes to correct the deficiencies noted, it should be possible to replace the current metal fuel tanks with plastic ones. The M939 and M309 cargo vehicles are the first candidates for this replacement.

MORE INFORMATION

Additional information may be obtained by contacting the TACOM project officer on this project, Ms. Dorothy McClendon, AV 786-6491/2 or Commercial (313) 973-6491/2. Also, the following technical reports have been prepared:

"Plastic Fuel Tank Development," Hollowform, Inc. (Contractor), December 15, 1980.

"Light-Weight Saddle Tank Development, Phase I - Fabrication and Material Feasibility," TACOM TR 12657, July 1982.

"Light-Weight Saddle Tank Development, Phase II - Feasibility Testing," TACOM TR 12657, July 1982.

Summary report, June 84, was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

APPENDIX I

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