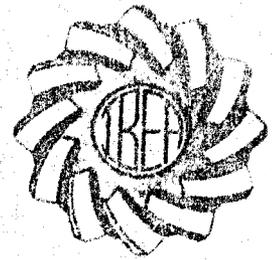


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US ARMY  
MATERIEL DEVELOPMENT AND  
READINESS COMMAND DIRECTORATE  
FOR MANUFACTURING TECHNOLOGY



AD-A154 052

**M**ANUFACTURING  
**M**ETHODS &  
**T**ECHNOLOGY

**PROJECT SUMMARY**

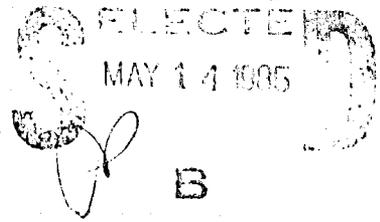
**REPORTS**

(HCS DRCMT-302)

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

REPLY TO  
 ATTENTION OF:

AMXIB-M

18 January 1985

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 AMC 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.

*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 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 AMC 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 63-5113, or Commercial (309) 782-5113, Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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 94 completed projects that were funded by the MMT Program. The summaries are prepared from Project Status Reports (CS 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, AMC, 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. Wayne R. Hierseman and ably assisted by Ms. Eileen Griffing, Ms. Debbie O'Connor and Ms. Sally Weckel with the typing and graphics arrangements.

temperature distribution elastic deflection, bulk shrinkage and other pertinent data had to be calculated using finite element analysis. Task three consolidated all the mathematical analysis into an overall interactive graphics system. The main program was called SPBEVL. It was developed by Battelle and is written in CDC FORTRAN. Spiral bevel gears are different from other types of gears because they cannot be illustrated entirely with simple geometric drawings. To determine accurately the tooth bearing load required a 2-D finite element analyses. This was the objective of task number four. At the completion of the four tasks, a demonstration of the interactive graphics developed under Phase I was arranged. At this point the effort was ready to enter Phase II.

Phase II was broken down into five (5) tasks: preform design, tool design, manufacturing of forging dies, forging trials and finishing and dimensional checking of forged gears. The CAD/CAM designed preform was designed as a solid ring with outer dimensions as close as possible to the outer dimensions of the finished gear. This task was very important to the cost aspects of forgings; 15 percent of the forging costs are in flash material of little recoverable scrap value. The CAD/CAM designed preform produced no flash. Task number two took advantage of the interactive system developed in Phase I. The tooling was designed to optimize material flow. Task number three used CAD/CAM methods to see that the electrode (Electro-Discharge Machining (EDM) was used to create the gear impressions on the die) geometry accommodated all corrections needed for accuracy. The following materials were used: near-net gear die, hot work steel H-11, net gear die, hot work steel H-13 and billet material, 8620 steel. Task number four involved the actual production of a finished spiral bevel gear. A 3,000 ton mechanical forging press was used. To heat the preforms, a specially designed induction coil was used with an infrared temperature measuring instrument to monitor forging temperature. After forging, the gears were placed teeth down in a sand-graphite mixture to reduce oxidation of the teeth during cooling. After two series of trials where minor problems occurred requiring small changes, a gear of excellent surface quality and superior die fill was produced. Task number five involved finishing the forged gears on conventional gear cutting machines and checking them for dimensional accuracy on a computer controlled coordinate measuring machine. Figure 1 shows a finished spiral bevel gear.

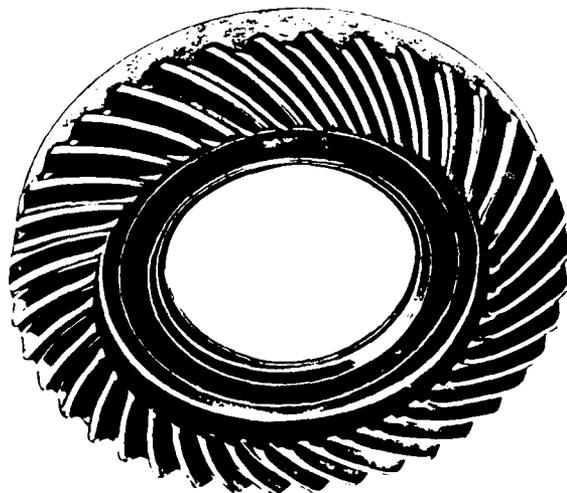


Figure 1 - A Cleaned Net Forged Gear

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

MNT Projects 478 5024 and 479 5024 titled "CAD/CAM Techniques for Optimum Preform and Finish Forging of Spiral Bevel Gears" were completed by the US Army Tank-Automotive Command in March 1983 at a cost of \$200,000 and \$345,000, respectively.

**BACKGROUND**

The traditional way of die design and manufacture is to use information developed by extensive experience along with trial and error. There have been many attempts to produce precision forgings of spiral bevel gears. A program using High Energy Rate Forging (HERF) techniques was initiated, and while valuable information concerning many aspects of forging was obtained, premature failure of dies due to plastic deformation occurred. Recent work has been done using powdered metals to produce forged spiral gears. The study resulted in quality material but additional work was needed in die design, dimensional control of bevel gear tooth form, metallurgical quality and inspection. The common denominator in all these studies was that, at some point, trial and error had to be used to develop a precision part. In none of the publicized development results (at the time of this effort) is there any reference to applying computerized techniques in die design and manufacture. The use of CAD/CAM technology can reduce the trial and error time and be applied to the entire family of bevel gears (straight, spiral, zoral and hypoid).

**SUMMARY**

This effort was divided into three (3) phases, the first two are the subject of this report.

Phase I: Optimize the design, manufacture and life of dies used in precision gear forgings by computer aided design techniques.

Phase II: Demonstrate effectiveness of CAD/CAM by manufacturing spiral bevel gears using computer aided manufacturing techniques.

Phase III: Apply CAD/CAM techniques and conduct forging trials and tests. This phase is currently in process.

Phase I was divided into four (4) tasks: transformation of dimensional data into computer compatible digital data, CAD of forging dies, development of an interactive CAD system and finite analysis of gear tooth loading. To complete task number one required deriving vector equations that simulate the spiral bevel gear cutting process using the kinematics of the Gleason gear cutting machines. To obtain the design accuracy required by task number two, the geometric variations between the finish forging die and the forged gear had to be corrected. Many variables such as stress distribution, load,

Phase I was divided into three tasks: Task 1, transformation of dimensional data into computer compatible digital data, Task 2, computer-aided design (CAD) of form dies, and Task 3, development of an interactive CAD system. In Task 1 the gear tooth geometry was generated by simulation of the motions of both hob and shaper cutter cutting machines. For defining the tooth geometry, standard equations were used to simulate the gear cutting process. All data required for the computations was obtained from standard summary sheets developed by gear designers and the geometry of the cutting tool. Task 2 involved the development of the CAD for the forming die. The geometry of the forming die differs from that of the formed gear because of shrink fit, heating of die, elastic deformation during forming, unequal coefficients of thermal expansions of billet-die and shrinkage due to cooling. To get an accurate formed gear all of the above geometric factors must be taken into account. Two different methods were employed to model elastic deflection; the "slab method" and Finite Element Method (FEM). Bulk shrinkage due to temperature was done using simple heat transfer analysis. Dimensional shrinkages caused by changes in the inner die were modelled using the "slab method". Task 3 involved the development of a interactive CAD system. A graphics oriented CAD program called GEARDI was developed and written in VAX FORTRAN. GEARDI enables the user to design an entire family of spur and helical gears.

#### **BENEFITS**

There are a number of benefits gained by adopting a CAD/CAM cold forged process. The tangible benefits are the cost savings and reduction in production time. There is an estimated savings to investment ratio of 2.16.

#### **IMPLEMENTATION**

Eaton Corporation is the subcontractor with the responsibility for producing the prototype gears. Eaton has plans to adopt this process upon the completion of Phase II of the effort.

#### **MORE INFORMATION**

Additional information may be obtained from the Tank-Automotive Command's final technical report for Phase I "Establishment of a CAD/CAM Process for the Production of Cold Forged Gears", DAAE07-82-C-4063 or by contacting Don Ostberg, US Army Tank-Automotive Command, Warren, MI 48090, AUTOVON 786-5814.

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Summary report, Dec 84, was prepared by F. Stonestreet, 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 482 5005 titled "CAD/CAM Process for the Production of Cold Forged Gears" was completed by the US Army Tank-Automotive Command in September 1984 at a cost of \$284,000.

**BACKGROUND**

The cold forging process is being used today to produce small gear blanks. The process has not proved feasible for larger gear blanks due to residual stresses and excessive distortion introduced during the manufacturing process. The cost is high using traditional design methods because they depend on extensive trial and error methods. Since cold forming processes offer potential savings in labor and material as well as improvement in product quality, it would be advantageous to have a method of not only designing target size gears but to be able to design families of gears. The use of CAD/CAM gives industry the tool to accomplish the task of designing and manufacturing cold forged gears.

**SUMMARY**

The project was broken down into two phases; Phase I, the development of a computer-aided design (CAD) program for cold forged gear dies and Phase II, the computer-aided manufacturing (CAM) of gears using the results of Phase I. This report summarizes work done for Phase I (figure 1).

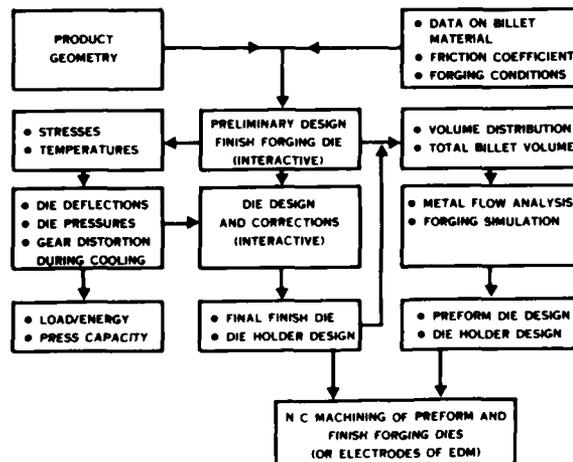


Figure 1 - Major Steps Common to CAD/CAM Methods Used For Forging Die Design and Manufacture

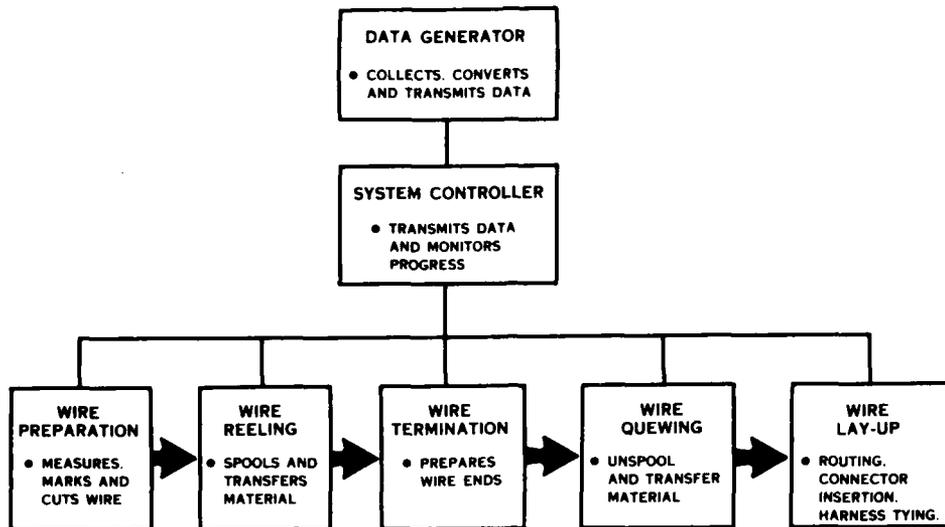


Figure 1 - Block Diagram of RWHAS

wire lay-up subsystem and then transfers the empty canisters back to the wire termination subsystem. The wire lay-up subsystem performs the actual wire harness assembly. It routes the prepared wires into the correct geometric configuration. Used in conjunction with required communication interfaces, the RWHAS operates as a highly efficient and time saving system.

#### **BENEFITS**

The RWHAS will do away with the monotonous and error prone manual assembly system. There will be a definite reduction in wire harness assembly costs and improved productivity. The projected cost savings over a 10 year period is over 7.5 million dollars.

#### **IMPLEMENTATION**

Implementation cannot be realized until completion of Phase III of the effort, 384 1109.

#### **MORE INFORMATION**

Additional information may be obtained by contacting J. Anderson, AUTOVON 746-2147 or Commercial (205) 876-2147 or by obtaining the Army Missile Command's final technical report "Robotized Wire Harness Assembly System" with Appendix (the report is in two volumes), US Army Missile Command, Redstone Arsenal, AL 35898-5270.

Summary report, Dec 84, was prepared by F. Stonestreet, 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 1109 titled "Robotized Wire Harness Assembly System" was completed by the US Army Missile Command in June 1984 at a cost of \$1,005,000.

**BACKGROUND**

Wire harness assembly methods have been virtually unchanged for 40 years. The old method of workers laying out the wiring harness on a vertical forming board is still in use today. Advanced equipment has become more widely used for some assembly operations. The equipment is mostly semiautomatic and is not applied to the entire assembly operation, therefore, many tasks are still done manually. The wiring harness assembly operations in use today can be monotonous and repetitious, leading to boredom and errors by the workers. A fully automatic system could solve the many problems of a manual system.

**SUMMARY**

The Robotic Wire Harness Assembly System (RWHAS) is a collection of computers, special equipment, communication interfaces, vendor software and application programs. This collection of parts is integrated together to form an automatic and computerized method of assembling electrical wire harnesses. A description of a wire harness is stored in the computer data base. An operator provides the appropriate material, then the system proceeds to fabricate the wire harness. Once the system starts, the only operator intervention is for possible fault correction. The RWHAS is comprised of seven elements; data generator, system controller, wire preparation, wire reeling, wire termination, wire queueing, and wire lay-up. Figure 1 depicts the basic structure of the system.

The data generator will take a computerized description of the wire harness and generate sequential data for each of the subsystems plus set-up instructions for the operator. The information that the data generator provides will be supplied by either manual entry, text editor or a CAD/CAM data base. The data generator provides sequential data directly to the system controller. The system controller uses the data from the data generator to control the five remaining elements or subsystems. The five subsystems provide the actual wire harness fabrication. The wire preparation subsystem selects a single wire from one of sixteen available reels. The wire is spooled onto a canister by the wire reeling subsystem, there it will be transferred to the wire termination subsystem. The wire preparation subsystem has a multitude of tasks, such as performing wire end preparation, calibrating the wire, handling full and empty canisters and wire drop-off. The wire queueing subsystem transfers the wire from full canisters to the

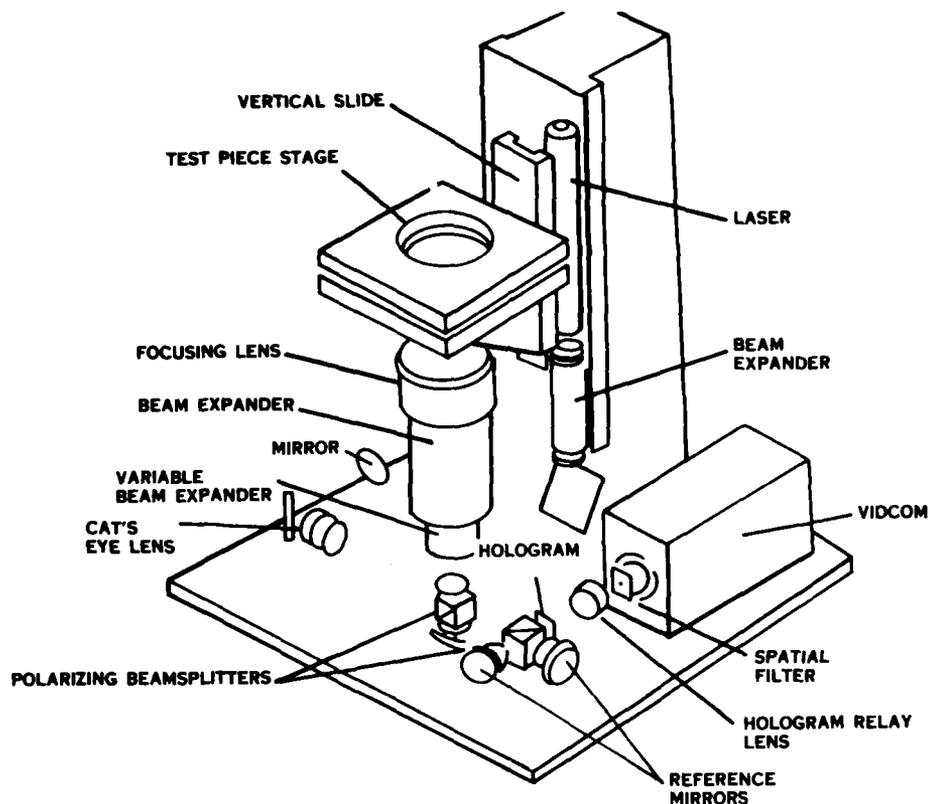


Figure 1 - Tropel CGH Interferometer Design

ography and this plot is then reduced to the required size. The computer generated holograms are then used to convert the spherical wave front. The interferometer is then set up into a readable aspherical fringe system that will show fabrication errors.

#### **BENEFITS**

The results of this project will allow the manufacture of high quality germanium lenses at a faster rate and lower costs. The asphericity of the optical elements will result in the need for fewer lenses, therefore a lighter system.

#### **IMPLEMENTATION**

Hughes Optical is currently using this process in a development program of their own.

#### **MORE INFORMATION**

Additional information may be obtained from Mr. James R. Adamson, Night Vision & Electro-Optics Laboratory, Fort Belvoir, VA 22060, AUTOVON 354-6666 or by obtaining a copy of the final technical report "MMT Optical Fabrication" published by the ERADCOM, Night Vision & Electro-Optics Laboratory, Ft. Belvoir, VA 22060.

Summary report, Dec 84, was prepared by F. Stonestreet, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project 277 9845 titled "Numerically Controlled Optical Fabrication" was completed by the US Army Electronics Research and Development Command in August 1982 at a cost of \$364,500.

**BACKGROUND**

In an effort to improve methods for producing spherical and aspheric germanium lenses for Forward Looking Infrared (FLIR) systems MMT project 277 9845 was undertaken. Conventional methods are currently used to produce germanium elements with spherical surfaces, however they are very expensive. Germanium requires much grinding, laborious finishing and tedious inspection operations. It would be advantageous to use aspheric lens element as opposed to spherical. The aspheric system only requires six or seven lenses while a spherical system needs about nine. Efficient production techniques for aspherical optical surfaces have not been available. This project's goal was to produce cost-efficient spherical and aspherical lens elements.

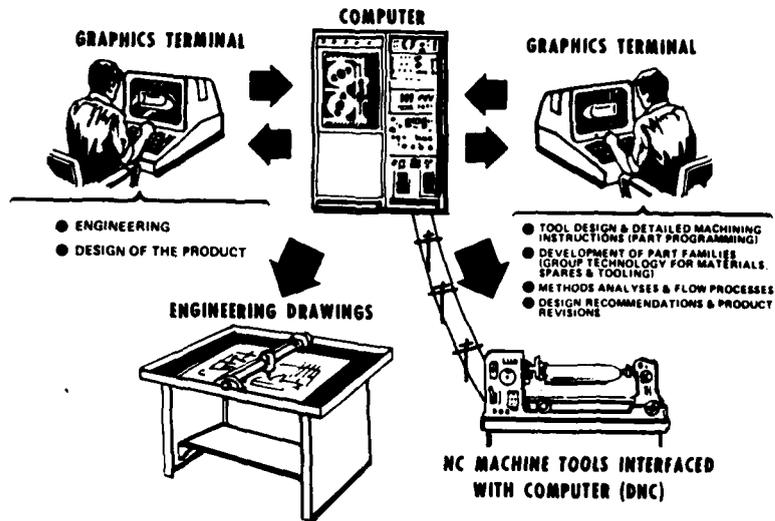
**SUMMARY**

It was determined during the fabrication phase of this project that extensive tooling would have to be designed and built. The limited number of lenses required did not warrant the cost involved, therefore it was decided that the germanium blanks be purchased in a preshaped condition. The remaining part of the project was devoted to developing the process of generating aspheric lenses using Single Point Diamond Turning (SPDT) on a numerically controlled machine. Involved in the development phase were the following: software development, vacuum chuck design and test equipment.

To cut a generalized aspheric surface required the development of custom software, since commercially available NC software lacked the pre-programmed sophistication for cutting a general aspheric surface. An explicit form of NC programming known as "point-to-point" mode of operation was used to cut the surface. The aspheric surface was figured then transferred to the NC machine. All aspheric surfaces were cut using this software. A special fixture had to be designed to secure the lenses to be fabricated. A vacuum chuck made of porous sintered bronze was designed with a spherical surface; the lenses, which were spherical on one surface were placed on the chuck and the aspheric surface was then cut.

To test the lenses a mirrored interferometer system was employed. The system used to test the mirror and lenses was the Tropel Model 4000 interferometer, modified to accept a hologram. See figure 1 on the next page. The test method is called Computer Generated Holography (CGH). A ray trace of the aspheric mirror/lens to be tested is done by a computer system especially programmed for this purpose. The output is plotted using electron-beam lith-

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



INFORMATIONAL FLOW IN A COMPUTER SYSTEM

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
179,80,81,82 7113	Composite Rear Fuselage (CRF) Manufacturing Technology	N-4

The major thrust of this effort was to develop and demonstrate cost saving manufacturing methods for building primary airframe structures with composite materials. The UH-60A Blackhawk rear fuselage was selected as the demonstration component because of its inherent complexity and labor intensive construction. Preliminary studies showed that the rear fuselage parts count and associated labor could be substantially reduced by changing from metal to composite structural materials. Success was attained by perfecting an approach to cocure large complex structures. The CRF is 38% more economical to manufacture than the current metal UH-60A rear fuselage. Eventual cost savings are projected at \$19,100,000. An additional benefit is a 10% weight reduction. The CRF is currently undergoing flight qualification testing.

H80 9897	Surface Acoustic Wave Resonator and Reflective Array Devices	E-33
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Requirements exist for small reliable RF/microwave frequency sources that consume little power, use low voltages and are highly stable over a range of temperature and other environmental conditions. The fundamental frequency of operation for currently available devices is limited to about 50 MHz. This frequency limitation is caused by the inability to produce the extremely thin physical dimensions required for higher frequency operation. This project was initiated to solve these problems. The ion beam etching process of the crystals was established as a viable production process for relatively large (6 in. long) lithium niobate devices. Using this method, devices with frequencies over 100 MHz can now be produced at rates of hundreds/month. Results of the project have been implemented at two different contractors. Potential applications include MILSTAR, SIGINT and cruise missiles. Expected cost savings are \$3.6 million.

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
579, 80 4062	Automated Manufacturing Systems for Mortar Increment Containers	MU-1

Mortar increment containers have typically been manufactured on a developmental basis, by manual methods and in small quantities. During Mobilization, large quantities of containers would be required. At present, costs are high and the small manufacturers are not capable of meeting Mobilization requirements. This project developed a high production and cost effective system to meet Mobilization needs. The new prototype slurry vacuum forming manufacturing/assembly system developed for containers can reduce labor requirements from 20 operators to 6 operators. This should reduce unit costs by 50-75%. The prototype lines to be built and tested will be made available to the private sector through competitive part buys.

57T, 76 4302	Acceptance Criteria for Continuous Single Base Propellant	MU-3
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Acceptance and homogeneity limits for propellants is heavily dependent on actual ballistic testing. Testing and collection of data also requires extensive production runs. This effort was initiated to establish nonballistic acceptance and homogeneity limits. It was focused on M1 propellants produced on the Continuous Automated Single Base Line (CASBL). A Simplex Measuring Microscope and a chemiluminescent technique to measure shifts in NOx levels are used. The instrument chosen provides a convenient method of artificially aging a propellant sample while automatically analyzing for evolved oxides of nitrogen. Changing the testing and quality assurance program from the batch method to the new techniques for CASBL processing 2.4 million pounds of M1 propellant can save approximately \$600,000/year.

574 6571	Engineering in Support of the Mortar Ammunition Metal Parts Modernization Program	MU-12
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A new mortar projectile metal parts manufacturing line was established at Riverbank Army Ammunition Plant. The existing method of manufacture of 60mm XM720 was unsuited for the new metal parts production line. Besides the need for a new process that would be compatible with the new line equipment, it was necessary to check the feasibility of eliminating or combining certain operations. It was also decided to analyze the effects of using powder metals, alternate wrought steels on metal parts and alterations of thermal treatment processes. The project was successfully accomplished over a number of years by dividing it into eight phases. It has now been implemented at Riverbank AAP for the production of both 60mm and 81mm mortar projectile metal parts. Savings per part is estimated at about \$0.15 and savings in equipment purchased is estimated to be over \$1,750,000. Net estimated savings on heat treatment equipment is over \$4,000,000.

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
677 7201	Artillery Weapons Firing Test Simulator	I-28

Live-firing has been virtually the only accepted method of testing large caliber gun mounts and recoil mechanisms since the advent of weapons using explosive propellants. Hence, it is expensive, noisy and normally cannot be located near manufacturing facilities. Earlier feasibility studies indicated that a hydraulically powered device could effectively simulate live firing of artillery and tank weapons. Later, a limited version simulator was fabricated and installed to prove the simulation concepts. An impulse programmer was added to enable testing of others. This project provided a second improved hydraulic simulator capable of testing five popular mounts at various elevations. It is being used to test gun mounts and recoil mechanisms at 30 to 60% of the cost of the live fire alternative for production acceptance testing. Engineering type tests are conducted at costs ranging from 5 to 17% of the live fire alternatives. The two simulators have generated over \$7,200,000 in savings when compared to live firing.

680 7928	Robotized Benching Operation	ME-26
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Past investigations of benching operations on breechblocks and rings have shown that current methods were both unsafe for the operator and excessively time consuming. The operation took approximately four hours depending upon weapon and component. A considerable amount of time was spent grinding radii on the ends of internal segmented threads. The thrust of this project was to determine the feasibility and requirements for implementation of a robot to perform the benching operations. A new system configuration was developed. It will be built and tested in MMT 681 7928. Upon completion of the effort, the benefits anticipated are a reduction of 50% of direct labor cost, elimination of tedious work, and an increase in product quality. It is also believed that the same robot can be adapted to other repetitive and/or hazardous tasks.

682 7940	Synergistic Platings with Infused Lubricants	ME-29
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The development of rapid fire weapons has resulted in increased wear in many of the moving parts. Present dry film lubricants, as well as greases or oils, tend to wear off with use. Therefore, they require frequent reapplication or reservoirs. Such maintenance or built-in reservoir systems often are not practical. This project was directed towards advancing a new technology of using a hard, self-lubricating coating for sliding surfaces such as armament components. The technique for applying the coating was to electroplate an alloy as a "spongy" (porous) layer, heat treat to harden it and then impregnate the pores with a solid lubricant. The coating developed uses a lubricant-impregnated, nickel-phosphorous alloy and the coating has excellent wear resistance. Qualification testing/test firing for coating weapon components will be carried out.

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
H79 9844	CMOS Circuits Using Silicon on Sapphire (SOS)	E-31

Silicon-on-sapphire has been difficult to manufacture because silicon must be grown epitaxially on sapphire wafers. Subsequently, circuitry is diffused into the silicon. The Army needed complex circuits on SOS wafers for its thermal imagers, multipliers, frequency synthesizers and other high frequency devices. The object of this project was to determine the epitaxial growth equipment's operating parameters including temperature and growth rate. Optimum operating conditions for silicon deposition equipment were established. Also, the ultra-violet reflective method was proven satisfactory for characterizing the surface of grown silicon. Results of this project were implemented at two contractors' plants and circuits made with these methods are used in DOD equipment.

R80, 81 3139	Production Methods for Millimeter Seekers for Terminal Homing Applications	E-6
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In recent years, improved weapon system performance has been sought to counter adverse weather and battlefield obscurants. This led to a major development effort within DOD to implement millimeter wave (MMW) technologies. One major application is the Assault Breaker class of terminally guided missiles operating in the 90 to 100 GHz band. The RF front end assembly is the primary cost driver of that MMW system. This effort was one of the first undertaken to reduce MMW cost at the seeker assembly level. Trade studies were undertaken in search of cost benefits in terms of: manufacturing processes, assembly techniques, inspection techniques, configuration, and test procedures. Next, the program implemented the producibility improvements delineated earlier and demonstrated the effectiveness in five pilot production line units. The significant quantifiable benefits are a 37% parts count reduction, a 15% volume reduction, a 53% weight reduction, and a 60% unit production cost reduction. All were accomplished without adversely affecting performance.

379 3268	Automatic Control of Plating	E-13
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Plating processes for Printed Wiring Boards (PWB's) utilize a large variety of chemical solutions which must be frequently sampled, checked and adjusted. This process is costly, prone to error, and not sufficiently time responsive for some key solutions whose composition changes rapidly during use. The objective of this project was to improve PWB yield and reliability by implementing a computer controlled process of automatic solution monitoring and control. The system developed includes a desk top computer, a controller/sequencer, and a polarographic analyzer. It is sufficiently versatile so as to apply to virtually any solution used for PWB processing. This system is currently being used by at least seven contractors with planned savings over the next decade in excess of \$17 million.

## HIGHLIGHTS OF NOTEWORTHY PROJECTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
382 1109	Robotized Wire Harness Assembly System	C-3

Wire harness assembly methods have been virtually unchanged for 40 years. Although advanced equipment has become more widely used for some assembly operations, many tasks are still done manually. This project developed a fully automatic system to solve the many problems of a manual system. It is called the Robotic Wire Harness Assembly System (RWHAS) and is a collection of computers, special equipment, communication interfaces, vendor software and application programs. A description of a wire harness is stored in the computer data base. An operator provides the appropriate material, then the system proceeds to fabricate the wire harness. Once the system starts, the only operator intervention is for possible fault correction. Besides saving money, the RWHAS will do away with the monotonous and error prone manual assembly system. The projected cost savings over a 10-year period are over \$7.5 million.

482 5005	CAD/CAM Process for the Production of Cold Forged Gears	C-5
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The cold forging process is being used today to produce small gear blanks. The process has not proved feasible for larger gear blanks due to residual stresses and excessive distortion introduced during the manufacturing process. The cost is high using traditional design methods because they depend on extensive trial and error methods. This project was begun since it offers potential savings in labor and material as well as an improvement in product quality. A CAD/CAM system was developed that gives industry the tool to design and manufacture cold forged gears. Not only can it be used to design target size gears, but, also, it is able to design entire families of gears. Already one contractor plans to adopt the process developed upon completion of Phase II of this effort.

T80, 81 5082	Flexible Machining Systems	C-10
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Flexible Manufacturing Systems (FMS) offer a means to capitalize on the economics of mass production techniques without sacrificing all the flexibility inherent in general purpose stand alone equipment. The objective of this program was to introduce high technology manufacturing systems into the Army's industrial base. The goal was to reduce risks associated with implementation by enhancing the understanding of FMS. Working with a number of defense contractors, an FMS Handbook was written. The handbook provides a methodical approach to answering questions such as: Why acquire a FMS?, Which manufacturing applications are best served by FMS?, What requirements does a FMS place on the existing organization?, Who designs an FMS? and How is it done? The handbook was supplemented with a series of decision support computer software programs.

## **BENEFITS**

The benefits of using CAD/CAM method to produce precision spiral bevel gears are: elimination of the trial and error method, decrease in time needed to produce a gear, cost reduction and increased life of the gears. Eaton Corporation will be responsible for manufacturing and testing of production gears as part of Phase III. Eaton is very interested in using this process for commercial production of spiral bevel gears.

## **IMPLEMENTATION**

A movie has been made showing the CAD/CAM process in action and Battelle is in the process of completing the modeling work. Production type gears will be manufactured and tested as part of Phase III.

## **MORE INFORMATION**

To obtain more information contact Project Officer, D. Ostberg, AUTOVON 786-5814 or obtain a copy of the final technical report titled "CAD/CAM Techniques for Optimum Preform and Finish Forging of Spiral Bevel Gears", US Army Tank-Automotive Command, ATTN: AMSTA-RCKM, Warren, Michigan 48090.

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Summary report, Dec 84, was prepared by F. Stonestreet, 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 T80 5082 and T81 5082 titled "Flexible Machining Systems" were completed by the US Army Tank-Automotive Command in March 1984 at costs of \$907,400 and \$779,000.

**BACKGROUND**

Flexible Manufacturing Systems (FMS) offer a means to capitalize on the economics of mass production techniques without sacrificing all the flexibility inherent in general purpose stand alone equipment (see figure 1). FMS is a relatively new concept integrating three primary elements: work stations, material transport, and automatic control. Justifying, purchasing, and optimal operation of FMS presents unique problems not common to stand alone equipment. Significant up-front engineering is required to address the systems engineering and integration aspects.

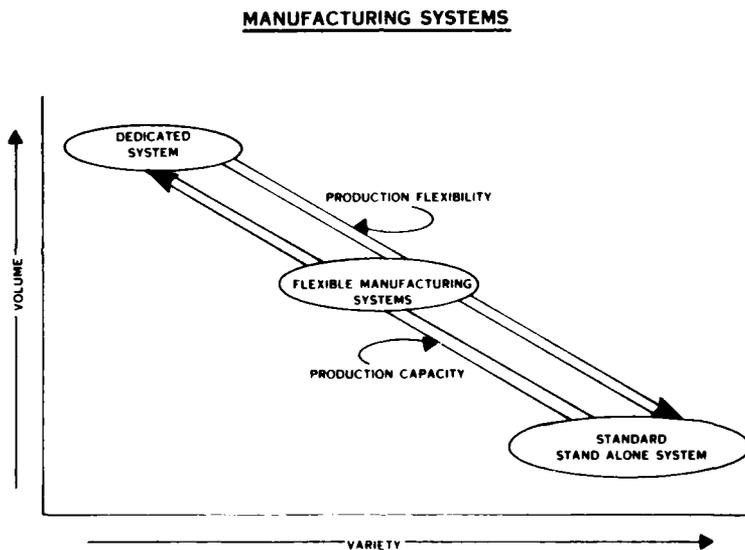


Figure 1 - Manufacturing Systems

**SUMMARY**

The objective of this program was to introduce high technology manufacturing systems into the Army's industrial base. The goal was to reduce the risks associated with implementation and operational feasibility by enhancing the understanding of FMS.

Working with a number of defense contractors, including Hughes Aircraft, FMC Corporation, General Electric Company, and Rock Island Arsenal, an FMS

Handbook was written. The handbook provides a methodical approach to answering questions such as: Why acquire a FMS?, Which manufacturing applications are best served by FMS?, What requirements does a FMS place on the existing organization?, and Who designs an FMS and how is it done? The handbook (see figure 2) was supplemented with a series of decision support computer software programs.

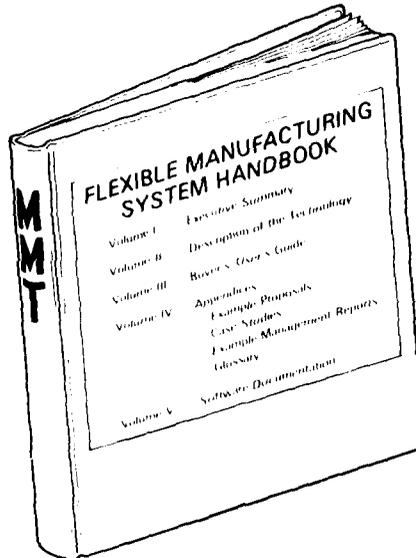


Figure 2 - Flexible Manufacturing System Handbook

The decision support software systems provide the FMS implementation team a tool for designing, evaluating, simulating, and optimizing an FMS. Issues such as scheduling priorities and identifying appropriate parts and tooling requirements including work stations, fixtures, material handling vehicles, tools, etc. can be assessed in light of constraints unique to a specified manufacturing installation. Software modules are also developed to address problem areas inherent to the operation of a FMS.

#### **BENEFITS**

FMS technology represents a relatively new strategy to increase productivity and is especially attractive to defense manufacturers. As a result of the program, application of the technology is taking place.

Over 600 copies of the handbook have been requested and distributed. The handbook is being used as reference material in university programs.

#### **IMPLEMENTATION**

Implementation is being pursued under two follow-on projects.

## **MORE INFORMATION**

A copy of the FMS Handbook is available from the Defense Technical Information Center; reference numbers A127927, A127928, A127929, A127930, and B073243 for Volumes I-V respectively. Additional information is available from Mr. Dave Pyrcce, US Army Tank-Automotive Command, AUTOVON 786-6722 or Commercial (313) 574-6722.

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

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

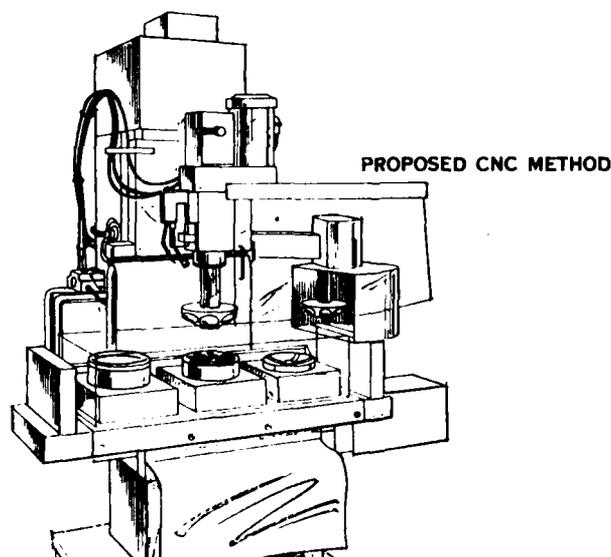
MMT Projects 678 7807 and 679 7807 titled "Programmed Optical Surfacing Equipment and Methodology" were completed by the US Army Armament, Munitions and Chemical Command in March 1983 at a cost of \$272,000.

**BACKGROUND**

Precision optics manufacturing is accomplished by the use of skilled optical technicians using the traditional grinding techniques to produce the final product. Using existing state-of-the-art equipment, a manufacturing system is being developed that will perform many of the tasks done by the technician and will lower set-up/process time by approximately 25 percent.

**SUMMARY**

The system is designated the Optical Surface Center/Computer Numerical Control System (OSC/CNC). The OSC/CNC consists of a BostoMatic 312 computer controlled machining center modified (as part of MMT Project 678 7807) by Boston Digital Corporation and the University of Rochester, figure 1 depicts the machine as modified. The in-house modifications were all aimed at mounting the three fabrication stations on the milling bed in a precisely controllable position which limit vibrations when the spindles are running. Grinding cups manufactured by Grit Tool Corporation are used for the rough and fine grinding operations. A Data General computer, the Eclipse S/140, will be used as an auxillary control computer and a 12.5 M6 Winchester fixed disc is used for storage. The software included with the Eclipse computer was an RDOS operating system, a MACRO assembler, a FORTRAN compiler, and a Linker/Loader program.



29 APRIL

Figure 1 - Programmed Optical Surfacing Equipment and Methodology

Operation of the OSC/CNC is simple once the position of the station spindles has been determined accurately. The operating procedure can be divided into three parts: initializing the part vectors, establishing communication with the BostoMatic and cycling the parts through the fabrication steps. The description of the parts (optical surfaces) that are to be fabricated are stored on the disk as part vectors. Once communication is established with the BostoMatic, the computer automatically cycles the blanks through the fabrication stage. After the machine finishes a part, it is tested in position.

The measuring system is an AC Fizeau interferometer which is mounted directly on the BostoMatic. Direct measurement of the part while still on the machine represents a hostile environment for interferometry. Vibration and focusing are the two greatest problems. The Fizeau interferometer was chosen because vibration efforts are minimized since both the reference beam and test beam travel together most of the time. By proper orientation of the focusing lens and reference beam, convex and concave optics can be measured with minimum vibration. The actual fabrication of the surface can be broken into several steps or cycles: machine travel time, rough grinding time, fine grinding time, polishing time, and testing time. The total cycle time is 21 minutes; however, about 15 minutes of that time is polishing time. Further work is being done to reduce polishing significantly.

#### **BENEFITS**

Upon completion of the effort, there will be a beneficial savings in set-up time, processing time, tool requirements, post-process inspection time, labor requirements and lower unit cost.

#### **IMPLEMENTATION**

Phase III of the effort (681 7807) begins with a demonstration of OSC/CNC system operation. Technicians will be trained in operation of system and documentation. At the conclusion of the effort, technology will be transferred to optical industry.

#### **MORE INFORMATION**

More information on effort 67X 7807 can be obtained by contacting Nathaniel Scott, Jr., AUTOVON 880-6945 or by obtaining the interim technical report titled "CNC Optical Surfacing Center" from the AMCCOM, Dover, NJ 07801.

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Summary report, Dec 84, was prepared by F. Stonestreet, 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 Q77 8053 titled "CAD/CAM of Parachute Hardware" was completed by the Natick Research and Development Center in October 1982 at a cost of \$218,000.

**BACKGROUND**

Most airdrop hardware, such as parachute and rigging components are produced as high strength steel forgings due to their special design and functional requirements. Currently forged airdrop hardware items are only produced by a limited number of manufacturers. These manufacturers are dependent on the availability of a few skilled die designers and die makers to produce the required master dies. These essential craftsmen are gradually retiring without documenting their art or passing their knowledge on to others. This has resulted in a critical situation affecting the future availability of sources for small forged airdrop hardware.

**SUMMARY**

The objectives of this project were twofold. First, to determine the feasibility of identifying and quantifying the steps used in the die design process. Second, to evaluate the feasibility of utilizing computer programs as an aid to design and manufacture master dies for small forged airdrop hardware. The underlying purpose was to advance the die design process from an art to a science.

Three tasks were performed:

- (1) determining die design rules and current practice via a literature survey and interviews with die designers;
- (2) identifying suitable modeling techniques so additional design rules can be developed and:
- (3) constructing a computer program capable of generating the necessary geometry of the various die cavities from the data on the engineering drawing, the given design rules, and the logical sequence used by the die designer.

Upon completion of these tasks, the following conclusions were made:

- (1) It is feasible to advance the design of dies for small forged components from an art to a science through identification and quantification of the steps used in the design process and to subsequently use the die design rules in noninteractive computer programs.

(2) Following a set of logical die design rules, using the Pascal computer language and the union of primitive shapes for representation of 3D objects. It was possible to generate the die impression geometries for an edger, flattener, blocker and finisher without interaction by a die designer.

(3) The preliminary computer programs are quite modular and may be easily expanded to adapt to additional primitive shapes and orientations.

(4) It is feasible to use the computer designed die impression geometries as the basis for computer aided manufacture of a master die on an NC machine.

(5) The CAD process is presently structured to require input from the user for the relative location of the die impressions across the die face, consistent with their forging shop layout and practices. However, the die impressions can be generated as isolated entities during the CAD process with their relative locations left to the individual forge shop during the CAM process.

(6) Due to variations in NC machines, the CAM program is structured to require inputs from the user of each given milling machine.

(7) After storing the part geometry, die design rules and machining practices in computer memory, an APT tape can be generated for the different impressions in the die block by inputting the part number of the particular "D-ring" desired.

(8) The set of test forging dies were successful as indicated by the quality of the finished forgings and also efficient in that only eight blows were required.

(9) The small forge shop has neither the time nor money to develop computer aided die design. However, they are willing to use computer assistance in die design and manufacturing if the system is "easy to use."

(10) Physical experimentation with interactive heuristic CAD of general objects and required preform shapes seemed to indicate that a rather large range of acceptable individual designs can be generated.

## **BENEFITS**

Operational feasibility of the developed CAD/CAM software was established.

## **IMPLEMENTATION**

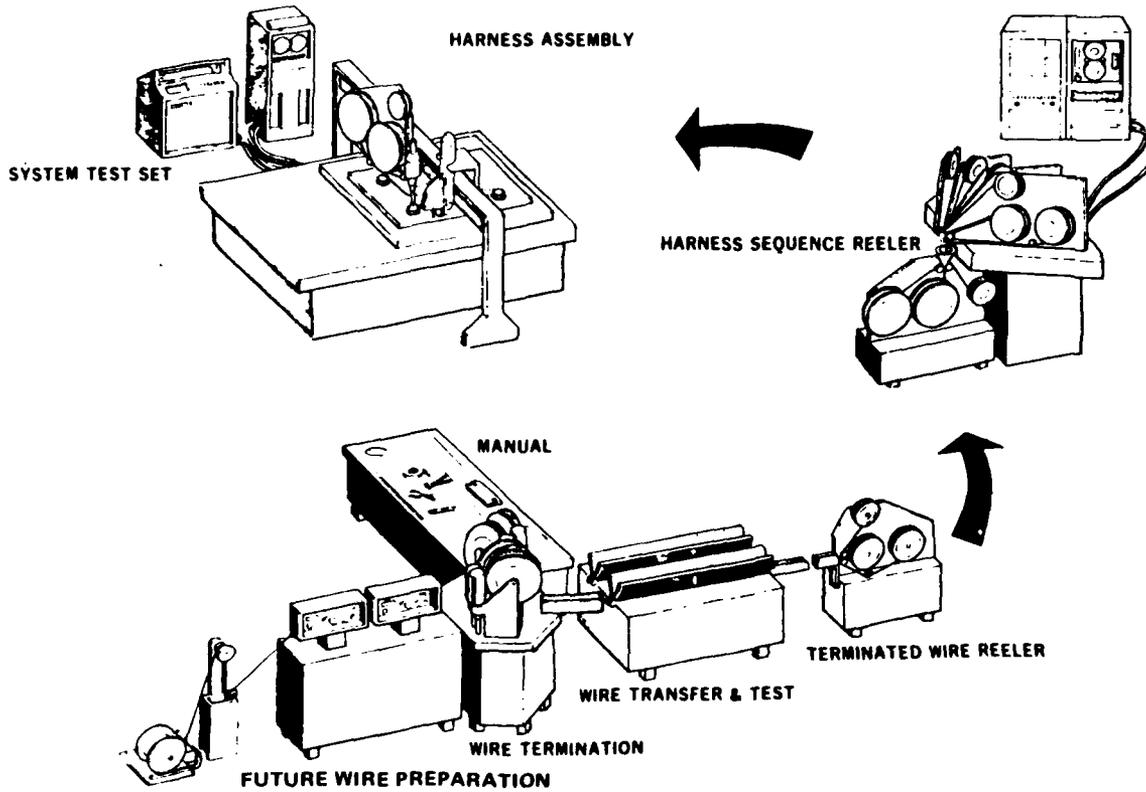
This project was not implemented due to intricacies of the APT language.

**MORE INFORMATION**

Additional information is available from Mr. Marshall Gustin, US Army Natick Research and Development Center, AUTOVON 256-5276 or Commercial (617) 651-5276.

Summary report, Dec 84, was prepared by J. Sullivan, 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 Project 277 9873 titled "Near Field Antenna Measurement System" was completed by the US Army Electronics Research and Development Command in July 1982 at a cost of \$719,400.

**BACKGROUND**

The standard method used in the measurement of antenna characteristics is to transport the antenna and beam steering control equipment to a high performance outdoor range (far field test). This can be a very expensive and time consuming operation. Such costs are particularly high for phased array radar systems where a large amount of information is required on each individual antenna in order to provide system calibration. A measurement technique called Near Field Probing has been developed to the point where it can provide an effective alternate to the far field measurement. The near field technique involves the sampling of the vector RF field on a periodic grid near the antenna radiating aperture. The data is then converted to a far field pattern by a mathematical algorithm equivalent to the actual creation of the far field pattern in space. The near field technique avoids many of the problems encountered when using the far field method.

**SUMMARY**

The purpose of this project was to develop an antenna pattern measuring system that is technically superior to and less costly than the traditional far field method. The near field measurement system satisfies these needs.

System Description

The near field probe (NFP) developed consists of a two axis x-y antenna probe positioner, an antenna mounting structure, a signal source, a phase amplitude detector and a computer display and control system. The system is entirely self sufficient. Special control devices for the antenna under test are required to perform a full measurement of all pertinent antenna parameters. The antenna mounting fixture, while designed primarily to support the AN/TPO-36 and AN/TPO-37 antennas, can readily be used on other antennas. Accurate position measurements in the x-y plane are made by a Hewlett-Packard laser interferometer. A frequency synthesizer (Hewlett-Packard 8672A) and network analyzer (Hewlett-Packard 8410) form the source and phase amplitude detector for the system. A Hewlett-Packard 1000 computer system and a 50 megabyte on-line disc provide control and data storage for the near field measuring system. Associated with the system is a CRT, electrostatic printing/plotting device and specially developed software. The block diagram depicts the basic layout of the system (figure 1).

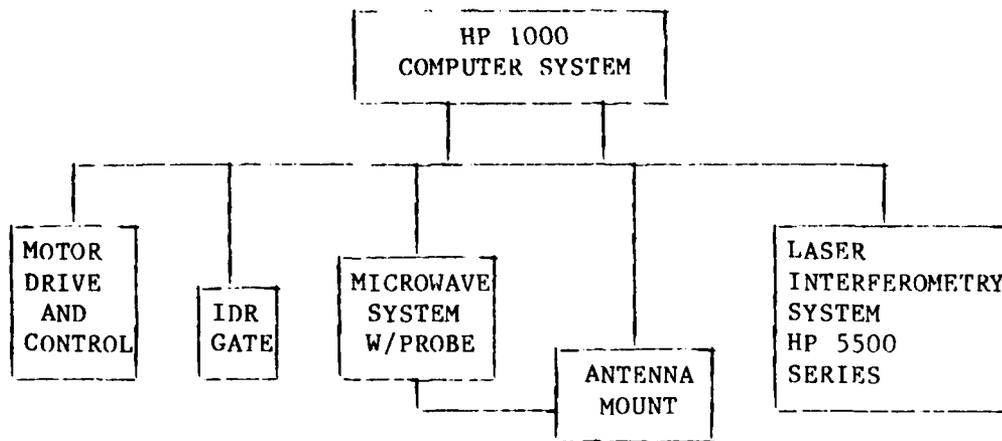


Figure 1 - Near Field Antenna Measurement System

### System Operation

The operation of the x-y positioner, including the laser interferometer, selection of the RF source frequency and recording and storing probe data is controlled by software subroutines. The system operates in two basic modes. One mode is normally used on either the AN/TPO-36 or AN/TPO-37 antennas using predetermined frequencies and beam positions. Basic parameters are already part of the program. The second mode of operation is for general use and all inputs can be varied by the operator. Measurement intervals are normally determined by the measurement frequency. After the entire data set has been acquired and stored, the analysis programs are initiated to produce the required output data.

Mechanical and electrical performance tests were done on the system. Mechanically the system met or exceeded expectations for all parameters affecting system accuracy. Electrical performance was determined statistically (in most cases) and independent of actual antenna operation. Actual near field and far field comparative testing was needed to verify electrical performance results.

### Near Field and Far Field Comparison

Under this study, two antennas, one at s-band and one at x-band, were to be measured and compared. Each antenna was measured at near field and far field to determine beam steering constants. The calculated Near Field Probe results give system beam steering constants which, when used in full system tests, gave performance as good or better than far field constants for the x-band system. For the s-band system, transfer of "absolute" position references has not been accomplished due to range geometry and alignment procedure differences. Near field beam position accuracy was estimated by comparing the calculated positions with theoretical positions expected from the beam steering commands used. The results were similar to the x-band results in their degree of accuracy.

## **BENEFITS**

The benefits are two-fold: the near field antenna measurement system is more cost effective because antennas can be tested at manufacturing sites. Secondly, the system can be used as a diagnostic tool, not only at production facility, but also at the Army depot level.

## **IMPLEMENTATION**

Negotiations are currently going on for the installation of the near field measurement system at the Sacramento Army Depot. The NF system is being used for diagnostic testing of the AN/TPQ-37 antenna in the FIREFINDER program.

## **MORE INFORMATION**

Additional information may be obtained by contracting Mr. John Borowick, HQ, US Army CS&TA Laboratory, AUTOVON 996-5143 or by obtaining a copy of the final technical report titled "Near Field Antenna Measurement System", contract DAAB07-77-C-0587-F1, ERADCOM, Ft. Monmouth, NJ 07703.

Summary report, Dec 84, was prepared by F. Stonestreet, 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 **F79 9938** titled "**LED Matrix Module**" was completed by the US Army Communications Research and Development Command in August 1984 at a cost of \$555,000.

**BACKGROUND**

The purpose of this program was to develop the manufacturing procedures for a flat dot matrix display panel. The specific application was a three color light emitting diode (LED) display module for the Tactical Display System (TDS). The TDS display was to be comprised of 288 individual display modules that were edge-abutted to form a 1 meter x 1 meter display. Each of the approximately 600,000 pixels in the display consists of a red and a green diode. Target production rate for the modules was 35 per 8 hour shift.

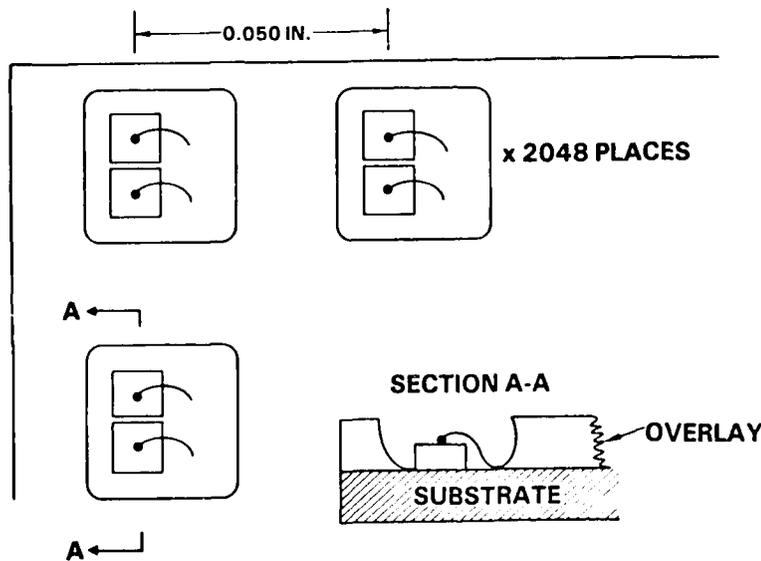


Figure 1 - LED Configuration

**SUMMARY**

The most difficult portion of this project was developing the means of placing the individual LED's on the substrate and performing the required interconnections as shown on the figure above. The problem was compounded by the sheer number of operations and the required accuracy (143,360 LEDs and wire connections were required in an 8 hour shift). These rates dictated a high rate pick and place machine. A FOTON machine with a peak rate of 6400 dies per hour was chosen. The LEDs are supplied on a 5" diameter loop and the FOTON machine picks the diodes from the loop and transfers them to the substrate. The diodes are placed one color at a time, i.e. the substrate is populated with the first color and then the sequence is repeated with the second color. Each color placement is on 0.050" centers and the color pairs have to be within 0.003 of each other over the entire 3.2" by 1.6" board.

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

MMT Project **R81 3445** titled "Precision Machining of Optical Components" was completed by the US Army Missile Command in March 1984 at a cost of \$637,000.

**BACKGROUND**

Due to the increasing DOD emphasis on electro-optical and laser material programs, the optics industry cannot keep up with demand, meet optical design requirements, or meet production schedules at a reasonable cost. Existing precision machining facilities are research and development oriented and are not compatible with production needs. The purpose of this effort (FY 79-\$300K, FY 80-\$400K, FY 81-\$637K) was to establish a commercial manufacturing base which will allow timely and cost-effective production of high energy laser and optical support items for Army systems. Particular emphasis was placed on aspheric elements up to 30 cm in diameter.

The following tasks were accomplished under the FY 79 and FY 80 programs.

1. Survey of capabilities and requirements.
2. Development of machine specifications:
3. Development of metrological specifications.
4. Development of facility specifications.
5. Selection and training personnel to operate precision diamond turning equipment:
6. Establishing manufacturing processes using an available single axis precision machine tool;
7. Establishing and checking out the facility to house the precision machinery;
8. Manufacturing a set of proof parts.

**SUMMARY**

The major objective of this effort was to integrate the single point diamond capabilities and interferometric aided computer control technology developed by ERDA into a production method for mirrors, lenses, and windows for laser, electro-optical, and missile systems applications. The goal of this project was to fabricate a machine capable of manufacturing optical components ranging in diameter from a few millimeters to 75 centimeters and weighing between a few grams up to 90 kilograms. A typical optical component is shown in figure 1.

temperature. The parts were machined and subsequently semiadditively plated to achieve the required surfaces or patterns. Subsequent testing of the completed parts indicated satisfactory performance.

The second part of this effort was to find a material/process system for producing multilayer cylindrical circuit boards. The material selected was a polyimide base double sided board with "one ounce" copper. The insulating sheet is 0.001 inch polyimide with 0.001 inch of acrylic on either side. The adhesive film used to bond the ends of the circuit board together is a modified acrylic film approximately 0.002 inches thick. The board is processed flat and then rolled and bonded into its circular configuration. Population of the board with components is from the inside with the leads emerging from the outer layer. An automated injection system is then used to apply solder paste to the leads and then the circuit is vapor phase soldered to complete the assembly process. Electrical and environmental tests were performed to assure that an acceptable unit was produced.

#### **ADVANTAGES**

The materials and processes for producing non-planar circuit boards have been established. Pilot equipment was used to produce samples that were subjected to electrical and environmental testing.

#### **IMPLEMENTATION**

This technology is available for implementation. The samples are being used to demonstrate capabilities available for future systems.

#### **FOR MORE INFORMATION**

Additional information may be obtained by contacting Mr. Robert Brown, US Army Missile Command, AUTOVON 746-8608 or Commercial (205) 876-8608. Also, a Final Technical Report titled "Manufacturing Methods and Technology for Non-Planar Printed Circuit Boards" has been prepared under contract DAH01-81-C-A777.

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Summary report, Dec 84, was prepared by H. Weidner, 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 3411 titled "Manufacture of Non-Planar Printed Circuit Boards" was completed by the US Army Missile Command in January 1984 at a cost of \$550,000.

**BACKGROUND**

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

**SUMMARY**

This is the final year of the 2 year effort to provide the processes and procedures required to produce non-planar circuit boards. Two configurations were used to demonstrate the results of this effort: a cassegrain antenna system and an eight layer cylindrical circuit board.

The antenna system consisted of four major types of components; a parabolic main reflector approximately 6 inches in diameter, a hyperbolic subreflector, a four port waveguide and a set of 1 inch diameter broad band spiral antennas (figure 1). All of the parts, except the waveguide, were injection molded from Mindel A-650. The primary difficulty in this molding was developing a process that would prevent phase separation of the material. The solution was to inject the melt slowly, and carefully control the mold

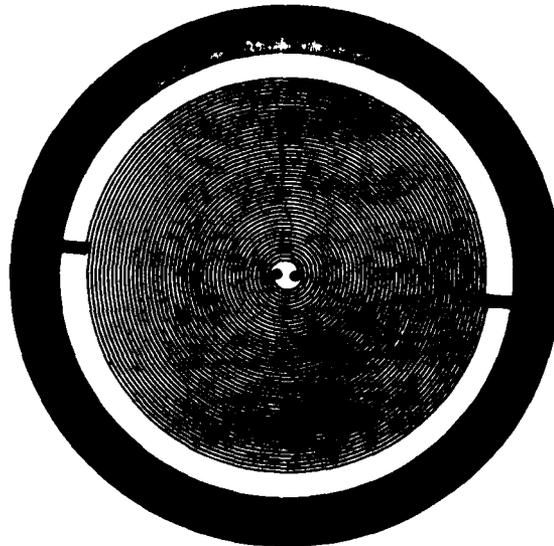


Figure 1 - Spiral Antenna Glass Negative

**MORE INFORMATION**

Additional information on this effort is contained in the Final Technical Report titled "Manufacturing Methods and Technology for Automatic Control of Plating" or may be obtained from Mr. Lloyd Woodham, MICOM, AUTOVON 746-4948.

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Summary report, Dec 84, was prepared by F. Stonestreet, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

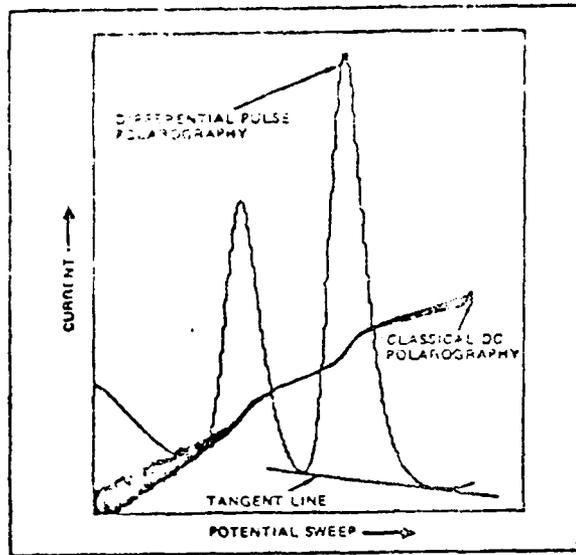


Figure 1 - Comparison of Differential Pulse and DC Polarograms

**BENEFITS**

The results of this project demonstrate that by developing an Automatic Monitoring and Control System (AMCS) that is versatile and maintains tight plating control, higher production rates, and lower cost can be obtained while improving quality.

**IMPLEMENTATION**

The following firms have indicated they are implementing the results of this project.

<u>COMPANY</u>	<u>LOCATION</u>	<u>YR. OF IMP.</u>	<u>SAVINGS OR POTENTIAL SAVINGS (MILLIONS OF DOLLARS)</u>
Digital Equipment Corp.	Greenville, SC	1984	9.3 after 10 years
Boeing Aerospace	Seattle, WA	1983	5.5 after 10 years
Economic Lab	Minnesota	1984	No Data
General Dynamics	Pomona, CA	1984	.67 after 10 years
Hughes	California	1984	No Data
Westinghouse	Baltimore, MD	1984	1.8 - 1984-1987
Ronald P. Wong	Chicago, IL	1984	No Data

**MANUFACTURING METHODS AND TECHNOLOGY  
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MMT Project 379 3268 titled "Automatic Control of Plating" was completed in September 1982 at a cost of \$450,000.

**BACKGROUND**

Plating processes for Printed Wiring Boards (PWB's) utilize a large variety of chemical solutions. For optimum results, these solutions must be maintained at uniform chemical compositions. In a typical PWB manufacturing facility, a major effort is expended in obtaining representative samples of these solutions, chemically analyzing them, computing the required additions, and making these additions in a reliable manner. This entire process is costly, prone to error, and not sufficiently time responsive for some key solutions whose composition changes very rapidly during use.

**SUMMARY**

The objective of this project was to improve printed wiring board yield and reliability by implementing a computer controlled process of automatic solution monitoring and control system. In addition, the developed monitoring and control technology is intended to be sufficiently versatile so as to apply to virtually any solution used for PWB processing. The results of this effort produced an automatic controlled plating system by integrating sensing devices with computer control. This system is currently being used by General Dynamics Corporation of Pomona, California. General Dynamics is involved in plating printed circuit board assemblies which are used in missile guidance systems.

The process control system includes a desk top computer, a controller/sequencer, and the polarographic analyzer. The integration of these components was designed to function in the following manner. The computer will direct all phases of the sensing and control system, handling each solution in a sequential pattern. First, sampling of each solution will be initiated so that a representative sample will flow into the sensing system along with any appropriate diluents and/or reagents. Then an analysis will be initiated and the results computed and stored in memory. Figure 1 represents the results one would obtain using the differential pulse polarographic method. These results will be compared against set point values which correspond to the optimum concentrations of the solution's constituents. Any deviation will trigger the appropriate metering pump so that replenishing can occur. The degree of adjustment will be fully regulated by computer algorithms to minimize over shoot. These steps continue until the controller/sequencer activates the pump of a specified period of time, at which time the cycle is completed.

solder joint cracking. Shock test results revealed that 20 lead packages survived the 10,000g shock level, however, eighty-four lead packages could only sustain a 3,500g shock level without failure. Acceleration tests demonstrated that 20/50, 20/40 and 44/50 LCCs sustained no damage after the 30,000g acceleration test level. Identically mounted 84/50 and 84/40 LCCs sustained damage after 30,000g and 25,000g but survived the 20,000g level. Undercoated and non-undercoated 84/50 LCCs survived over 400 thermal cycles without any solder joint cracking.

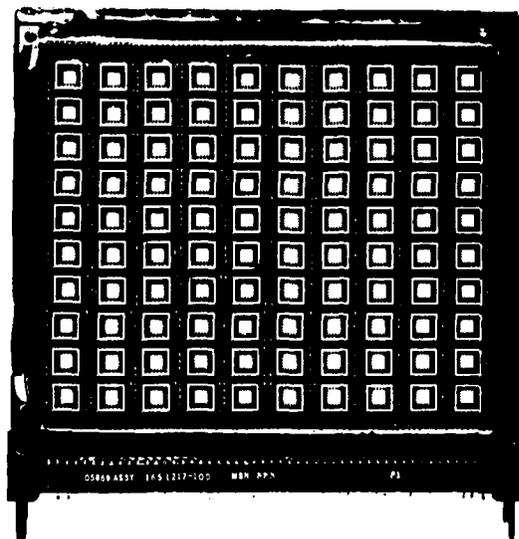


Figure 2 - Typical Test Assembly with 20 Lead Packages

#### **BENEFITS**

This effort was successful in significantly improving reliability for LCCs attached to PCBs. Survival life of the LCC solder joints was greatly enhanced.

#### **IMPLEMENTATION**

The results of this effort have been implemented into the Hughes Air Defense Radar (HADR) and Hughes Improved Terminal (HIT). Also, the technology is expected to be implemented into the Attenuated Side Lobe Canceller (ASLC). Also, the Advance Medium Range Air to Air Missile System (AMRAAM), Position Locating and Recording System (PLRS) and Enhanced Modular Signal Processor (EMSP) are planning to use leadless chip carriers.

#### **MORE INFORMATION**

Additional information may be obtained from Mr. Paul Wanko, MICOM, Redstone Arsenal, AL, AUTOVON 746-5619 or Commercial (205) 876-5619.

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

Solder pastes from several manufacturers were evaluated in percent solid content, oxidation resistance and screenability tests. Additionally, particle shape and size, flux activity and paste flux content were examined. Results indicated that Cermalloy, ESL and DuPont solder pastes exhibited superior characteristics to those of other manufacturers. Cermalloy Sn62 was selected and for consistency used throughout the effort.

Several adhesives for bonding PCB to TMP were evaluated. Abelfilm 504 Adhesive was chosen because of its low curing temperature, ease of application, high thermal conductivity and ability to reduce warpage in the bonded assembly. Castall 301 AD, an alumina filled epoxy, was selected for the thermal gap compound (undercoat) due to its low viscosity and high thermal conductivity. Low viscosity was necessary for injecting the thermal undercoat into the gap between LCC and PCB.

Nickel plated copper, copper clad molybdenum and copper clad Invar were candidate materials for the TMP. Material evaluation was based on TCE, thermal conductivity, weight, modulus of elasticity, fabricability, availability and cost. Copper clad Invar best met the required criteria and was selected for the TMP material.

Phase II was primarily concerned with process improvement. Printing parameters for solder pastes from Phase I were optimized with both manual and screen printers. An 80 mesh 90 degree stainless steel screen constructed from 0.001 inch diameter wire with an emulsion thickness of 0.001 inch produced highest quality solder prints for LCC attachment.

Both vapor phase soldering and wave soldering were examined for attaching LCCs to printed circuit boards. Vapor phase soldering offered several important advantages and was selected over the wave solder method. These advantages included minimized oxidation during soldering, reduced component overheating, lowered thermal stresses, and improved component placement by self-alignment during soldering.

An improved technique for injecting thermal undercoat into the air gap between LCC and PCB after soldering was also devised.

Thermal mounting plate bonding to the PCB was recommended after vapor phase soldering because it was compatible with the thermal injection process. It also allowed a wider variety of adhesives to be used.

Phase III was concerned with environmental testing. Tests were conducted on fifty-eight PCBs assembled with leadless chip carriers of 20/40 (20 lead/40 mil centerline) to 8<sup>1</sup>/<sub>40</sub> sizes. Test PCBs were approximately 5" x 5" in size. A typical test assembly with 20 lead packages is shown in figure 2. Boards fabricated from the materials selected in Phase I and assembled in accordance with processes developed in Phase II were tested in humidity, vibration, and thermal cycling in accordance with MIL-STD-202E, whereas acceleration and mechanical shock testing conformed to MIL-STD-883 Condition E.

PCBs subjected to humidity testing showed no corrosion or any form of degradation. All PCBs with one exception passed vibration testing. The exception was found in the 84/50 LCCs without the undercoat, which exhibited

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MMT Projects 380 3263 and 381 3263 titled "Printed Wiring Boards Utilizing Leadless Components" were completed by the US Army Missile Command in June 1984 at a cost of \$250,000 and \$400,000, respectively.

**BACKGROUND**

Leadless chip carriers (LCC's) are used in the electronics industry to increase component density, improve electrical performance and reduce assembly costs.

When the LCC is directly attached to a printed circuit board (PCB), solder acts as both the electrical and mechanical connection. Since LCC's are devoid of leads, mismatch between Coefficients of Thermal Expansion (CTE) for LCC and PCB results in solder joint stress during thermal cycling. This condition leads subsequently to fatigue, and ultimately joint failure.

Primary emphasis by industry has been to extend fatigue life by minimizing the CTE difference between LCC and PCB. CTE control, critical to reliable LCC use on printed circuit boards, is achieved by selection of materials and by the composite PCB structure. The most successful approach is to use standard PCB materials but to add a core thermal mounting plate (TMP) to the module for restraining expansion and providing an appropriate CTE at the module surface. A conceptual sketch of a composite LCC/PCB interconnection system is shown in figure 1.

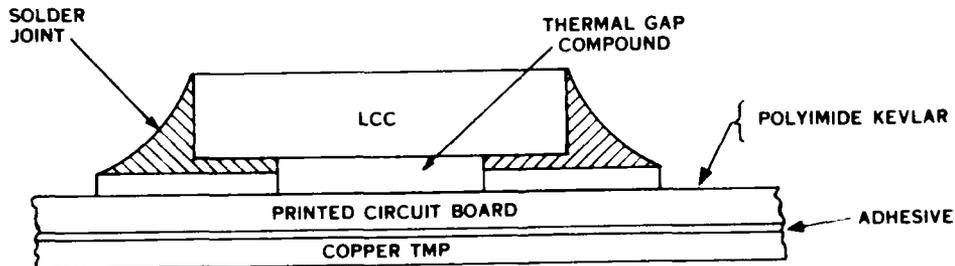


Figure 1 - Sectional View of a Simplified LCC/PCB Interconnection System

**SUMMARY**

This effort's objective was to establish optimum materials and processes for direct LCC attachment to PCBs. Work was divided into three phases and contracted to Hughes Aircraft Company, Fullerton, CA and Microelectronics Corporation, Auburn, AL.

Phase I comprised material evaluation and selection. PCB substrate materials evaluated included epoxy-glass (FR-4), polyimide-glass and a modified polyimide/Kevlar. Physical property examination and electrical tests on the modified polyimide/Kevlar laminate demonstrated its superiority for direct LCC attachment and it was chosen as the PCB material.

H-3010 MMW Sources for 60 and 94 GHz  
H-3011 Indium Phosphide Gunn Diodes  
H-5041 MMW Mixers and Arrays  
H-5232 Low Cost MMW Ferrite Circulators  
H-5187 Tunable MMW InP Gunn Sources  
H-5234 MMW Three Terminal Devices  
H-6009 Integrated Hybrid 94 GHz Transceiver  
3-1131 Integrated 94 GHz Submunition Transceiver

## **BENEFITS**

The significant quantifiable benefits are summarized as follows:

- 37 percent parts count reduction.
- 15 percent volume reduction.
- 53 percent weight reduction.
- 60 percent unit production cost reduction.
- Performance - uncompromised to the Baseline Requirements.

## **IMPLEMENTATION**

An implementation plan (Report No. SJ-240-36038-2) was developed to document the proposed program approach. The intent of this document was to propose a detailed plan for the MMT program methodology and for the implementation of the benefits derived. This implementation plan was modified to represent the pilot production phase of this program.

The implementation of this MMT study program was planned to take place in three phases. These phases being the study phase, the functional validation phase using simulated tools and equipment, and the full scale production phase with the required hard tooling and equipment investment. The object or goal of all three phases being the development of cost effective concepts and approaches geared to high volume production in lot sizes of 200/400/800 Assault Breaker seekers per month.

## **MORE INFORMATION**

Additional information may be obtained by contacting Mr. August Green, MICOM, AUTOVON 746-1728 or Commercial (205) 876-1728. A presentation of the results of this effort was made to the ninth DARPA/Tri-Service Millimeter Wave Conference, October 1981. The technical report number is SJ8411-36052-1. The contract number is DAAH01-81-C-B239.

Summary report, Dec 84, was prepared by D. Richardson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

Equipment specifications were generated, tooling defined and facility requirements established for high production quantities. The details of each stage of design maturity is reflected in the technical data packages. This preliminary documentation was further developed and refined during the prototype and pilot production build, and validated so as to demonstrate the capability of producing millimeter seekers at the given production rates.

Specific studies undertaken were selected from the list of cost drivers developed. An MMT Study Log was initiated and published periodically to give status visibility to the studies. Regular progress review meetings were scheduled to ensure that all proposed approaches received proper evaluation. Each study initiated was reviewed at each meeting to ensure that the best approaches and candidates for success received the highest priority. At the conclusion of the research and development stage of each study, the cost of each approach was compiled. These costs were analyzed, cost trade-off studies performed, and make or buy decisions made. The best choices were then given a final review and incorporated into the new design concept.

The most significant technical achievements accomplished in the performance of this program are summarized as follows:

- Performance versus cost analysis of the RF componentry leading to a least cost baseline system.
- The extensive material analysis and laboratory effort associated with selecting antenna materials compatible with performance and permitting injection molding.
- The implementation of fine line processes to produce precise fine line parts required to meet VSWR measurements of the antenna.
- The design, development and manufacture of three automatic test stations for the acceptance test of the RF front end assembly which substantially reduces expected test time by a factor of 18 to 1 (Baseline to Unit Production Cost Goal).
- The demonstration that MMW antennas can be assembled with the focus built in.
- Using wire EDM as the machining process to achieve the close tolerance required for the bore of the Conscan Motor Shaft.
- Developing a procedure and identification of a strobe light fixture to locate and ensure the zero positioning by phase of the Conscan Motors.

A number of recommendations were made by Sperry Gyroscope concerning tasks to be accomplished before any attempt at LRIP is made. One of those tasks, the establishment of a cryogenic-noise standard in the 75-110 GHz range has been completed by the National Bureau of Standards. Some others are the subject of on-going MMT efforts. Army MMT efforts addressing MMW seeker component work are:

of separable subassemblies. This modular design has reduced the parts count, volume, and weight which is considered to be of prime importance in both the manufacturing cycle and missile applications.

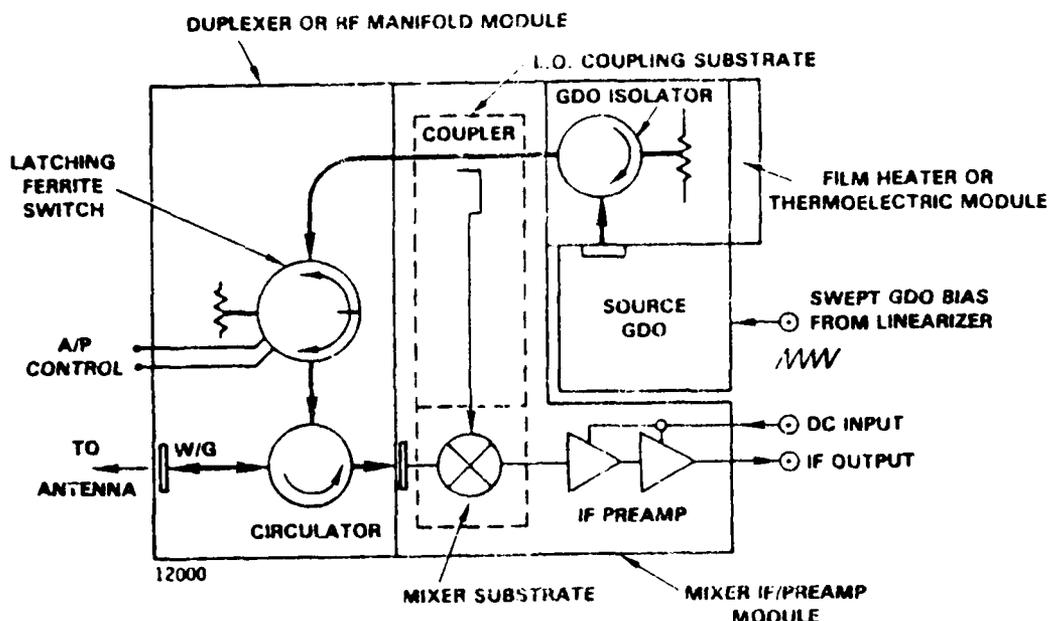


Figure 2 - Integrated RF Production Base Configuration

#### SUMMARY

Sperry Gyroscope made a thorough technical review of the Assault Breaker Phase Two design package considered to be the Base-line MMW Front End Section. Trade studies were undertaken in search for cost benefits in terms of: manufacturing processes, assembly techniques, inspection techniques, configuration, and test procedures.

The second phase of the program implemented the producibility improvements delineated in the first phase and demonstrated the effectiveness in manufacturing five pilot production line units. Assessments were performed during and at the conclusion of this program to determine what achievements were gained in the conduct of this MMT Program.

During the basic effort of this MMT study, technical data packages were developed for the various approaches. These technical data packages contained detailed documentation of candidate approaches, results of experimentation, conclusions, and recommended action. Basic process input drawings, and sketches become part of this technical data package. The state-of-the-art was researched to optimize the processes established.

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MMT Projects R80 3139 and 381 3139 titled "Production Methods for Millimeter Seekers for Terminal Homing Applications" were completed by the US Army Missile Command in March 1984 at costs of \$415,000 and \$1,300,000 respectively.

**BACKGROUND**

During the past several years, the requirement for improved weapon system performance in adverse weather and battlefield obscurants has led to a major development effort within DOD to implement millimeter wave (MMW) technologies. There have been many efforts to move the use of MMW technology from the research laboratory to anticipated uses in the battlefield. One major alternative implementation was the Assault Breaker class of terminally guided submissiles in the 90 to 100 GHz band (figure 1). The RF front end assembly is the primary cost driver of that MMW system.



Figure 1 - Assault Breaker Submissile Seeker

This effort was one of the first undertaken to reduce the cost of the RF source/isolator, mixer IF/preamplifier and duplexer (figure 2) at the seeker assembly level. It concerns the practical near term approach to fully integrate the major elements of the RF front end into a single assembly comprised

The FOTON machine can operate at rates of up to 6400 die placements per hour. In order for this rate to be achieved, however, it is necessary for the dies to be accurately placed on the tape received from the vendor. Large deviations (but within lock-on capability) in die placement on the tape can slow the machine to 3000 dies/hour. If lock-on is lost then manual intervention is required and the shutdown is serious. A reliable die present sensor is a necessity since attempting to place a die with none present will foul the placement tool with epoxy requiring a machine shutdown for cleaning. A Hughes 2460 automatic wire bonder was used for making the electrical contacts to the previously placed diodes. This machine can bond at a peak rate of 4 wires/second with a realistic sustained rate of 2 wires/second. The operator manually makes the first red and green connection. Then an automatic step and repeat sequence completes the board.

### **BENEFITS**

This program set up and demonstrated a manufacturing capability for producing multicolor LED panels. The size of each panel is 1.6" x 3.2" and they are edge abutable for constructing larger panels. The pixel (individual diode pair) pitch is 0.050" and three colors can be produced (red, green, and amber). Test exerciser equipment was also developed as part of this project to provide semiautomated testing for the finished panels.

### **IMPLEMENTATION**

The results of this project will not be implemented on the Arrays Tactical Display System due to phasing out of the system. Other services, however, will implement this technology for the Universal Display and Control System (a 144 x 288 green display), the hand held terminal (a 144 x 96 red display) and the cockpit displays for the S-3A viking (4 green modules of 45 x 121 diodes each).

### **MORE INFORMATION**

Additional information is contained in a final report titled "MM&T Program for Three Color Light Emitting Diode Display Modules", contract number DAAK80-80-C-0566. The Communications Electronics Command project engineer is Mr. Robert Miller, AUTOVON 995-4144 or Commercial (201) 544-2825.

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Summary report, Dec 84, was prepared by H. Weidner. Manufacturing Technology Div., US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

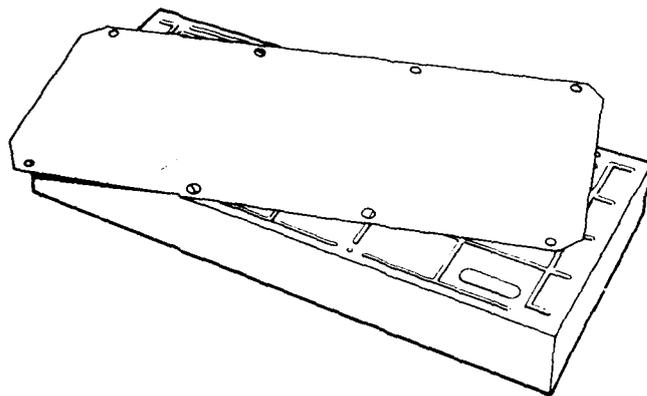


Figure 1 - Part and Fixture for Fly Cutting Very Thin, Flat Sheet Mirror

The diamond turning equipment depicted in figure 2 was built. The machine features an in-process metrology capability.



Figure 2 - Multi-Axis Precision Diamond Turning Machine

#### **BENEFITS**

A commercial manufacturing base capable of producing finished aspheric surfaces in a timely, cost effective, manner was established. Experience with this machine will provide input to the design of the next generation configuration incorporating a higher level of automation and remote-controlled machine settings with computerized feedback loops.

#### **IMPLEMENTATION**

This machine tool is being used full time in the production of a variety of precision surfaced components at IntOp Division of Kollmorgen.

**MORE INFORMATION**

For additional information on this equipment, contact Mr. W. A. Friday, MICOM, AUTOVON 746-8611 or Commercial (205) 876-8611.

Summary report, Dec 84, was prepared by J. Sullivan, 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 H81 3031 titled "10.6 Micrometer Carbon Dioxide TEA Lasers" was completed by the US Army Electronics Research and Development Command in June 1983 at a cost of \$550,000.

**BACKGROUND**

The 10.6 micron pulsed carbon dioxide (CO<sub>2</sub>) Transversely Excited Atmospheric (TEA) laser provides improved propagation characteristics and is eye-safe. The pulsed CO<sub>2</sub> TEA laser has direct application in Army rangefinder applications. Its modular construction insures integration with existing Thermal Imaging Subsystems (TIS) utilized in the M-1 tank, Remotely Piloted Vehicle (RPV) and High Survivability Vehicles (HSVs).

This MMT effort concentrated exclusively on the laser transmitter tube. Electrical pulsers and power forming networks (PFNs) were scheduled under a separate program. Existing methods permitted CO<sub>2</sub> TEA laser tube fabrication only in single unit quantities. Manufacturing techniques available for large scale production were required.

**SUMMARY**

Raytheon Company at Sudbury, MA, established the manufacturing processes for a laser transmitter tube used in armored vehicle, infrared rangefinder equipments. Major laser tube components consisted of an alumina (fired ceramic) laser body, two main discharge copper electrodes, a single row alumina sparkboard preionizer, laser mirror and mount, and ZnSe output coupler. Major MMT TEA laser tube components are shown in figure 1.

Laser tube overall dimensions were dictated by the M-1 tank laser rangefinder packaging requirements. Maximum tube length allowed was 7.25 inches with a cross section 2.25 inches high by 1.88 inches wide. Figure 2 shows the ceramic laser tube assembly prior to furnace braze.

Discharge copper electrode contour was precisely controlled to insure a uniform glow discharge without arcs during pulsing. Copper electrode parallelism was maintained with less than 200 microns deviation in gap spacing along the discharge length. Mirror parallelism was maintained within 4 arc seconds.

A noninert gas mixture of 15% CO<sub>2</sub>, 11% N<sub>2</sub>, 4% CO, 0.7% H<sub>2</sub> and 69.3% helium was selected to fill the tube at a pressure of 1 atmosphere rather than high vacuum. This mixture permitted sufficiently rapid recombination to allow continuous pulsing at the 1 Hz repetition rate without deterioration. A gas fill station was constructed, fill processes established, and gas chromatography installed on-line to quantitatively evaluate the gas mixture.

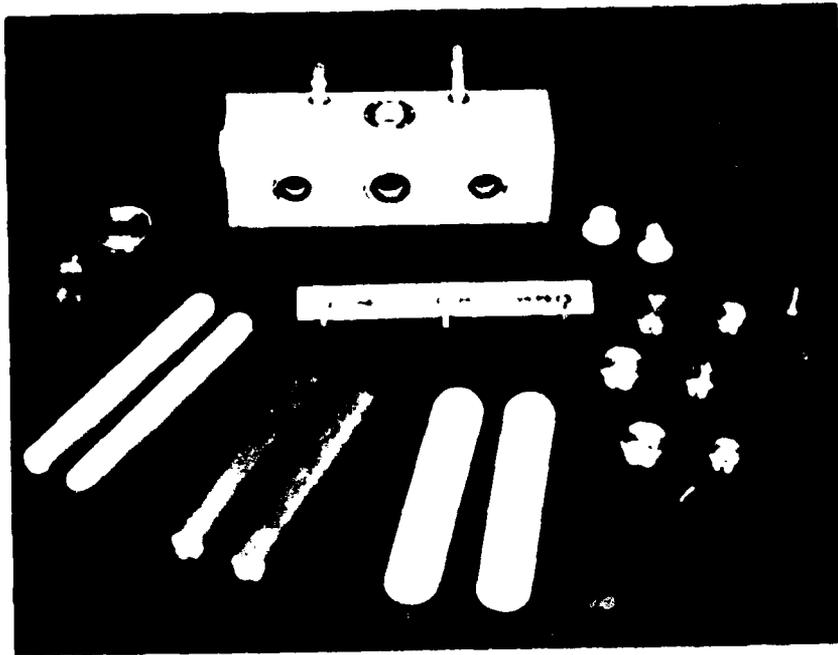


Figure 1 - Transversely Excited Atmospheric Laser Tube Components

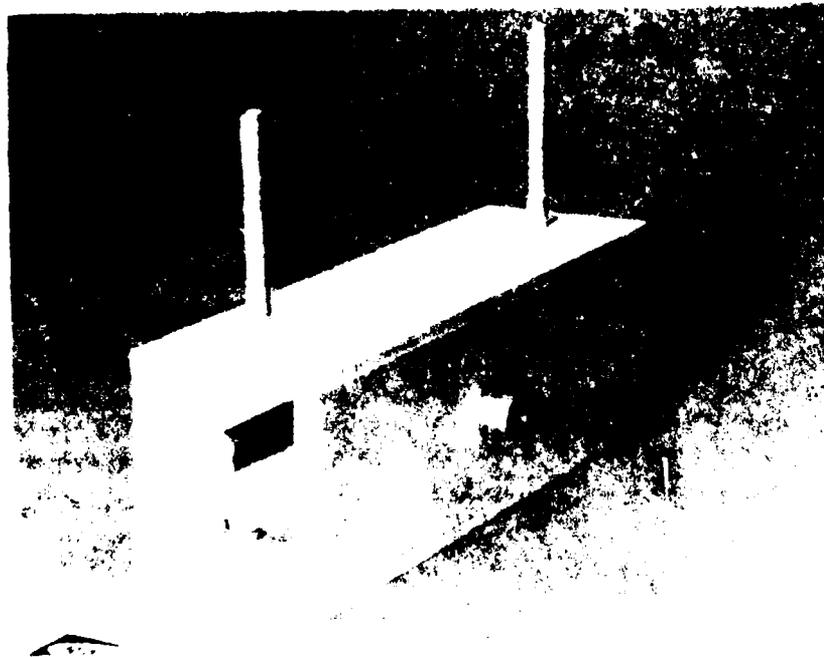


Figure 2 - Ceramic Laser Tube Assembly

Facilities utilized for tube manufacturing included high temperature reducing atmosphere furnaces for firing ceramic greenware, metalizing the alumina, and brazing the components together in specially designed fixtures. Since the ZnSe coupler could not be fired at high temperature without damage, a low temperature vacuum SnAg soldering technique was devised for attaching coupler to laser body assembly. Process optimized for production included sputter metalization, plating, brazing, electrical discharge machining (EDM), vacuum soldering, heliarc welding, vacuum bakeout, back-fill and pinch-off.

Optical alignment and performance testing was completed with calibrated pulse energy and fast response power detectors which evaluated laser output. Specific energy measuring equipment included a Gentec Model ED 2000 pyroelectric detector which was periodically calibrated with a Scientech Model 38-0102 joulemeter. A Rafin Model 7441 photon drag detector measured laser peak power and pulse shape.

The contract was terminated at the end of engineering sample phase when advancements in the CO<sub>2</sub> TEA laser area made this tube obsolete.

#### **BENEFITS**

Independent laser technology advancements including eliminating the need for a ceramic tube housing and corona preionizer technology deleted the benefits initially anticipated from this effort. However, the ceramics work and optics hard seal developed in this effort are noteworthy and transferable to other laser designs.

#### **IMPLEMENTATION**

Laser transmitter tube was not implemented due to significant industry improvements in CO<sub>2</sub> TEA laser design and performance. A concurrent laser rangefinder requirements change which necessitated higher tube power output, also precluded tube usage.

#### **MORE INFORMATION**

Additional information may be obtained from Mr. David N. Spector, Night Vision and Electro-Optics Laboratory, Ft. Belvoir, VA, AUTOVON 354-1424 or Commercial (203) 664-1424.

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Summary report, Dec 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 H80 9563 titled "Miniature High Voltage Power Supply for Image Intensifiers" was completed by the US Army Electronics Research and Development Command in August 1984 at a cost of \$409,000.

**BACKGROUND**

The purpose of this project was to develop the manufacturing processes and procedures for producing third generation power supplies for night vision systems.

This miniature high voltage power supply is approximately one half the volume of the previous generation. It must supply up to 7000 volts output while maintaining stringent safety and reliability requirements. Because of the packaging density and resulting high voltage gradients and insulation resistance requirements, the current manufacturing methods are inadequate.

**SUMMARY**

The single most important and most difficult obstacle to the accomplishment of the program objective was the very small physical package configuration. This factor was the primary driver in all design decisions and trade-off considerations. The project consisted of delivering power supplies in four submissions: first and second engineering samples, confirmatory samples and a pilot production run.

The first engineering sample was very similar to the current production units. Fifteen of these were produced and tested to provide as a baseline for subsequent submissions. Many mechanical and electrical performance problems were identified during this phase of the effort. The goal of the second engineering submission was to develop the final production design (see figure 1). It was to optimize the mechanical design for producibility and the electrical design for reliability. Modifications to the transformer regulator, and voltage multiplier section were implemented to improve performance under adverse environmental conditions. Significant improvements in the packaging area provided better fits and a more easily assembled power supply.

A pilot run of 100 power supplies was used to establish the pilot line and to identify any remaining problems. Most in-process problems were related to various types of lead breakage. The extremely small size of the power supply necessitated the use of small and fragile components and leads and there is little margin for error in component placement and lead dress. The conclusion was that these problems can only be solved by intensive training of the assembly and inspection personnel. Subsequent quality conformance testing of these units indicated no discrepancies related to the power supplies.

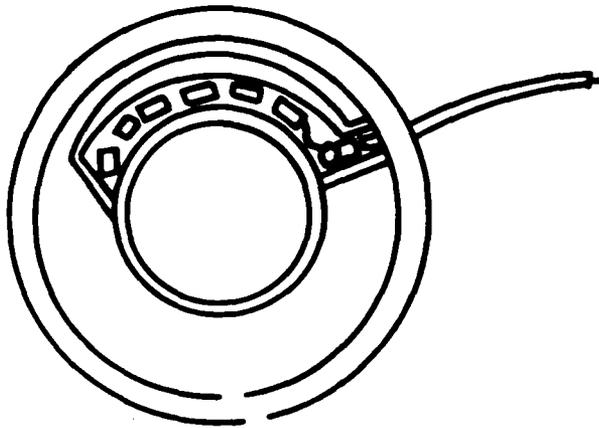


Figure 1 - Extended Circuit Board Design

### **BENEFITS**

The most significant accomplishments contributing to improved performance and producibility of the power supplies involved the respecification and redesign of components such as capacitor banks, diode banks, transformer cores and bobbins, hybrid circuits and voltage multipliers.

Implementation of these improvements resulted in input current reductions and elimination of the start-up problem. The mechanical aspects significantly reduced the difficulty of assembly while maintaining performance. Labor content was reduced and product yields were improved.

### **IMPLEMENTATION**

The results of this effort have been implemented into the K and M Electronics production line.

### **MORE INFORMATION**

Additional information is available in the project final report titled "Manufacturing Methods and Technologies for Miniature High Voltage ANVIS Power Supplies", contract no. DAAK70-80-C-0120 or from the project engineer, Mr. Joseph L. Evans, Jr., AUTOVON 354-1551 or Commercial (703) 664-5724

Summary report, Dec 84, was prepared by Hal 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 Project H77 9754 titled "Continuous Cycle Processing of Shock Resistant Crystal Units (Phase II)" was completed by the US Army Electronics Research and Development Command in March 1984 at a cost of \$2,094,000.

**BACKGROUND**

This project was a follow-on effort to establish a pilot line for shock resistant 22 MHz AT-cut quartz crystals. The Phase I task was primarily to build a five chamber interconnected vacuum system capable of cleaning, plating and sealing precision quartz crystal units in ceramic flatpacks.

This Phase II effort was funded for prove-in and qualification of the Phase I hardware. Work for both phases was performed at a government owned, contractor operated facility, General Electric Neutron Devices (GEND), a contractor for the US Department of Energy. The crystals were required for use in evolving systems such as REMBASS, GPS, SCOTT and CIS/BIFF.

**SUMMARY**

This effort's work scope required a pilot line build of 700 crystals using the ultravacuum quartz crystal fabrication facility (QXFF) hardware constructed under the previous phase. The vacuum hardware system is shown in figure 1. Its five chambers (entrance, bake, plate, seal, and exit) are separated from each other by gate valves. Entrance and exit chambers permit the processing chambers to operate at high vacuum for extended times. The combined vacuum length was optimized at 24 feet.

Activities were added for processes occurring before entry and after exit from the vacuum system. Processes added before entry included incoming inspection, ceramic processing, piece part cleaning, contact evaporation, blank-frame assembly, and gasket attachment. Tasks added after exiting from the vacuum system were leak testing, performance and environmental tests including frequency vs temperature, shock, and aging.

Shortly after the engineering sample run, a change in REMBASS requirements eliminated the crystal high shock requirements. This resulted in replacing the natural quartz crystal material with premium Q cultured quartz.

Figure 2 shows the crystal with contacts mounted in a ceramic flatpack. The crystal was bonded to four molybdenum clips using a silver filled polyimide. The polyimide provides both conduction and a strong bonding material with minimum outgassing in a precision vacuum QXFF. Minimal outgassing reduces aging in the finished unit. A fixture was also developed to assist with the assembly. Finished subassemblies were stored in an argon atmosphere until scheduled for final assembly in the QXFF.

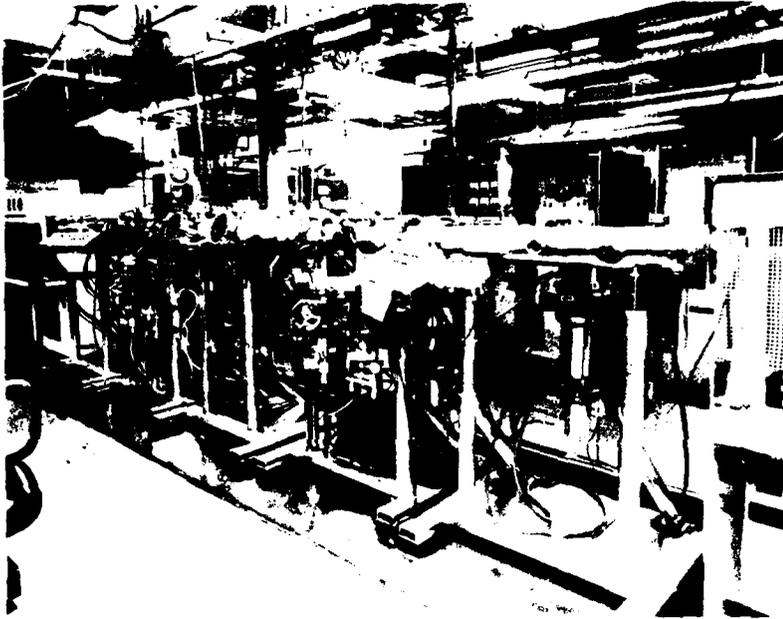


Figure 1 - Vacuum Hardware System

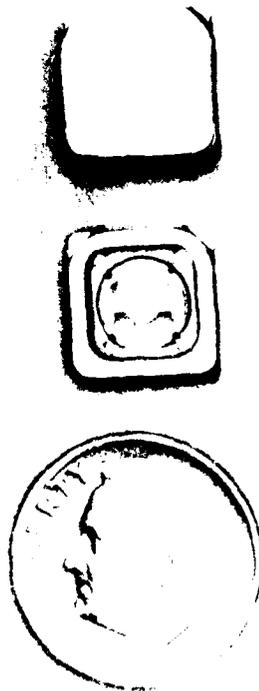


Figure 2 - Crystal with Contacts Mounted in a Ceramic Flatpack

Several modifications to the QXFF were determined necessary before continuous processing was possible. Major improvements and changes included the following:

1. Electrical solenoids that actuated the vapor beam shutter and contacts were replaced with small pneumatic cylinders to permit more reliable frequency monitoring.
2. Signal leads were superseded with coaxial cable and shielded feed-throughs to preclude erratic signals on the plating console.
3. New masks were designed and built having larger contact pins. This avoided no signal contact problems at rough evaporations.
4. An electrical interlock was added to open the contacts when the manipulator is moved from neutral. This eliminated bent contact pins resulting from loading crystals into the mask while contacts are closed.
5. Four-layer molybdenum shields were replaced by five-layer tungsten shields to prevent plating sources from heating crystals out of specification.

The minimum required pilot line quantity of 700 was exceeded when 736 valid flatpack crystals were processed through the QXFF with no major problems.

#### **BENEFITS**

This project established a complete production capability for 22 MHz precision quartz crystals in sealed ceramic flatpacks. Prior to this effort, no production capability existed for these devices. Also the Department of Energy has duplicated the QXFF and utilized the technology demonstrated, in order to meet a critical nuclear weapons related need.

#### **IMPLEMENTATION**

Follow-on project H79 9807, Phase III now in progress at GEND is utilizing the pilot line developed by Phase I and II. Phase III work has been expanded to 5 MHz and 10 MHz SC-cut quartz crystals for high stability oscillators, such as required by GPS and SCOTT.

#### **MORE INFORMATION**

Additional information may be obtained from Dr. Raymond Filler, Electronics Technology and Device Laboratory, Ft. Monmouth, NJ. AUTOVON 955-2467 or Commercial (201) 544-2467.

Summary report, Dec 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 H76 9766 titled "Measure for Miniature High Voltage Hybrid Multiplier Modules" was completed by the US Army Electronics Research and Development Command in December 1983 at a cost of \$183,000.

**BACKGROUND**

High voltage power supplies are required for operation of night vision image intensifier tubes. At the time of contract award, multipliers were fabricated integrally to the power supply and could be tested only as part of a completed power supply. This project sought to establish the manufacturing processes to fabricate high voltage multiplier modules as single units. These units could then be inspected and tested prior to insertion in the power supply.

**SUMMARY**

Erie Technological Products was awarded the contract to establish production techniques for a hybrid multiplier module constructed as a thick film hybrid circuit. It was composed of a special electrically oriented high voltage silicon rectifier diode array connected in parallel between two ceramic capacitor banks. Two optimum configurations, curved and rectangular, were fabricated under this effort. Each configuration contains 12 diodes. The devices and their diode orientations are depicted in figures 1 and 2. Goals were to build a pilot line capable of producing 125 units per week.

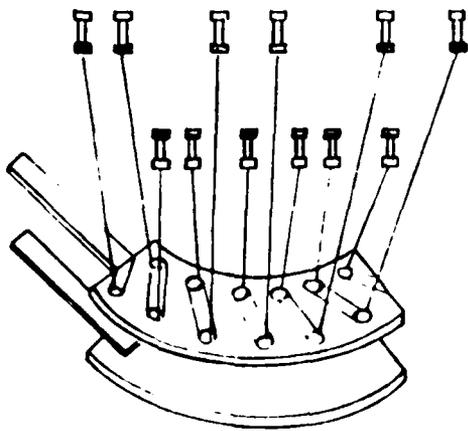


Figure 1 - Orientation of Diodes  
In Curved Multiplier

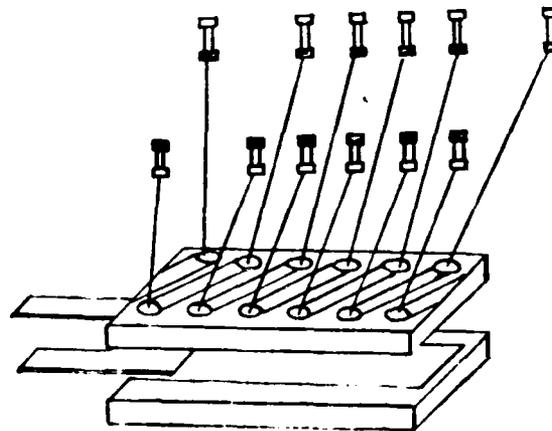


Figure 2 - Orientation of Diodes  
In Rectangular Multiplier

Both diode devices and capacitor banks were improved from the preliminary design. Diode modification consisted of a silver slug addition which assured proper diode solder attachment to the capacitor bank. Bank capacitance was lowered by reducing the capacitor electrode area. Diodes used for assembly were etched, varnished, epoxy coated and 100 percent tested before assembly.

Hand soldering was replaced by vapor phase soldering. Jigs and fixtures were constructed to be compatible with vapor phase soldering lines already existing in the contractor's plant. Additional processes optimized for production included ceramic substrate preparation, silver epoxy substrate screening, multiplier freon vapor degreasing (cleaning) and electrical testing. Electrical measurements included output voltage, charging current (microamps), input capacitance (pf), and multiplier efficiency.

A pilot line was brought into operation, substrates were solder screened, ground strips and diodes were vapor phase solder attached and system operating parameters were documented. The pilot line successfully demonstrated a production rate of 187 units per week, a rate greater than the contract requirements.

#### **BENEFITS**

This project established a manufacturing capability for miniature high voltage multipliers. As a separate unit the hybrid multiplier provided increased reliability, reduced number of components, and lower rework cost.

#### **IMPLEMENTATION**

Due to the long time required to develop reasonably efficient manufacturing processes, the AN/PVS-5, AN/PVS-7 and AN/AVS-6 systems which could have used the high voltage multiplier are either in production or in the final stages of engineering development. It was determined that it would not be cost effective to redesign, repackage and requalify the power supplies used in these systems to permit multiplier utilization. Project results were not implemented due to economic considerations but the technology is available for future use.

#### **MORE INFORMATION**

Additional information may be obtained from Mr. Joseph L. Evans, Jr., US Army Night Vision & Electro-Optics Laboratory, Ft. Belvoir, VA. AUTOVON 354-1551 or Commercial (703) 664-1551.

Summary report, Dec 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)**

MT Project **H79 9844** titled "**CMOS Circuits Using Silicon on Sapphire (SOS) Techniques**" was completed by the US Army Electronics R&D Command in December 1983 at a cost of \$770,000.

**BACKGROUND**

When this project was conceived in 1978, silicon-on-sapphire was difficult to obtain. Sapphire boules first had to be grown and then sliced into wafers and polished, and then silicon grown epitaxially on the wafers. Subsequently, circuitry was diffused into the wafer, as is standard practice. The Army needed complex circuits on SOS wafers for its thermal imagers, multipliers, frequency synthesizers and other high frequency devices. About this time, a new method of growing sapphire consisted of an edge-defined film-fed growth technique (EFG) in which a ribbon of sapphire was pulled from a melt. The object of this project was to better define the sapphire ribbon pulling technique and then process semiconductors on it in the normal manner.

When the project was put out for bid, no firm would bid on the edge-defined ribbon pulling method and the project had to be redirected toward use of standard wafers sliced from a boule upon which silicon was to be grown epitaxially.

**SUMMARY**

A contract was awarded to Rockwell International at Thousands Oaks, CA and Rockwell contracted to Union Carbide to perform the epitaxial growth of silicon on sapphire wafers. The object of the contract was to determine the epitaxial growth equipment's operating parameters including temperature and growth rate. Union Carbide worked with Rockwell to establish growth parameters and test methods for measuring surface and other qualities.

Material characterization data and electrical parameters were developed during the engineering portion of the contract in which epitaxial growth conditions and material characterization measurement techniques were analyzed. Union Carbide applied Ultra-Violet Reflectometry (UVR) measurement techniques to obtain readings of surface quality. They found the UVR method to be far more sensitive to film crystallinity than the X-Ray Rocking Curve measurement method previously used. This produced two results: the use of a rapid production oriented quality test for SOS wafers--ultra-violet reflectometry, and determination of an optimum set of epitaxial growth conditions for the reactor based on data gathered using the UVR technique. Electrical parameter data established a correlation between device carrier mobility and hence device speed with values obtained using the UVR technique. Specifically, film with UVR values less than 10 have better quality surfaces than wafers with higher UVR values.

Union Carbide found optimum operating conditions for its silicon deposition equipment: a deposition rate of 1.2 micrometers per minute and a temperature of 910°C. This resulted in an almost fault-free film of single-crystal silicon on sapphire.

To prove the substrate material, Rockwell's Microelectronics R&D Center made a production run of CMOS/SOS large scale integrated circuits. This proved the viability of both the material improvement and quality screen. The test vehicle was Rockwell's 16-bit multiplier circuit. A wafer fabrication yield of 79% and wafer probe functional yield exceeding 15% and as high as 26% proved the methods. One hundred MIL STD multiplier circuits were delivered to ERADCOM to prove the methods.

#### **BENEFITS**

The outcome of the contract was that Union Carbide established optimum operating conditions for silicon deposition equipment and this information has been made known to the industry. Also, the ultra-violet reflective method was proven satisfactory for characterizing the surface of the grown silicon.

#### **IMPLEMENTATION**

Results of this project were implemented both at Union Carbide and at Rockwell's Microelectronics R&D Center. Circuits made using these methods have been used in several DOD equipments.

#### **MORE INFORMATION**

Additional information on this project may be obtained by contacting Mr. Nick Korolkoff at the US Army Electronics R&D Command, Ft. Monmouth, NJ. AUTOVON 995-4040 or Commercial (201) 535-4040. The contract No. at Rockwell was DAAK20-80-C-0311.

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

In addition to the literature survey, the results of a questionnaire sent out to 100 researchers active in the area of chemical characterization of fiber composites is also presented. In this survey, the correspondents were asked to list five answers in ranked order about references most used in their characterization strategy. They were also asked about the most important instruments in characterization methods in use and the five instruments or characterization methods which are not currently being used but which they would want to obtain over all others. The results were that the most valued currently used method is high performance liquid chromatography. The most desired method is Rheology analysis. The most used reference books, journals, reports and articles were extensive with no clear-cut preference for the Journal of Applied Polymer Science and the Handbook of Epoxy Resins (Lee and Neville, McGraw-Hill, 1967). The report also presents an extensive bibliography.

### **ITS**

This project establishes an excellent overview of characterization techniques for composite structures and a discussion of their application in development, production and use of composite structures. This information will result in more efficient application of technology to the production of composite structures, and will also engender greater confidence in the designer and in management toward the use of composite materials.

### **IMPLEMENTATION**

Implementation of project results will be accomplished with the distribution of the handbook on nondestructive in-process inspection of composite structures.

### **INFORMATION**

The results of this project have been published in report form: AVRADCOM Technical Report No. TR 82-F-3, May 1982, entitled "Quality Control and Nondestructive Evaluation Techniques for Composites Part I - Overview of Characterization Techniques for Composite Reliability." Additional information is available and can be acquired by contacting Dr. Richard J. Ford, Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts, on AV 955-5572 or Commercial (617) 923-5572.

This report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rockford, IL 61299-7260.

Each of these parts is a separate study, and the results are available in ADCOM technical reports. The subject of this summary report is the result a survey of available reference literature. The survey results are summarized in an AVARADCOM Technical Report (No. TR 82-F-3, May 1982) entitled "Quality Control and Non-Destructive Evaluation Techniques for Composites, Part I - Overview of Characterization Techniques for Composite Reliability."

This overview discusses the detailed characterization methods in the context of management concepts for implementing specific tests. The scope of characterization begins with material selection and continues through manufacture and use of a composite material.

This project addresses, specifically, fiber reinforced composite characterization and covers the full range of special topics from initial quality acceptance of prepreg constituents to durability analysis and service life prediction of the reinforced composite structure. The characterization methods addressed in this project are described and reviewed in detail with respect to their advantages and limitations.

The conclusion of the review is that cure monitoring and management are of high importance in the composites industry, and that chemical characterization is already developed a mature status. A life prediction program is presented (Figure 1) that should direct future research into establishing laminate life prediction. This descending flow chart is an outline of composite material interactions under UV radiation, hydrothermal cycling, and mechanical loading which leads to property changes and damage mechanisms that diminish reliability and durability. The types of chemical, physical and mechanical tests which accompany the stages of degradation are listed on the right side of the chart.

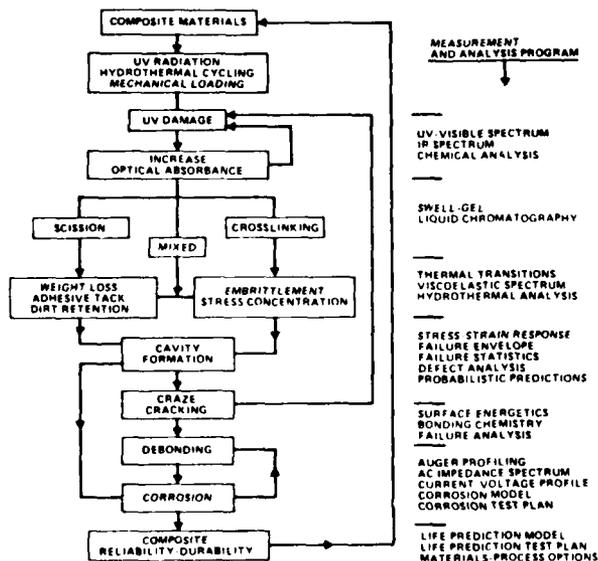


Figure 1 - General Laminate Life Prediction Program

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

Project 177 7119 titled "Non-Destructive Evaluation Techniques for Composite Structures" was completed by the US Army Aviation Research and Development Command in May 1982 at a cost of \$475,000.

**BACKGROUND**

The incorporation of structural composites in Army helicopters and missiles, and to a lesser extent in ground vehicles, is accelerating. In the next generation helicopter, the LHX system, this trend will reach its culmination. In the LHX, the entire airframe, the main rotor blade, and the tail rotor blade will be constructed of composites. The transmission and landing gear will contain composite parts as well. Considerable manufacturing problems will need to be solved, and among these will be quality control techniques. At this time, a large number of non-destructive testing (NDT) techniques have been developed and are being used with composite structures of widely varying configurations. Unfortunately, however, this technology is scattered among laboratories, contractor plants and various literature. A major step forward in advancing the present NDT state-of-the-art would be to formalize this technology and make it available to the manufacturing community.

**SUMMARY**

The purpose of this project, and the total effort of which it is a part, is to compile a comprehensive manufacturing handbook devoted to non-destructive in-process inspection of composite structures. The handbook titled "Quality Control and Non-destructive Evaluation Techniques for Composites" will be organized into eight parts as listed below:

- Part I - Overview of Characterization Techniques for Composite Reliability
- Part II - Physiochemical Characterization Techniques - A State-of-the-Art Review
- Part III - Liquid Chromatography - A State-of-the-Art Review
- Part IV - Radiography - A State-of-the-Art Review
- Part V - Ultrasonic Characterization - A State-of-the-Art Review
- Part VI - Acoustic Emission - A State-of-the-Art Review
- Part VII - Thermography - A State-of-the-Art Review
- Part VIII - AH-1 - Composite Main Rotor Blade Quality Control, Mechanical Tests and NDE Methods

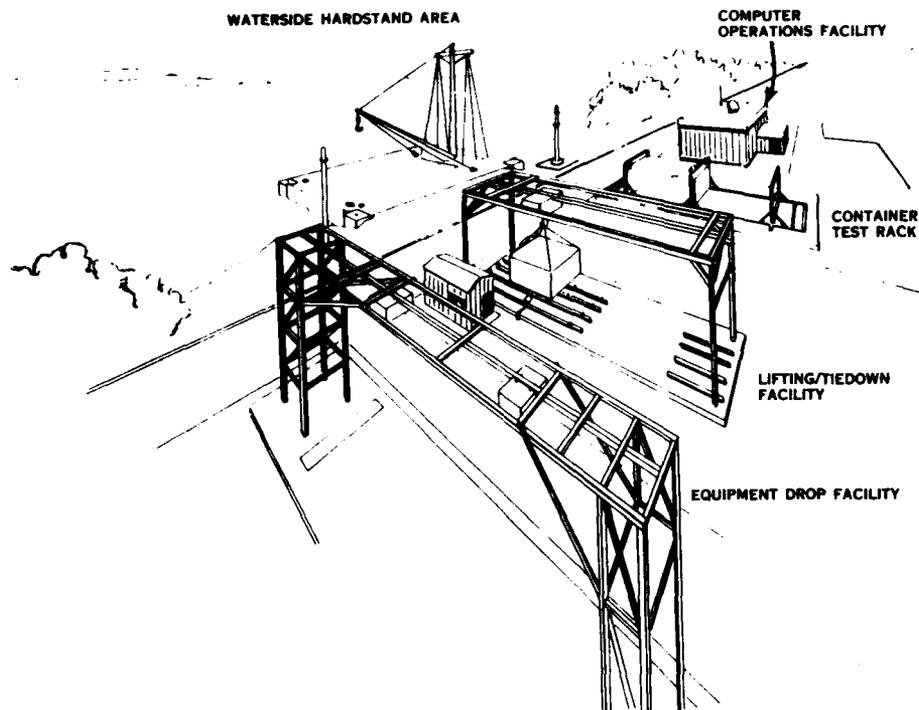


Figure 1 - General Purpose Transportability Test Area (GEPTTA)

#### **IMPLEMENTATION**

The facilities needed for the GEPTTA will be acquired in order of urgency and implemented at a preselected site at the Aberdeen Proving Grounds.

#### **MORE INFORMATION**

Additional information may be obtained from the final technical report "General Purpose Transportability Test Area (GEPTTA)", US Army Test and Evaluation Command, Aberdeen Proving Grounds, MD 21005, ATTN: AMSTE-AD-M or by contacting W. Deaver, APG, AUTOVON 283-3677.

Summary report, Dec 84, was prepared by Frank Stonestreet, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 082 5071-101 titled "General Purpose Transportability Test Area (GEPTTA)" was completed by the US Army Test and Evaluation Command in September 1983 at a cost of \$7,600.

**BACKGROUND**

Prior studies by the Aberdeen Proving Ground (APG) facility on evaluating transportability of military equipment and container testing recommended the development of an integrated test facility. Another study performed on rail, marine, and highway transportation also recommended the development of an integrated test facility. The original idea for the facility was rejected due to its prohibitive cost and limited versatility. The idea was discussed further and a decision was made that a limited test facility using computer technology could satisfy the demand for an inexpensive General Purpose Transportability Test Area (GEPTTA).

**SUMMARY**

The first step in the study was an extensive search of the available technical literature. Discussions with other agencies and organizations were held to obtain information and guidance. Computer programs were created depicting the primary modes of transportation; air, marine, rail and highway, and their relationship to transportability requirements. The most urgently needed transportability testing modes were determined and a GEPTTA site was selected. It was determined that there existed insufficient justification to warrant initiation of a full-scale testing facility. The investigation resulted in three immediate needs: a rail impact test, a Universal lifting/tiedown facility and the upgrading of container test facilities. Of the three aforementioned facilities the final two, a universal lifting/tiedown facility and the upgraded container test facility, were deemed most urgent. These two were the prime candidates for the GEPTTA. Figure 1 is an artist depiction of the General Purpose Transportability Test Area.

**BENEFITS**

The centralization of transportability test facilities will decrease the need for separate testing and reduce costs for the testing. The GEPTTA would eliminate conflict of use for facilities and give transportability testing the prestige of having specially designated areas.

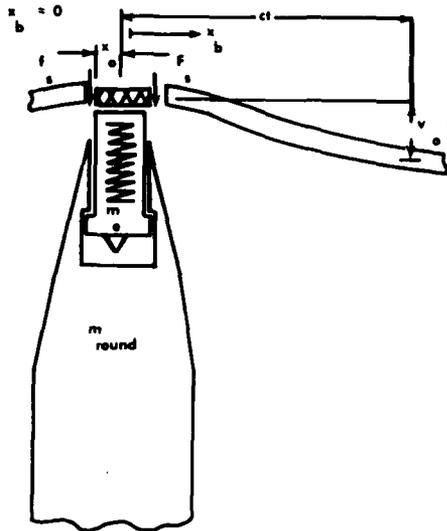


Figure 1 - Projectile Penetration of a Deforming Branch

optimum method and could be used for both rainfall and vegetation studies. The study concluded that wooden dowels provide a viable alternative to actual branches for measuring impact sensitivity of ISD's. A rain-simulation facility should be built to test rainfall-ISD impact characteristics.

#### **BENEFITS**

The proper evaluation of fuse sensitivity is of prime importance in the areas of safety and field effectiveness. A standardized test method would increase the confidence in evaluating a fuse. A more realistic test method will decrease the number of fuses being rejected thereby reducing production costs.

#### **IMPLEMENTATION**

The results of this study will be used in Phase II to develop and validate the testing methods.

#### **MORE INFORMATION**

Additional information may be obtained from the final technical report "Improved Methods for Evaluating the Effects of Rain and Vegetation on Point Detonating Fuses and Impact Switches (Phase I)". January 1982 or by contacting Mr. William Deaver, US Army Test and Evaluation Command, Aberdeen Proving Ground, MD 21005, AUTOVON 283-3677.

Summary report, Dec 84, was prepared by F. Stonestreet, 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 082 5071-92 titled "Improved Methods for Evaluating the Effects of Rain and Vegetation on Point-Detonating Fuses and Impact Switches (Phase I)" was completed by the US Army Test and Evaluation Command in March 1984 at a cost of \$7,400.

**BACKGROUND**

The Point-Detonating Fuze (PDF) and impact switch are both classified as Impact-Sensitive Devices (ISD's). The ISD is designed to initiate the explosive train of ammunition upon impact with a solid or semi-solid surface. To assure reliable detonation, ISD's are increasingly designed for greater sensitivity. The negative aspect of the increased sensitivity is there exists a greater probability of premature detonation upon impact with vegetation and raindrops. It is impossible to find a location where the rainfall is constant enough to test ISD's under natural conditions, therefore the need for simulated rainfall is important. The test method currently used by TECOM is to fire the ISD against 3.2mm thick wood veneer, a test used to simulate both rain and vegetation. As ISD's become increasingly sensitive, a need for test methods of greater sensitivity and validity becomes apparent.

**SUMMARY**

The overall objective of this subtask is to analyze the possible test methods used to evaluate the sensitivity of fuses to rainfall and vegetation. The best test methods were selected and recommendations made for Phase II of the subtask. Before the test methods could be evaluated, the parameters to be tested for were determined. The parameters were divided into two groups: rainfall parameters and vegetation parameters. To determine the approach needed to study rainfall effects, a definition of rainfall had to be derived. After analysis, it was decided to identify a 0.5%-risk rainfall; which is a rainfall of 0.80 mm/min, having a drop-size distribution of 0.5mm to 6.4mm diameter. Other parameters such as terminal velocity of drops and water temperature were determined to have no significant effect. Vegetation parameters were determined from prior studies of six types of environments (temperate forests, jungle tangle, etc.) and used in conjunction with computer simulations of randomly distributed twigs, tangle and branches to create a theoretical environment that the ISD will enter.

The parameters are used to develop mathematical models of raindrop-ISD impact and vegetation-ISD impact. Figure 1 depicts an idealized projectile penetrating a branch. This type of mathematical modeling is used to determine the optimum test method. The next step was to determine the best means of testing. It was decided that the test track approach was the

<u>ENVIRONMENT FACTORS</u>	<u>CAPABILITY CATEGORIES</u>	<u>ENVIRONMENTAL REGIONS</u>	<u>ISSUE AREAS</u>
Natural (16)	Close Combat (6)	Tropic	Operability
Induced (8)	Fire Support (4)	Desert	Reliability
Constructed (7)	Air Defense (4)	Cold	Mobility
Combat Peculiar (9)	Other Combat Support (5)	Temperate	Vulnerability
	Ballistic Missile Defense		Availability
	Command Systems (6)		Fightability
	Intelligence, Surveillance and Target Acquisition (3)		Safety
	Combat Service Support (6)		Maintainability
	Other Logistics (4)		Survivability
	Overall Testing Support		Transportability

Figure 1 - Primary Elements of the Issue Finder Matrix

#### **IMPLEMENTATION**

The Engineer Topographic Laboratories (ETL) has implemented the EIGHT concept in their effort to write a military handbook on environmental issues. The ETL will address the rating system to be used in the issue finder matrix and what issues are involved.

#### **MORE INFORMATION**

Additional information may be obtained from the technical report "Environmental Issues Guide Concept Plan", TECOM project 7COPB1-TT1-001 or by contacting W. Deaver, TECOM, AUTOVON 283-3677.

Summary report, Dec 84, was prepared by F. Stonestreet, 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 081 5071-79 titled "Environmental Issues Guide Concept Plan" was completed by the US Army Tropic Test Center in March 1984 at a cost of \$12,000.

**BACKGROUND**

In 1980 it was determined that there was a need for a systematic approach to the process of identifying Army material design and test issues related to operating Army material systems in various climatic conditions. The Environmental Issues Guide for Humid Tropic Testing (EIGHT) was a result of attempting to fill this need. The EIGHT concept actually covers all types of climatic conditions, therefore the "Humid Tropic" is misleading. The EIGHT concept was incorporated into the US Army Engineer Topographic Laboratories effort to publish a handbook with the same basic goals as EIGHT. The application of the EIGHT concept will be of great value to planners in their continuing effort to address important issues involving climate, system capabilities and environmental effects on equipment.

**SUMMARY**

The central result of the investigation was the development of a matrix format describing the environmental issues the planner would be concerned with. The system consists of two matrices; an issue finder matrix and an issue/data matrix that contains specific issues and design implications. The primary matrix is the issue finder matrix, a four dimensional matrix containing 64,000 cells or elements. The matrix is defined by four environmental regions, forty capability categories, ten issue areas and forty environmental factors (see figure 1). A second and third matrix called the issue/data matrix addresses the issues in detail that are involved in planning system capabilities. For example, suppose a systems evaluator was concerned about the effect vegetation (environmental factor) had on the operability (issue area) of a tank (capability category) in a tropical area (environmental region). The cell referred to in the issue finding matrix would show a rating, from "not important" to "critical". If more detailed information on the issues was needed the investigator could refer to the issue/data matrix, which contains no issues, one issue or many issues. The advantage of the EIGHT system to the planner, evaluator, or engineer is very obvious.

**BENEFITS**

It is impossible to remember all the environmental factors that can degrade a system. The EIGHT concept fills this void by having a computerized system that can provide the data quickly and efficiently.

Parameters such as air velocity, orifice area and material concentrations were used to develop a physical model so that the efficiency of the DPG sampler could be determined. Different statistical methods were applied to the data to determine the "best fit" model for the DPG sampler, depending on the obscurant being used. The testing results determined the following: a) isokinetic samplers were not a proper standard to use, b) the DPG sampler was not a valid sampler for FO, c) sampler orientation from 0° to 60° did not effect the efficiency of the sampler, and d) the recovery efficiency for IRZ and IRT obscurants increased with increasing wind speed. The tests concluded that using isokinetic samplers as calibration tools was not advisable and that developing a method of sampling fog oil was needed. The most important results were for the IRZ and IKT sampling where it was determined that the DPG filter sampler does a very good job and is not effected by orientations up to 60°.

#### **BENEFITS**

By using the results of this subtask, investigators can now sample IRZ and IRT obscurants with greater confidence. The sampler can now be adjusted for collection efficiency which will lead to a better understanding of the battlefield obscurant.

#### **IMPLEMENTATION**

The methodology investigation concluded that the DPG filter sampler should be used as a standard field sampler.

#### **MORE INFORMATION**

Additional information is available in the final technical report "Smoke Sampling Characterization of DPG Filter Samplers" dated February 1982 or by contacting W. Deaver, US Army Test and Evaluation Command, AUTOVON 283-3677.

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Summary report, Dec 84, was prepared by F. Stonestreet, 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 081 5071-74 titled "Smoke Sampling Characterization of DPG Filter Samplers" was completed by the US Army Test and Evaluation Command in March 1984 at a cost of \$40,000.

**BACKGROUND**

Subtask 74 is part of the Army's ongoing effort to improve its test and evaluation methodology through the MMT and TECOM sponsored Production Test Methodology Engineering Measures Program. An important part of the Army's Dugway Proving Ground (DPG) mission is the quantitative characterization and comparison of battlefield obscurants. The DPG filter sampler was used to collect quantitative data in 1981 field trials. Anomalies in the data led to this methodology investigation of the DPG filter sampler.

**SUMMARY**

The DPG filter sampler consists of a glass fiber filter in a metal filter holder. A critical orifice is designed to maintain an effective flow of about 6 liters/min through the filter (see figure 1). To correctly evaluate the data obtained, the DPG filter samplers were compared with two isokinetic samplers to be used as calibration standards. Isokinetic sampling uses a streamline of airflow that carries the material through an orifice without disturbance or acceleration of any kind. Thirty-six trials were conducted in the DPG wind tunnel with each trial consisting of two isokinetic samplers and four stations with four DPG samplers at each station. The DPG samplers were at four discrete angular orientations and tested at three different wind speeds.

APPROXIMATELY TO SCALE

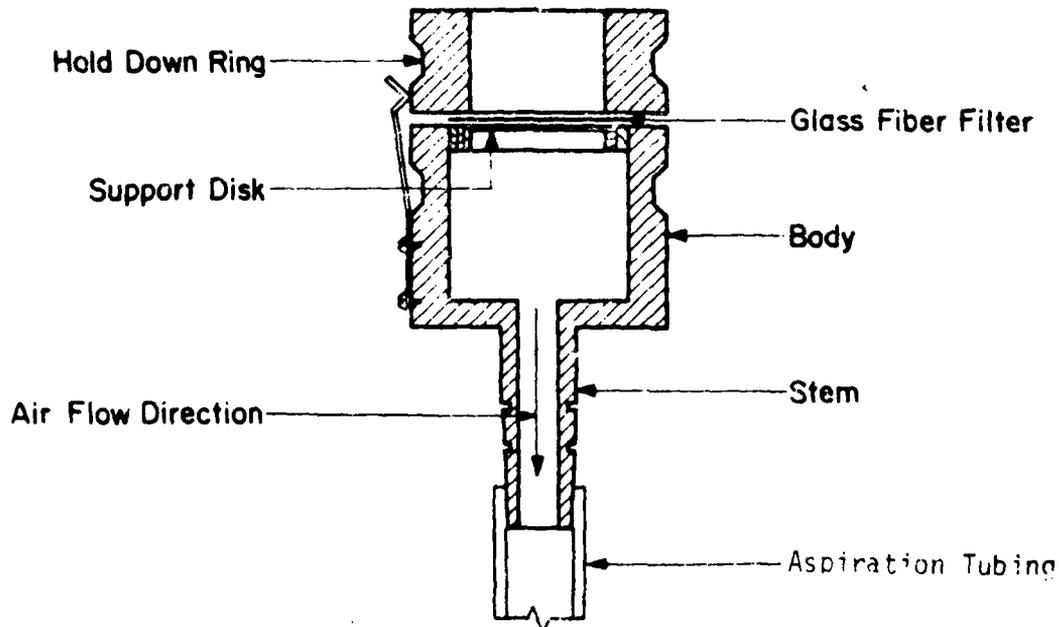
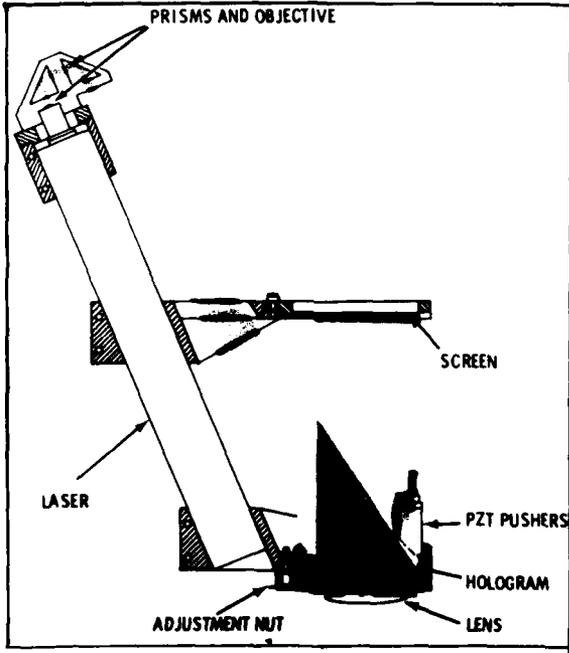


Figure 1 - DPG Filter Sampler

INSPECTION AND TEST



OPTICAL HOLOGRAPHIC TEST EQUIPMENT

developed so that the devices can meet military environmental requirements. This new configuration also eliminates the need for a metal partition between the input and output transducer. This partition which also required partially cutting the substrate was required to maintain acceptable levels of feed-through suppression. The problem was eliminated by staggering the transducer alignment and placing impedance matching networks in separate cavities.

A second phase of this effort that would have provided resonators was discontinued. The second engineering samples were still considerably out of specifications and the funds were expended. Oscillators that were produced will be used for frequency stability investigations.

#### **BENEFITS**

As a result of this project, Reflective Array Compressors produced in small quantities (50-100) now cost about \$3000 each as compared to \$8000 to \$10,000 previously. An industry demonstration was held that provided a comprehensive review of the developed technology.

#### **IMPLEMENTATION**

Results of the project have been implemented at Hughes Aircraft and TRW. Potential applications include MILSTAR, SIGINT and cruise missiles. Expected cost savings are \$3.6 million.

#### **MORE INFORMATION**

Additional information on this project can be obtained from the ERADCOM project officer, Mr. E. Mariani, AUTOVON 995-2647 or Commercial (201) 544-2647.

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Summary report, Dec 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 DRGMT-302)**

MMT Project H80 9897 titled "Surface Acoustic Wave Resonator and Reflective Array Devices" was completed by the US Army Electronics Research and Development Command in April 1984 at a cost of \$626,000.

**BACKGROUND**

Requirements exist for small reliable RF/microwave frequency sources that consume little power, use low voltages and are highly stable over a range of temperature and other environmental conditions. Recent developments in surface acoustic wave (SAW) technology indicate that SAW resonators can provide these characteristics that are not possible with any other technology.

The fundamental frequency of operation for currently available devices is limited to about 50 MHz. This frequency limitation is caused by the inability to produce the extremely thin physical dimensions required for higher frequency operation. This project was initiated to solve these problems.

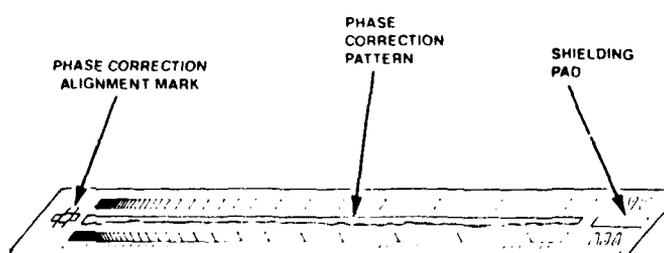


Figure 1 - RAC Crystal Configuration (Pilot Production)

**SUMMARY**

The primary problems to be solved were etching of the crystals, providing part to part consistency and designing an environmentally acceptable package for the devices. The ion beam etching process was established as a viable production process for relatively large ( $\approx 6$  in. long) lithium niobate devices. Using this method, devices can now be produced at rates of hundreds/month. The etched grooves are precision milled into the surface of the polished crystal to depths ranging typically from 0.05 to 0.15 microns and are spaced approximately 4 microns on centers. The reflective array configuration is shown in figure 1 above. A new packaging configuration was

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

NMT Project 179 7119 titled "Non-Destructive Evaluation Techniques for Composite Structures" was completed by the US Army Aviation Research and Development Command in June 1982 at a cost of \$400,000.

**BACKGROUND**

The incorporation of structural composites in Army helicopters, and to a lesser extent in missiles and ground vehicles, is accelerating. This trend will reach its culmination in the next generation helicopter, the LHX. In the LHX, the entire airframe, the main rotor blade, and the tail rotor blade will be constructed of composites, and the transmission and engine will contain composite parts as well. Many manufacturing problems will need to be solved, and among these will be quality control techniques.

At this time, a large number of non-destructive testing (NDT) techniques have been developed and are being used on composite structures of widely varying configurations and materials. Unfortunately, however, this technology is scattered among laboratories, contractor plants, and various literature. A major step forward in advancing the present NDT state-of-the-art would be to centralize this technology and make it available to the manufacturing community.

**SUMMARY**

The purpose of this project, and the total effort of which it is a part, is to compile a comprehensive manufacturing handbook devoted to non-destructive in-process inspection of composite structures. The handbook entitled "Quality Control and Non-destructive Evaluation Techniques for Composites" will be organized into eight parts as listed below:

- Part I - Overview of Characterization Techniques for Composite Reliability
- Part II - Physiochemical Characterization Techniques - A State-of-the-Art Review
- Part III - Liquid Chromatography - A State-of-the-Art Review
- Part IV - Radiography - A State-of-the-Art Review
- Part V - Ultrasonic Characterization - A State-of-the-Art Review
- Part VI - Acoustic Emission - A State-of-the-Art Review
- Part VII - Thermography - A State-of-the-Art Review
- Part VIII - AH-1 - Composite Main Rotor Blade Quality Control, Mechanical Tests and NDE Methods

This summary report summarizes Part IV, "Radiography - a State-of-the-Art Review." The objective of this project was to determine the state-of-the-art in the x-ray, gamma ray, and neutron radiography of composite materials. The project work consisted of a review of radiation principles, application and radiation sources. It also included the process of making a radiograph, exposure formulation, and a detailed review of composite material investigations.

The portion of the review dealing with the mechanism of radiography serves as an excellent introduction to radiography for those new to the field, and an excellent refresher to one knowledgeable in radiography. The principles of radiography and the basic setups for x-ray and gamma radiation (figure 1) and neutron radiation (figure 2) are presented.

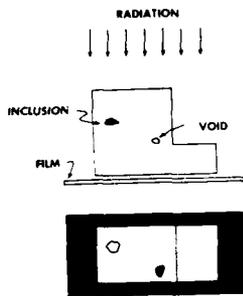


Figure 1-Basic Radiographic Set-Up

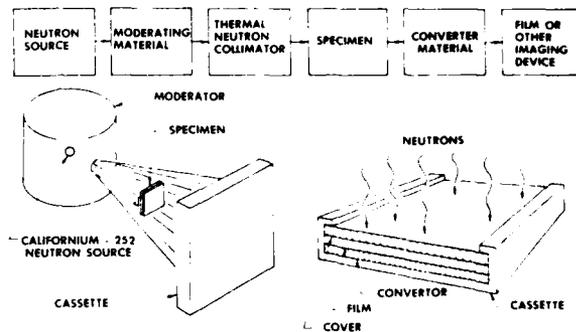


Figure 2-Neutron Radiographic Imaging

The section dealing with radiation sources describes the x-ray tube and its operation, gamma radiation sources (radium, cobalt 60, iridium 192, thulium 170, and cesium 137), and neutron radiation sources (nuclear reactors, californium-252, and electronic sources). The section describing the making of a radiograph discussed geometric factors, object effects, radiation scattering and film effects. The discussion of exposure formulation consists of a review of the generic procedure and detailed procedure for x-ray and gamma ray exposure charts. It also includes controls of scattered radiation, penetrometers, radiographic sensitivity, and reviewing and interpreting radiographs.

The most valuable portion of the project deals with composite material investigations. In composite material investigations, the radiographer has had to deal with a vast spectrum of reinforcement and matrix material systems, together with a number of associated types of defects. In particular, some of the defect considerations investigated with radiography include: bond evaluations, curing effects, damage considerations, flaw content and growth, voids, failure mechanisms, fatigue behavior, fiber characteristics and fiber breaks, fracture characteristics, moisture effects, physical properties, resin content, and thermal effects. The need for detection of these types of

defects and the general nature of composite systems has brought about a number of advancements in the traditional, straightforward radiographic technique. It also has spurred the development of some new and promising techniques.

This section of the project focuses on the methods and capabilities of some of these techniques, including the use of automatic computer-based radiographic image enhancement systems, conventional radiography; micro-radiography; stereo-microradiography; neutron radiography; the use of opaque additives such as tetrabromothane (TBE), diiodobutane (DIB) and molten sulfur; the use of opaque fibers (boron with tungsten core), and the use of automatic computer-based radiographic image enhancement systems.

The project also included the compilation of a selected and extensive bibliography.

### **BENEFITS**

This project has fulfilled a need to present the available information on the application of radiography to composite structures in one document. This project can also serve as a valuable introduction to the radiography of composites.

### **IMPLEMENTATION**

Implementation of project results will be accomplished with the distribution of the handbook entitled "Quality Control and Nondestructive Evaluation Techniques for Composites."

### **MORE INFORMATION**

The results of this project have been published in report form: AVRADCOM Technical Report No. TR 82-F-4 entitled "Quality Control and Nondestructive Evaluation Techniques for Composites, Part IV: Radiography - A State-of-the-Art Review." Additional information is available and can be acquired by contacting Dr. Richard J. Shuford, Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts, on AV 955-5572 or Commercial (617) 923-5572.

Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 180 7119 titled "Nondestructive Evaluation Techniques for Composite Structures" was completed by the US Army Aviation Research and Development Command in May 1983 at a cost of \$260,000.

**BACKGROUND**

The incorporation of structural composites in Army helicopters, and to a lesser extent in missiles and ground vehicles, is accelerating. This trend will reach its culmination in the next generation helicopter, the LHX. In the LHX, the entire airframe, the main rotor blade, and the tail rotor blade will be constructed of composites, and the transmission and engine will contain composite parts as well. Many manufacturing problems will need to be solved, and among these will be quality control techniques.

At this time, a large number of nondestructive testing (NDT) techniques have been developed and are being used on composite structures of widely varying configurations and materials. Unfortunately, however, this technology is scattered among laboratories, contractor plants, and in various literature. A major step forward in advancing the present NDT state-of-the-art would be to centralize this technology and make it available to the manufacturing community.

**SUMMARY**

The purpose of this project, and the total effort of which it is a part, is to compile a comprehensive manufacturing handbook devoted to non-destructive in-process inspection of composite structures. The handbook entitled "Quality Control and Nondestructive Evaluation Techniques for Composites" will be organized into eight parts as listed below:

- Part I - Overview of Characterization Techniques for Composite Reliability
- Part II - Physiochemical Characterization Techniques - A State-of-the-Art Review
- Part III - Liquid Chromatography - A State-of-the-Art Review
- Part IV - Radiography - A State-of-the-Art Review
- Part V - Ultrasonic Characterization - A State-of-the-Art Review
- Part VI - Acoustic Emission - A State-of-the-Art Review
- Part VII - Thermography - A State-of-the-Art Review
- Part VIII - AH-1 - Composite Main Rotor Blade Quality Control, Mechanical Tests and NDE Methods

This summary report covers Part VII, "Thermography - a State-of-the-Art Review." The objective of this project was to review the techniques available for the application of thermographic nondestructive testing and evaluation techniques to composite materials.

Thermography is the general term given to the technique whereby contours of equal temperature - isotherms - are mapped over a surface. As a technique for nondestructive testing and evaluation, the application of thermography is based upon the assumption that defects, inhomogeneities, or other undesirable conditions of the test object will evidence themselves as local hot or cold spots in the isothermal mapping. To apply this technique, one must first excite a thermal pattern in the test object to be studied; second, measure the areal temperature distribution on the surface of the examined test object; and third, interpret the results according to well-established and understood physical principles. The state-of-the art is well advanced for performing steps one and two but is still in the developmental stage for step three. While the physical principles of heat conduction and radiation are well understood, the interpretation of these principles for predicting type and effect of damage or defects needs further study. A schematic diagram of a basic thermograph NDE system is presented in figure 1.

This review covers both active and passive heating of test composites. (figures 2 and 3). Measurement of temperature includes both contact and noncontact methods. The contact methods discussed are thermally induced, visible chemical reaction in applied coatings, thermal phosphor coatings, thermally sensitive papers, liquid crystals, thermionic order-disorder compounds, temperature-sensitive surface tension compounds, and frost melting technique. The noncontact methods discussed covers the detection of emitted infrared radiation. A detailed discussion of the nature of infrared emission and its nature as applied to composite materials and surfaces is presented as well as a review of the two types of detectors, photon effect and thermal devices.

The applications of thermographic nondestructive testing is covered in sections reviewing procedures, equipment, parameter selection and applications. The considerations leading to the selection of a test procedure are discussed at length with respect to composite material, part size, flaw size and location, and economics. The section on equipment emphasizes the desirability of instruments to record and analyze the image. Parameter selection is discussed in length and considers conductivity, surface reflectivity and emissivity, and damping of composite materials. Finally, the section on applications states that the principle application of thermography, which began in about 1974, is for the detection of defects and the general monitoring of damage development and growth. This method is especially valuable for the detection of debonds and delaminations. It is concluded that since these defect types result in the failure of composite structures, the thermography technique is valuable in detecting and recording damage development during mechanical and physical testing.

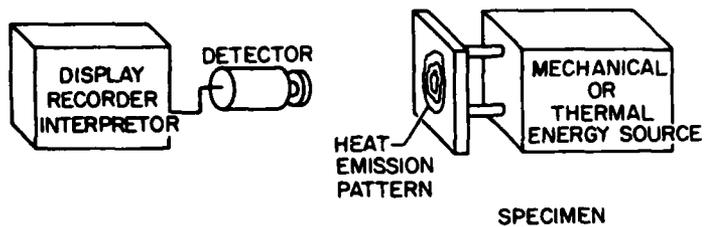


Figure 1 - Basic Thermograph NDE System

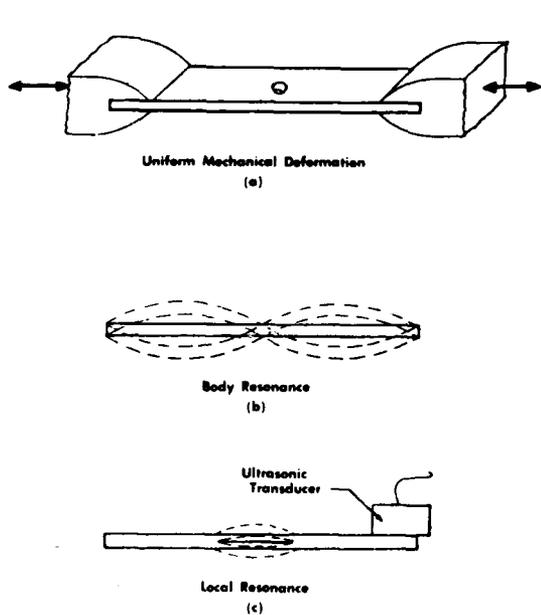


Figure 2 - Examples of Heat Generation by Active Techniques

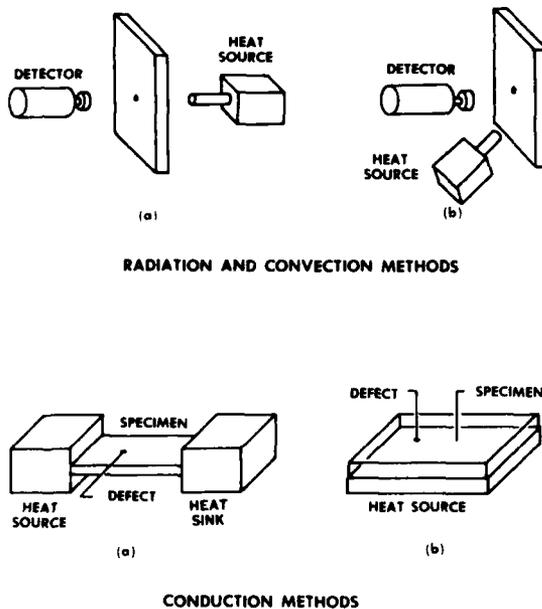


Figure 3 - Example of Arrangements For Introducing Heat Into a Specimen Passively

## **BENEFITS**

This project has resulted in a review that will serve as an introduction to thermography of composite materials.

## **IMPLEMENTATION**

Implementation of project results will be accomplished with the distribution of the handbook entitled "Quality Control and Nondestructive Evaluation Techniques for Composites."

## **MORE INFORMATION**

The results of this project have been published in the form of a technical report (AVRADCOM TR 82-F-5, "Quality Control and Nondestructive Evaluation Techniques for Composites - Part VII: Thermography - A State-of-the-Art Review" dated March 1982). Additional information can be obtained by contacting Dr. Richard J. Shuford, US Army Materials and Mechanics Research Center, Watertown, MA, on Commercial (617) 923-5572 or AV 955-5572.

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Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 382 1073 titled "Real Time Ultrasonic Imaging" was completed by the US Army Missile Command in January 1984 at a cost of \$960,000.

**BACKGROUND**

The evaluation of the quality of a production line item is an essential and significant part of the production process. Often the factors affecting quality can only be detected using radiation that passes through part of the material. The most common forms of penetrating radiation are x-rays and ultrasound. An ultrasonic inspection method is often chosen to avoid radiation hazards and because it is uniquely effective for detecting defects. Standard production line ultrasonic testing methods use a transducer to scan the item, generating an echo whenever a void volume or inclusion is encountered. Specialized scanning techniques have been developed that generate either a cross-sectional view (B-scan) or a plan view (C-scan). These scanning methods are too slow as they do not generate real-time images that would permit 100 percent inspections in production line situations. To develop a rapid automatic flow detection, decision logic would be difficult if not impossible using these methods. As a result, this effort was initiated to develop a real-time ultrasonic image inspection system.

**SUMMARY**

The objective of this effort was to develop a Real-Time Ultrasonic Imaging System (RTUIS) for inspecting fiber laminated and metallic structures. The results of this phase, Phase II of a two-phase effort, produced a production prototype RTUIS for rapid inspection of tubular structures. The RTUIS consists of a liquid surface holographic inspection system to which a number of digital features have been added to provide video monitoring, 3-D flow presentation, frame summing, computerized decision making, contrast enhancement, filtering, and smoothing, figure 1.

This system demonstrates the capability to locate flaws in composite and metallic structures including thin graphite epoxy cylinders, Viper launch tubes, Viper rocket motor casings and thick (5 inch) austenitic steel weldments. The manipulator designed to handle these tubes is driven by digital motors under the control of a small computer. Separate rotation and elevation motors allow a variety of scan routines. One of the unique features of the prototype RTUIS is the digital image processor which is designed to scroll the image at a rate which matches the circumferential speed of the tube being examined. This introduces a form of frame averaging which reduces both specular and background noise and greatly extends the area viewed at any given instant. Hard copy records become more meaningful because they encompass a much larger (4.8 x 5 inch vs. 5 x 1 inch) area than could be seen prior to using this technique. A strip 5 inches long (axial direction) is scanned at the rate of 2.75 inches/second. The resulting image is fed into a

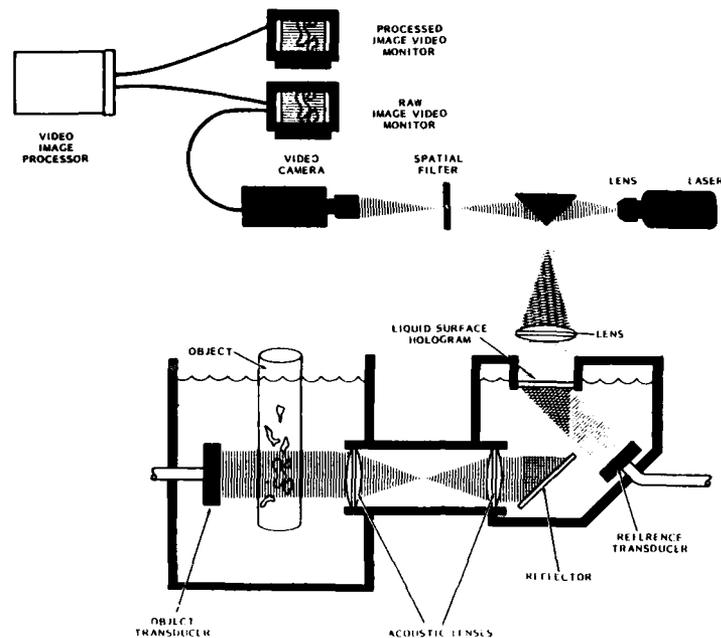


Figure 1 - RTUIS Schematic Diagram

scrolling memory plane. The stored moving image is rapidly scanned to electronically detect flaws. Further programming is expected to introduce and demonstrate feature recognition capability so that structural features can be distinguished from electronic defects.

The RTUIS system was recently demonstrated by General Dynamics Convair Division at Battelle-Pacific Northwest Laboratories. During the demonstration, the imager operated at 60 frames per second. A video camera, focused upon a liquid surface detector plane, generated the initial unprocessed video image signal. Five pieces of video image processing equipment were used to provide frame averaging, video signal analysis, threshold detection, and X, Y, Z isometric display using the brightness level as the Z dimension. A special slit camera was designed and built to demonstrate the anticipated benefits of digital frame averaging. Manipulators were used to carry objects through the field of view in a manner compatible with the operation of the slit camera.

Production components were used in demonstrating the imaging characteristics of the RTUIS. These consisted of the Viper launch tubes, rocket motor cases, Tomahawk cruise missile aluminum squeeze casting and heavy austenitic steel weldments. The RTUIS concept demonstrated a real-time capability to locate flaws in composite and metallic structure.

## IMPLEMENTATION

The results of this effort, a RTUIS production prototype inspection system, was programmed to be used on the Viper production. However, the Viper program was cancelled by the Army. Battelle-Pacific Northwest Laboratories is in the process of transferring the system to MICOM where it will be placed in a development laboratory.

**MORE INFORMATION**

A technical report titled "Manufacturing Methods and Technology for Real-Time Ultrasonic Imaging", Report Number MMT 1073FR, dated 31 December 1983 has been published. For additional information, contact A. Marsili, MICOM, AUTOVON 746-2147 or Commercial (205) 876-2147.

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Summary report, Dec 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 579 4139 (Phase II) titled "Application of Radar To Ballistics Acceptance Testing of Ammunition. Engineering Enhancement Study" was completed by the US Army Armament Research and Development Center in August 1983 at a cost of \$499K.

**BACKGROUND**

As a result of increasingly sophisticated ammunition testing requirements, the US Army designed and fabricated in the mid-1970s the ARBAT (Application of Radar to Ballistic Acceptance Testing of Ammunition) system (see figure 1). ARBAT demonstrated the ability to measure and report in real time vital ballistic testing characteristics such as space position, true velocity, acceleration, drag, and trajectory events (ignition, burnout, accidental part loss), etc.

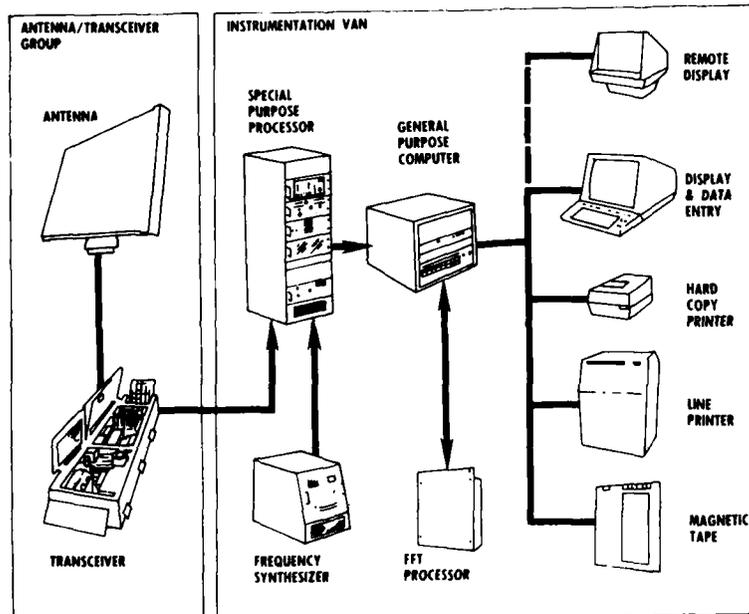


Figure 1 - ARBAT System

**SUMMARY**

The objective of this project was to analyze, partially redesign, modify and field test the ARBAT system. This study was undertaken to obtain improvements to the capability of the ARBAT system to track projectiles under the conditions of low received signal.

These objectives were, in part, accomplished. It was demonstrated that after hardware and software modifications were accomplished, the ARBAT could track and provide data for a variety of ammunition and rockets. Not all the

udy objectives were met due to funding constraints. However, the ARBAT improvements did demonstrate the practicality of its use by producing more useful data, on a round-by-round basis, both real and non-real time, than any other system of its kind. Further, it was concluded that additional ARBAT finements to both hardware and software were needed in order to satisfy the liability and accuracy requirements of all Army Proving Grounds.

## **NEFITS**

The following changes to the ARBAT system were recommended based on study findings:

- a. Transmitter/Receiver - Recommend upgrading and reconfiguring the transmitter/receiver.
- b. IF Processor/Frequency Synthesizer - Recommend upgrading and reconfiguring the IF processor/frequency synthesizer.
- c. Computer - Recommend replacement of the computer with a state-of-the-art system.
- d. Tape Drives and Controller - Recommend replacement of the tape drives and controller with state-of-the-art components.
- e. Software - Recommend restructuring and upgrading the software.
  - (1) Simplification of changes
  - (2) Multitasking
  - (3) High/Low level software descriptions.
- f. Operator Interface - Recommend reconfiguration of the operator interface and adding selected software necessary for Government (versus contractor) operation.
- g. Documentation - Recommend complete hardware/software documentation package.

The preceding ARBAT recommendations would, if implemented, provide the Government with the reliability, maintainability, and accuracy in range instrumentation needs to support all Army Proving Grounds.

## **IMPLEMENTATION**

The ARBAT system is undergoing a major retrofit under MMT Project 582 557.

## **MORE INFORMATION**

A final technical report on the enhancement study is available. Contact Mr. J. P. Secko, Armament Research and Development Center, AUTOVON 880-4758 or Commercial (201) 724-4758.

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



Setback Generator was upgraded to a plug-in type generator. Longer terminal posts were provided to mate with Printed Wire Board (PWB) connectors. This improvement eliminated soldering of the posts to the Magnetic Power Supply Assembly (MPSA) PWB circuitry.

Magnetic Power Supply Assembly Acceptance Test Console was fabricated. Tests the assembled MPSA installed in the rotor housing assembly prior to insulation. The test console is computer controlled and has the capability to accept or reject each unit tested. The tester has the capability to test 42 units per hour.

Four-Nest Centrifuge and Arming Time Acceptance Test Console was fabricated. This test console incorporated many improvements including: test positions for sequential testing, computer control with accept-reject capability. The tester has the capability to perform 40 tests per hour. This tester may be adapted for various fuzes by reprogramming the computer.

Proveout of the semi-automated manufacturing, inspection and testing process to produce magnetic pulse generator power supply assembly was successfully demonstrated by manufacturing 1000 M509 fuzes. The proveout of this system also demonstrated increased product reliability and producibility.

### **BENEFITS**

The primary benefits realized by the Army from this effort is the ability to mass produce M509 fuze magnetic pulse generator power supply assemblies at a production rate of 40 per hour.

### **IMPLEMENTATION**

The M456A2 HEAT cartridge munition round may not be procured by the Army. Therefore, the results of this effort may not be implemented for the manufacture of the M509 fuze magnetic pulse generator power supply assemblies. However, this process is being considered for the manufacture of XM763 and XM764 fuzes. Only minor modifications will be required to the process to manufacture XM763 and 764 fuzes. An Industrial Plant Facilities Conversion project will be initiated to perform these modifications.

### **ADDITIONAL INFORMATION**

Additional information may be obtained from S. Israels, AMCCOM, AUTOVON 724-5591 or Commercial (201) 724-5591. A technical report, AD-E401119 dated 1984, titled "Magnetic Power Supply Assembly of M509A2 El Fuze" is available.

A preliminary report, Dec 84, was prepared by D. Brim, 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 576 6599 and 582 6599 titled "Electro-Optical Cavity Inspection System" were completed by the US Army Armament, Munitions, and Chemical Command, Armament Research and Development Center in February 1984 at a cost of \$267,000.

**BACKGROUND**

A visual inspection is performed to determine the condition of the high explosive (HE) projectile bodies cavity surfaces. The projectile cavity surface is visually examined to determine the presence of scale, fins, burrs, imbedded material, draw marks, sets, or sharp protrusions. Currently these inspections are performed in less than ideal conditions as the cavity surfaces are viewed through the fuze thread hole which is approximately 2 inches in diameter. This visual inspection method is not only costly but is unreliable under the best of conditions.

**SUMMARY**

This project was initiated to establish an automated system to inspect the surface conditions of the internal cavity of the HE artillery projectile bodies. This inspection system was designed to check the interior surfaces of the 155mm M107 and 105mm M1 projectiles using a TV camera and wide angle lens to obtain video images.

The theory of this inspection system is based on a defect/ flaw creating a shadow whether it be raised material, crack, pit, or other depression. This shadow will be in sharp contrast to the brightly illuminated, opposing cause maximum positive and negative voltage excursions in the video output. Also, these sharp contrast signals have the fastest rise and fall time in the video signal. This allows these signals to be separated from the rest of the video signal by a process called differentiation.

The automatic system commences the inspection by placing the projectile in the turret where it is clamped between vertical V-blocks. The turret rotates 90 degrees where a movable carriage with the TV camera, light source, lens tube and wide angle lens positions the lens tube through the fuze hole to inspect the shell interior. Illumination of the interior projectile cavity is obtained from a group of fiber optic bundles surrounding the lens. If a defect is detected, the carriage immediately stops and withdraws the lens tube from the projectile body. The turret rotates 90 degrees clockwise, and the projectile body is placed on the reject conveyor. If the shell is acceptable, the turret rotates 180 degrees from the inspection position and places the projectile on the "accept" conveyor, figure 1.

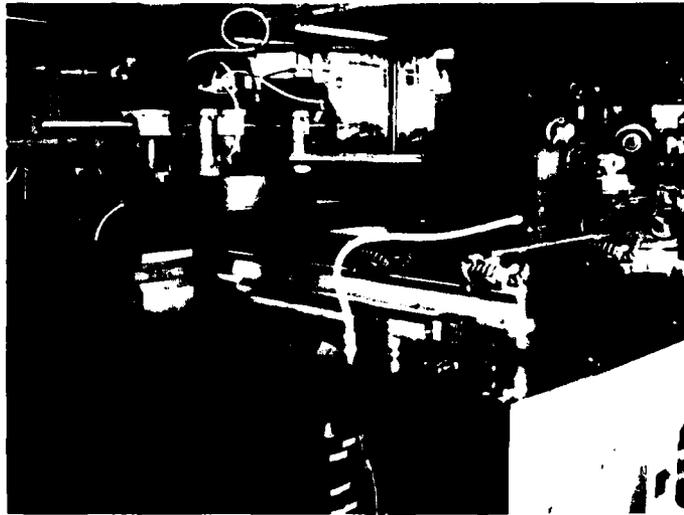


Figure 1 - Electro-Optical Cavity Inspection System

During the debugging phase of this project, it was discovered in the automatic mode that a continuous false "defect" signal was present. This caused every shell, good or bad to be rejected. This condition was caused from reflected light from the walls of the tubing connecting the wide angle lens to the TV camera. This resulted in creating a circular fan around the image which is of a different contrast. Since the system functions on the principle that a defect causes a sharp change in contrast, the circular band generated multiple false "defect" signals. The logic circuit design to inhibit false signals did not have the capability compensate for this condition. At this point, a decision was made to terminate the effort. It was determined that this was an insurmountable problem considering the availability of funds and the obsolete optical electronics of the system.

#### **BENEFITS**

Since the effort was technically unsuccessful, the Army did not realize any positive benefits.

#### **IMPLEMENTATION**

Implementation of the results of this effort is not possible since it was technically unsuccessful.

#### **MORE INFORMATION**

To obtain more information, contact project officer, H. Wolter, AUTOVON 880-5317 or Commercial (201) 724-5317.

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Summary report, Dec 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 677 7201 titled "Artillery Weapons Firing Test Simulator" was completed by the US Army Armament, Munitions and Chemical Command in July 1984 at a cost of \$820,000.

**BACKGROUND**

The testing of large caliber gun mounts and recoil mechanisms has historically been an expensive operation. Live-fire testing has been the accepted method since the advent of weapons using explosives propellants. Live fire testing is expensive, noisy and normally cannot be located near manufacturing facilities.

Feasibility studies completed in 1972 indicated that a hydraulically powered device could effectively simulate live firing of artillery and tank weapons. During 1974 a limited version simulator was fabricated and installed to prove the simulation concepts and tests were conducted on the M158 Gun Mount, the M45 Recoil Mechanism, and the M198 Howitzer. A second impulse programmer was obtained in 1977 allowing for testing of M178, M140, M551, and M60A2 gun mounts. Both simulators are shown in figure 1.



Figure 1 - Hydraulic Simulators

**SUMMARY**

The objective of the overall program was to develop an alternative to live-fire testing. This project provided a second, improved hydraulic simulator, see figure 1, capable of testing the following mounts at various elevations:

M178 Mount for M109A1 Howitzer  
M140 Mount for M60A1 and M60A3 Tanks  
M551 Mount for M551 Tank  
M60A2 Mount for M60A2 Tank  
M1 Mount for M1 Tank

The simulator operates by means of a hydraulic power supply. A programmer (a fluid spring filled with varying amount of oil and nitrogen) with attached weights is accelerated to velocities at the time of impact equal to the required weapon peak recoil velocity, plus that required to compensate for internal resistances of the simulator. The weight of the programmer, plus attached weights, are approximately the same as the weapon recoiling parts.

The simulator is capable of a continuous testing rate of three cycles per minute. During the actual firing sequence, data from up to five channels provide the test engineer a quick visual check of the test results making it possible to validate or make appropriate changes before the next firing.

#### **BENEFITS**

The simulator is being used to test gun mounts and recoil mechanisms at 30-60 percent of the cost of the live-fire alternative for production acceptance testing. Engineering type tests are conducted at costs ranging from 5 to 17 percent of the live-fire alternatives.

The first simulator, installed in 1974, has generated approximately \$6,500K in savings when compared to live firing. The second simulator, fabricated under this MMT project, has already saved over \$740,000.

#### **IMPLEMENTATION**

The equipment has been installed and is operational. Qualification testing for the M1 and M178 gun mounts are complete and production of M178's are being acceptance tested on the simulator. M1 production testing is planned.

#### **MORE INFORMATION**

Additional information is available from Mr. Jerroll S. Hansen or Mr. Doyle L. White, Rock Island Arsenal, AUTOVON 793-6745 or Commercial (309) 794-6745.

Summary report, Dec 84, was prepared by J. Sullivan, 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 8036 titled "Weapon Aiming System for the 6-Degree of Freedom Simulator" was completed by the US Army Armament, Munitions and Chemical Command, Armament Research and Development Center in February 1984 at a cost of \$126,000.

**BACKGROUND**

The US Army is currently developing fire-on-the-move fire control systems for combat vehicles and helicopters. These systems have stabilized weapon platforms and sights. Army's Ware Laboratory production acceptance testing six-degree-of-freedom (6-DOF) simulator's weapon aiming system does not have the capability to maintain rounds in the target area while experiencing large amplitude vibrations under firing conditions. Currently, there is not any way of viewing the target when the simulator moves or a way to maintain the weapon on target during motion imparted by the simulator. Maintaining the weapon on the target while the simulator is in motion, requires that the weapon system be driven in the direction opposite to the simulator motion.

**SUMMARY**

The objective of this effort was to establish a weapon aiming system for production acceptance testing of fire-on-the-move fire control systems. This effort produced a weapon aiming system with remote control and display capability that provides a gunners line-of-sight independent of hull motions induced by the 6-DOF simulator. With this system, the gunner is insured that the weapon is aimed continually on the target during firing bursts.

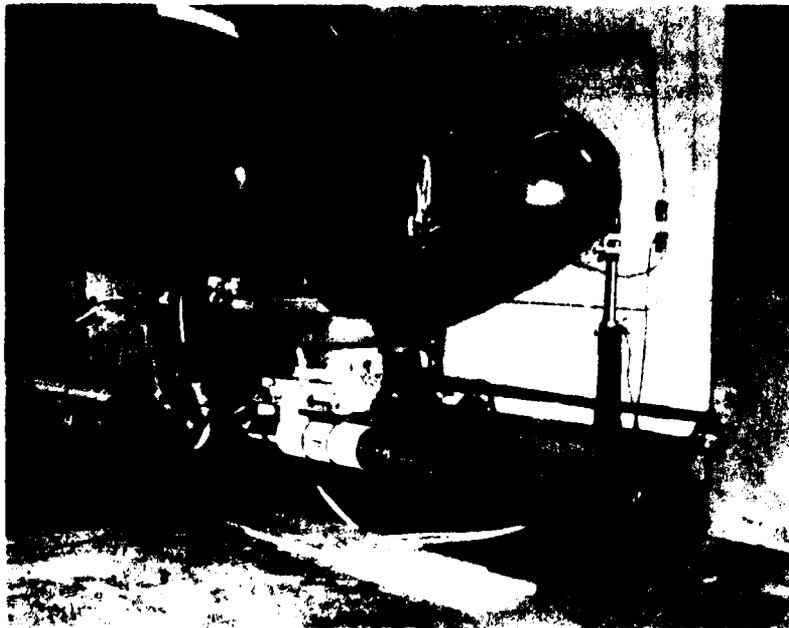


Figure 1 - 6-DOF  
Simulator Weapon  
Aiming System

This was accomplished by mounting a TV camera to a Universal Turret System and boresighted to the same point of aim as the gun, see figure 1. This combination plus two TV monitors and a gunner M28 control station simulate what a gunner would see during a helicopter flight. One monitor displays the picture from a camera mounted in the helicopter cockpit depicting a view downrange. The second monitor displays the picture as viewed from the turret; i.e. where the gun is aimed. The first monitor gives an indication of how the helicopter is moving and the second monitor displays what a gunner would see through the gun sight. As yaw and pitch motions are imparted to the helicopter by the 6-DOF simulator, the gunner is able to track a target by backdriving the gun system opposite to the helicopter motion.

#### **BENEFITS**

The US Army now has a production acceptance testing capability to evaluate stabilized weapon platform and sights for fire-on-the-move fire control systems. This capability does not exist anywhere else in the United States.

#### **IMPLEMENTATION**

The establishment of this weapon aiming system is a self-implementing effort. This system is now in place on the 6-DOF Ware Laboratory simulator. The aiming system is used each time a production acceptance test plan calls for firing of a gun while the simulator is providing motions to the weapon system.

#### **MORE INFORMATION**

Additional information concerning this effort may be obtained from R. Radkiewicz, US Army Armament, Munitions and Chemical Command, AUTOVON 793-6868 or Commercial (309) 794-6868.

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 680 8060 titled "Improved Manufacturing Processes Related to Final Inspection of Cannon Tubes" was terminated by the US Army Armament, Munitions, and Chemical Command after expending \$60,000.

**SUMMARY**

The objective of this project was to establish mechanized cannon tube final inspection equipment. The final inspection of gun tubes involves the following operations: cleaning, magnetizing and demagnetizing penetrant application, ultrasonic test, bore straightness and diameter checks, magnetic particle inspection and a laser scan for bore indications. To perform this final inspection operation of some sixteen crane lifts were required which is very time consuming and expensive.

This project was terminated due to subsequent changes in the manufacturing line which made the implementation of the project results not economically feasible.

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Summary report, Dec 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 DRGMT-302)**

MMT Projects H77 9805 and H79 9805 titled "Automatic Microcircuit Bridge Measurement System for Quartz Crystal Units" were completed by the US Army Electronics R&D Command in June 1984 at costs of \$875,000 and \$725,000, respectively.

**BACKGROUND**

At the time of contract award, crystal impedance meters were used to test quartz crystals utilized in military equipment. Crystal performance requirements, including parameter tolerances and quality assurance provisions, are now being increased for future systems applications in 0.8 MHz to 220 MHz range. New, more accurate and efficient diagnostic measuring hardware was needed to overcome existing testing deficiencies.

**SUMMARY**

Hughes Aircraft Co., Industrial Electronics Group, Newport Beach, CA was awarded the contract to establish an automatic microcircuit bridge system (AMBS) for precision measurement of quartz crystal parameters over the 0.8 MHz to 220 MHz range. Goals were to provide automatic National Bureau of Standards (NBS) traceable crystal measurements and replace four crystal impedance meters required to cover this frequency range. The system was built with the ability to automatically measure series and parallel resonant frequency, series and parallel resonant resistance, static and motional capacitance, quality factor and spurious response. A system block diagram and equipment layout are shown in figures 1 and 2, respectively.

The basic system elements fabricated consist of the Electronically Tunable Microcircuit Bridge (EMCB), Single Crystal Oven (SCO), Offset Local Oscillator (OSLO), and Bridge Balance Control Unit (BBCU). The original Tracking Servobridge Detector (TSBD) was manufactured by the Genrad Company. This equipment was modified by Hughes to facilitate its use on the AMBS system. The procured equipment which was added to complete the system consists of an oscilloscope, a frequency counter, a frequency synthesizer, and a calculator/controller.

The heart of the system is the EMCB. This bridge is a Schering (equivalent circuit) type with the unknown in the parallel arm. The variable elements used for capacitance and resistance balance were varactors. Technical accomplishments performed on the fabricated elements are listed on the next page:

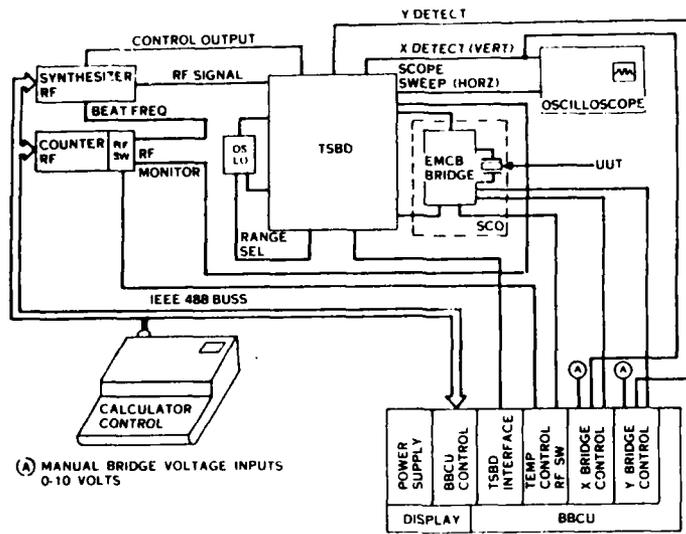


Figure 1 - Automatic Microcircuit Bridge System (AMBS) Block Diagram

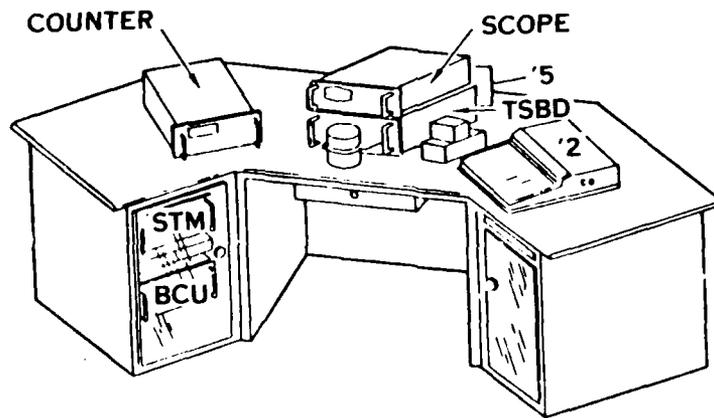


Figure 2 - AMBS Visualization Sketch

a. EMCB - Varactors were assembled without damaging their electrical characteristics by bonding moly tabs to the varactor housing at a temperature of 380°C. Substrate resistance was kept within  $\pm 5$  percent specification by determining optimum curing time and temperature, resulting in yields above 70 percent. Gold plating of the inserts and bridge block elements was performed twice to assure meeting the required 50 micro-inch thickness. The connection between the solid coaxial cable and the bridge block was changed to a coaxial connector. Previously, the solid coaxial cable had been soldered directly to the bridge leads. This change enhanced bridge reliability. Additional protection was provided the hybrid circuitry by enclosing it with soldered plates.

b. SCO - Stainless steel was selected in lieu of the specified chrome-plated metal cup for its better temperature retention, wear characteristics and handling tolerance. Single-handed loading capability was provided by replacing piano key clamps with rigid-mounted contacts.

c. OSLO - Modules were individually packaged using commercially available housings. The circuitry was completely enclosed for purposes of shielding and connected by semi-flexible coaxial cable.

d. BBCU - Active circuitry comprising the assembly was contained on five multilayer circuit boards which were interconnected by means of a mother board. A separate power supply, enclosed in a shielded compartment, provided the necessary current and voltage levels for the assembly.

Overall system control is performed by a desktop computer (calculator/controller) Hewlett-Packard HP9825T. Software written for the system comprised six programs, BEGIN, SYSTEM, AUTOPH, CALELE, CALIBR and AUTO.

#### **BENEFITS**

This effort demonstrated the capability for automatically testing quartz crystals in the frequency range 0.8 MHz to 220 MHz. Data generated by National Bureau of Standards substantiated high accuracy of the AMBS for measuring quartz crystal electrical parameters in this frequency range.

#### **IMPLEMENTATION**

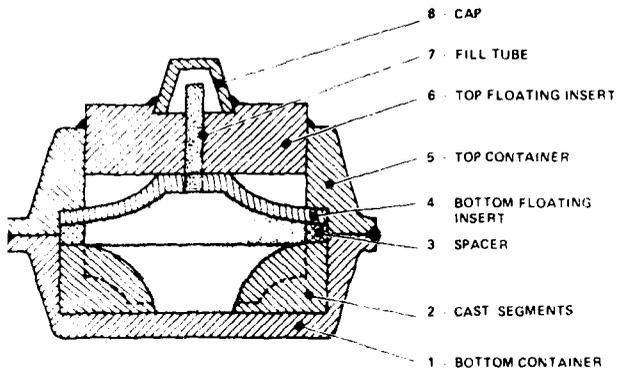
The results of this effort are available for implementation. A final technical report number DELET-TR-78-2080-F was distributed to both industry and government. XOTECH, a recently formed company, appears interested in adapting portions of the microcircuit bridge for crystal measurements.

#### **MORE INFORMATION**

Additional information may be obtained from Mr. Vincent Rosati, US Army ERADCOM, ET&DL, AUTOVON 995-4878 or Commercial (201) 544-4878.

Summary report, Dec 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 Projects 178, 79, 80 7241 titled "Hot Isostatic Pressed Titanium Castings" were completed in August 1982 by the US Army Aviation Research and Development Command at a cost of \$113,000, \$522,700 and \$100,000, respectively.

**BACKGROUND**

Currently, the titanium rotor hub for the Blackhawk is produced from a forging, see figure 1. This results in a substantial loss of material and the use of expensive machining operations. By establishing a commercial manufacturing process for a hot isostatically pressed casting, the material utilization could be greatly improved and machining operations minimized.

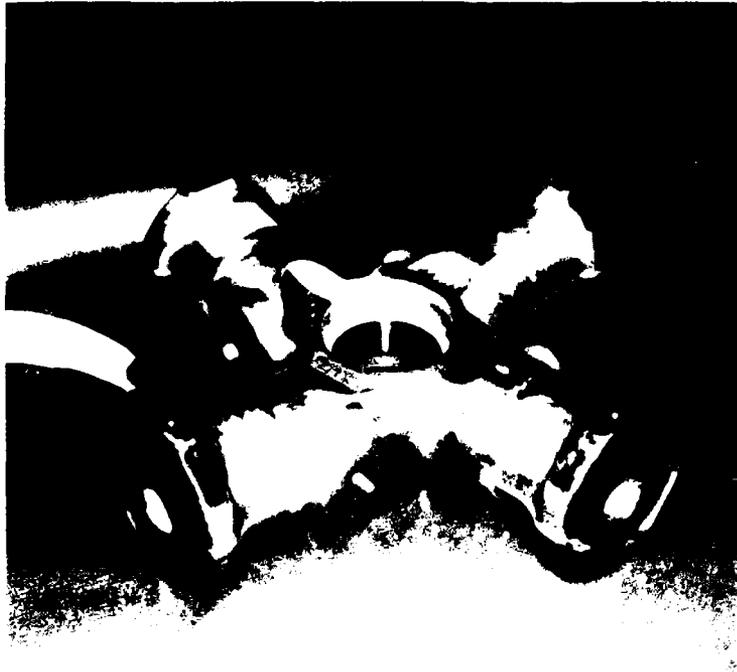


Figure 1 - Blackhawk Rotor Hub

**MORE INFORMATION**

Additional information may be obtained by contacting Mary S. Binseel, HDL, AV 290-1551. The final technical report is titled "M445 Fluidic Generator" CDRL Sequence Number A002 dated 14 Sep 1984.

Summary report, Dec 84, was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

Phase II, Task 1, entailed the development of a nickel-iron alloy investment casting process for fabricating magnet keepers. Phase II, Task 2, entailed the design, fabrication and procurement of a specialized in-process test equipment that will automatically test, accept, and reject fluidic generators.

An engineering review was conducted of the fluidic generator baseline drawings and redesign components and specifications as necessary to improve mass producibility features. An assessment was made that identified critical production parts or assemblies which required specialized equipment facilities. The proposed pilot production line would be capable of fabricating and testing fluidic generators at a rate of 5,000 per month. The recommended fluidic generator assembly redesign did not affect its functional operation, but did affect interchangeability of parts that are fabricated in accordance with the baseline drawings and the MMT redesigned drawings. Present plans require the utilization of eight automated assembly/test machines to optimize fabrication, assembly and test operations for the fluidic generators.

The redesigned generator components reduce the cost of piece parts and increase part compatibility for automated assembly and test techniques. Simplicity of operation of test and assembly equipment was given major consideration throughout the design phase. The use of the test equipment has significantly reduced labor cost for each generator.

#### **BENEFITS**

This program has established an approach for fabricating and assembling a fuze fluidic generator at a substantially reduced cost by the:

- ° Development of an investment casting process to produce the two magnet keepers that were formerly machined.
- ° Design and fabrication of an automated fluidic generator test system.
- ° Design and fabrication of an automated assembly machine to assemble the coil and magnet assembly.

#### **IMPLEMENTATION**

The assembly machine successfully assembled the coil and magnet, and was conditionally accepted by HDL in December 1983. During the course of machine fabrication, engineering development altered the design of piece parts for the coil and magnet assembly. This machine was not modified to assemble coil and magnet assemblies having these revised parts.

Following the acceptance demonstration, the machine was transferred to the contractor's facilities. The contractor was to modify the machine to assemble the revised parts. These machines will then be used to assemble coil and magnet assemblies as defined by the updated technical data package.

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

MMT Project 580 1001 titled "Pilot Line for Fuze Fluidic Power Supplies" was completed by the US Army Electronic Research and Development Command in January 1981 at a cost of \$253,000.

**BACKGROUND**

Fluidic generators are being used as power supplies for a variety of rockets and bombs. Proper operation of the present design of these generators depends largely on a complex geometrical configuration in which allowable dimensional deviations and interplay between components are extremely critical. The requirement for close tolerance fabrication and assembly of precision components results in high manufacturing costs and low yield for these devices. There was a need to establish economical manufacturing processes and techniques for mechanizing the assembly line for the production of fluidic power supplies.

**SUMMARY**

The objective of this project was to establish a production capability to manufacture ring-nozzles, slotted collars, magnets and associated fluidic generator parts as well as a pilot line for the assembly of these parts into fluidic generators. See figure 1. This project and activities were defined and funded by phases and tasks. Phase I entailed an engineering study to define those production components and manufacturing techniques necessary to fully automate the manufacture and reduce the cost of fluidic generators.

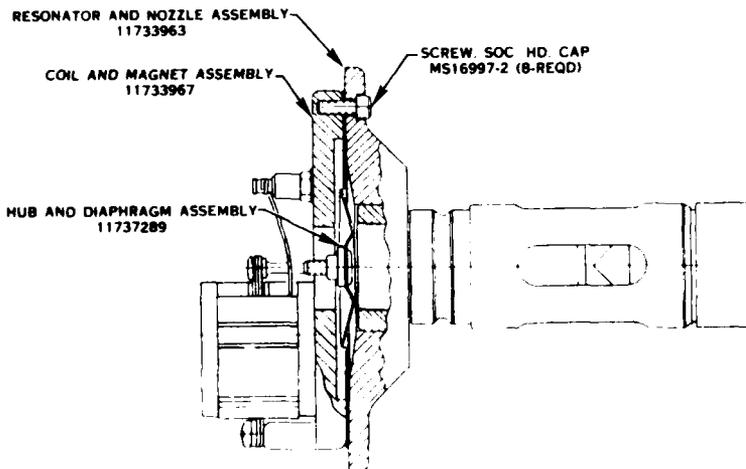


Figure 1 - Fluidic Generator Assembly

Welding parameters were also developed for aluminum in anticipation of utilizing aluminum alloys for missile container fabrication. Laser welding of aluminum produced welds of poor quality and erratic producibility. The problem was attributed to poor coupling of the laser beam due to the high reflectance of the aluminum.

Various techniques were investigated to counter the reflectance. Aluminum alloys were painted with carbon black, various paints, and anodized coatings. Results indicated that coupling of the laser beam is a function of the type and thickness of the coating. For example, anodic coatings coupled much better than paints. However, as with other coatings which differ from the base metal constituents, weld quality was impaired.

The most efficient coupling was one where the reflected beam was redirected back to the workpiece via a copper mirror located just above the weld zone. This arrangement, in addition to a helium jet gas shielding design, significantly improved coupling efficiencies; and often more than doubled the heat input over the conventional gas shielding system.

Laser welding of missile containers was shown to be feasible; however, to be economically effective, extensive modification of weld joints, current manufacturing sequences, and design standardization of the multitude of types of shipping containers would be necessary in order to maintain a simple mode of external optics. Complex optics systems would not be economically suitable for the quantities of containers currently manufactured.

#### **BENEFITS**

A process was established to laser weld missile containers. There are no benefits due to the complex shape of the various containers along with low volume.

#### **IMPLEMENTATION**

None planned at this time.

#### **MORE INFORMATION**

Additional information covering this project may be obtained from Mr. Phillip Ormsby, US Army Missile Command, AV 746-4933 (205) 876-4933.

Summary report, Dec 84, was prepared by Wally Graham, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MNT Projects 378 3441 and 379 3441 titled "Application of Laser Welding to Missile Hardware" were completed in June 1984 by the US Army Missile Command at a cost of \$490,000 and \$400,000, respectively.

**BACKGROUND**

The CMU 238E missile storage container is a welded assembly consisting of several sub assemblies which are welded manually by the Gas Metal Arc Welding (GMAW) process. The present manufacturing process involves six operators and at times two welders. The low productivity of this welding operation suggested an automated process such as laser welding for investigation.

**SUMMARY**

The primary objective of this project was to demonstrate the application of high energy lasers by establishing the welding parameters and associated costs of the missile container manufacturing process. The secondary objective was to establish the effect of high energy laser beam in welding aluminum.

The welding parameters were established for the steel used in the missile container. Various test pieces were welded to determine the acceptable welding process. Figure 1 shows typical weld joints which were investigated.



Figure 1 - Typical Cross-Sections of Laser Welds on 1/8" Steel Missile Container Material Welded at Optimum Parameters

The program also revealed generic rotary roll forming technology can be applied to integral flow-forming of rocket motor case nozzles. However, flow-forming (spinning) machines with the required capacity, rigidity, accuracy, and higher power are not yet part of the US Industrial Base.

#### **BENEFITS**

This program has fallen short of its goal to provide a less expensive rocket motor case. The results of the study showed that rocket motor cases, through the manufacturing technology developed in phase 2, would cost 58% more than the present method of manufacturing. The three roller flow-forming machine required in this procedure is not yet part of the US Industrial Base.

#### **IMPLEMENTATION**

The manufacturing procedure developed in phase 2 of this project is available for implementation, but the US does not have the industrial base for this method of manufacturing rocket motor case nozzles.

The cost analysis developed through a short production run does not indicate feasibility of using this method of manufacturing rocket motor cases.

#### **MORE INFORMATION**

Additional information may be obtained by contacting Mr. William Crownover, MICOM, AV 746-5821 or Commercial (205) 886-5821.

Summary report, Dec 84, was prepared by Rolf Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.



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

MMT Project 381 3294 titled "Production Process for Rotary Roll Forming" was completed by the US Army Missile Command in August 1983 at a cost of \$175,000.

**BACKGROUND**

This project is a continuation of an FY80 project to utilize low cost mill products such as standard commercial tubing or pipe to produce motor cases for tactical rockets. The project shall establish manufacturing techniques and procedures for rotary forming of rocket motor cases.

The current manufacturing methods are expensive. Through the development of this technology, indications are that a significant reduction in manufacturing cost can be realized on an entire group of tactical rockets currently being manufactured or planned for production.

The first phase of this effort evaluated, justified and specified the optimum processing sequence for full nozzle forming to manufacturing rocket motor cases from electrical resistance welded (ERW) mechanical tubing or pipe.

**SUMMARY**

The objective of the second phase is to establish detail manufacturing procedures, analyze manufacturing cost, develop a concept demonstration with a short production run, and deliver rocket motor cases for test firing.

It was determined in phase 1 that three roller CNC flow-forming is the most feasible and least expensive of several methods previously investigated and, therefore, was the basis for the phase 2 manufacturing process.

The three-roller flow-forming of a integral nozzle into 1035 steel ERW (electric resistance weld) mechanical tubing encountered several problems.

There was a problem with the amount of ovality that existed in the tube. The mill reported near the completion of the program that the problem of ovality had been caused by strip annealing. The mill developed a procedure to full body anneal which is expected to minimize ovality. Standard tolerances appear to be attainable.

There was also a problem of availability within this country of a three-roller flow-forming machine with the capacity required to form the rocket motor case. Therefore, forming was performed on a Leifeld model ST56-75 CNC three-roller flow-forming machine in Ahlen, West Germany, at Leifeld and Co.

The FY81 project included consolidation trials and processing evaluation. Technical problems encountered resulted in difficulty in achieving both necessary shape and full density. A complete redesign and fabrication of new fluid dies to make impellers was completed.

Several compactions were run using mechanical presses without success in achieving the desired geometry and necessary titanium density required for a highly stressed part. Several recent changes include adding a "ceramic composite" block of material which becomes viscous at the compaction temperature (1750°F) to the top of the Fluid Die, and use of a 6000-ton capacity hydraulic press. Four impellers were compacted and evaluation of these parts indicated that satisfactory density was obtained and better dimensional control was demonstrated. As a result, a supplemental task was added to the program to fabricate four additional impellers and three pancakes for further metallurgical and dimensional inspection.

Future work on this effort includes: testing of the parts produced during this phase, fabrication of additional impellers and pancakes, final rotor fabrication, hardware evaluation, spin testing, material design data generation, final manufacturing specification, and preparation and delivery of final technical reports.

#### **BENEFITS**

These projects (FY79, 80, 81), in addition to the FY82 follow-on project, will result in a new method for manufacturing centrifugal compressor impellers. The powder metallurgy consolidation method will increase material utilization and reduce machining costs compared to current forging methods. In the size class pertinent to the auxiliary power unit, it is estimated the resulting manufacturing process will reduce the buy cost by approximately \$1300 per engine compared to a forged and machined impeller. The benefits of this effort will occur upon implementation after completion of the FY82 project.

#### **MORE INFORMATION**

Additional information on this project is available from Mr. J. Lane, US Army Applied Technology Laboratory, AUTOVON 927-2771 or Commercial (804) 878-2771.

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

The Fluid Die (figure 1), developed by Kelsey Hayes, consists of a steel body of integral or built-up construction with an internal cavity configured to the desired final part contour after consolidation. The cavity is filled with metal powder, evacuated, sealed, and hot forged to achieve powder consolidation. The resulting PM near-net shape is extracted first by machining and then by chemical pickling of the steel envelope. The forged PM detail may be finished (figure 2) to a final contour using chemical milling to remove the contaminated surface. The Fluid Die process has the potential for yielding titanium alloy centrifugal impellers with properties equivalent to those achieved by forging, but at reduced fabrication costs.

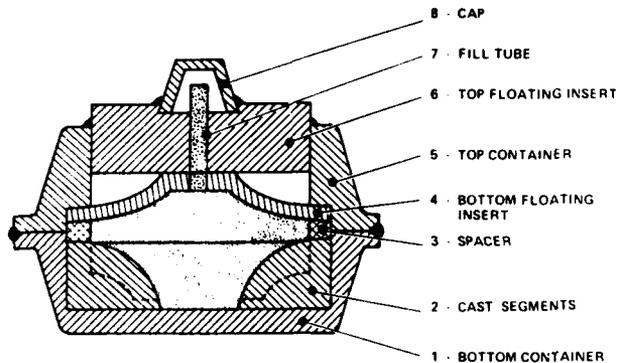


Figure 1 - Fluid Die Schematic

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



Figure 2 - First Iteration  
Ti-6Al-4V Titanium Alloy Impeller  
(S/N-4C1)

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

MMT Project 181 7291 titled "Titanium Powder Metal Compressor Impellers" was completed by the US Army Aviation Systems Command in June 1984 at a cost of \$229,000.

**BACKGROUND**

Centrifugal compressor impellers are typically produced by machining the flowpath and blades from oversized forgings. Impeller airfoils have complex shapes, high twist gradients, large camber and close spacing. Machining to net shape from oversized forgings results in a substantial loss of the forged material. Typically, 75 percent of the initial forging weight is machined as scrap. Labor costs associated with processing the forgings are approximately two-thirds of the total cost of the impeller.

By hot-isostatic-pressing powder metal (PM) to the near-net shape, material utilization is greatly increased. By chemical milling the aerodynamic surfaces to final tolerances, the labor costs associated with finishing operations inherent in conventional forging techniques are essentially eliminated.

This MMT effort is a joint service, multi-year investigation, funded by both Army and Air Force, under contract to the Garrett Turbine Engine Company.

**SUMMARY**

The overall objective of the four year effort (fiscal years 79, 80, 81 and 82) is to develop and validate the manufacturing process necessary for the fabrication of low-cost high-quality compressor impellers using powder metallurgy techniques. Development of this process, which is a co-funded effort with the Air Force Materials Laboratory, will provide fabrication processing for several components.

The FY79 project initiated a contract with the Garrett Air Research Manufacturing Company. Partial funding of the FY79 project limited the work accomplished to the design of tooling and associated tooling interface.

The FY80 project continued work on tooling to include tooling shape development. The objective of the contractual effort is to develop manufacturing technology for the production of integrally bladed impellers using titanium pre-alloyed powder and the fluid die powder metal consolidation process. The program is predicated on employing powder produced by using the Nuclear Metals, Inc. plasma rotating electrode process (PREP). This powder was selected for the fabrication of rotating engine parts since the PREP process theoretically is capable of yielding a titanium alloy product with an extremely low tungsten impurity content.

S/N	Casting Vane	Frequency Hz	Stress ksi, -	Cycles 10 <sup>6</sup>	Remarks
1	5A	1962	40	10.0	
	5B	1977	50	57.0	
	6A	1932	45	10.0	
24	3A	1836	40	10.0	
	3B	1856	50	10.0	
	4A	1775	50	10.0	
	6B	1868	55	0.93	
	4B	1788	55	0.59	
	5B	1920	50	8.6	
2	3A	1904	40	10.0	
	3B	1859	50	9.6	
	4A	1909	45	10.0	
	4B	1939	50	4.4	
	5A	1967	45	10.0	
	5B	1933	60	1.20	
16	6B	2009	45	4.05	
	3A	1852	40	10.00	
	3B	1910	50	10.00	
	4A	1933	60	0.53	
	4B	1848	55	4.95	
	5A	1789	50	0.84	
8 1	5B	1724	50	10.00	
	6A	1843	65	0.51	
	6B	1877	60	0.71	
	6	1281	50	1.8	
	8	1160	45	10.0	
	16	1204	45	2.2	
8 2	6	938	50	10.0	
	8	846	55	10.0	
	10	818	60	3.7	
	12	770	60	10.0	
8 3	1	993	50	10.0	
	3	1026	45	10.0	
	5	1091	40	10.0	
	7	961	40	2.7	
	9	1126	40	10.0	
	11	991	60	0.19	
8 4	15	928	55	0.84	
	2	1278	50	10.0	
	4	1152	55	10.0	
	8	1142	60	2.1	
	10	1024	45	10.0	
	12	1024	40	10.0	
	14	1172	60	0.4	
	16	1256	60	0.17	

Figure 1 - High Cycle Fatigue Properties

**IMPLEMENTATION**

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

**MORE INFORMATION**

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

Summary report, Dec 84, was prepared by Wally Graham, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 180 7285 titled "Cast Titanium Compressor Impellers" was completed by the US Army Aviation Research and Development Command in July 1983 at a cost of \$353,000.

**BACKGROUND**

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

**SUMMARY**

The major objective of this program is to develop and demonstrate a pilot production process for investment casting titanium centrifugal compressor impellers to near-net shape. The compressor impellers were produced and tested to completely evaluate the economic advantages of the selected casting technique and processing against life cycle costs of the conventional forged and machined compressor impeller. Twenty 250-630 castings and 13 GMA500 second stage castings were produced from the pilot production run. Specimens were tested for tensile and high cycle fatigue properties. See figure 1. The tooling and wax patterns for the production run were ordered. A detailed analysis of the processes developed will be reported in the final year of this project.

**BENEFITS**

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

## **SUMMARY**

The objective of this project was to establish a commercial manufacturing process for a hot isostatically pressed (HIP'ed) cast titanium rotor hub for the Blackhawk Helicopter. The scope of the effort encompassed three phases - two of which are covered in this report. Phase I effort included performing a technical assessment of the capabilities of titanium casting suppliers, hot isostatic processing subcontractors and heat treatment vendors. A specification and a drawing for the production cast Blackhawk hub were prepared.

Phase II included the letting of contracts to vendors for the actual castings, heat treatment and test evaluation. The hub castings were made and evaluated. Work on the last two of the 11 cast hubs required for this program was stopped because of technical problems, although the tooling for molding, casting, and processing the cast hub were adequate to fabricate prototype parts. The fatigue evaluation of specimens machined from three hubs revealed that this material has a large coefficient of variation (scatter) compared to forged titanium hub materials ( $S/X = 23.9\%$  as opposed to  $10.9\%$  for typical titanium forgings). Fracture examination of the test specimen depict the existence of anomalies which are considered a contributing factor in the fracture mode and in the wide variations observed in the generated data. For that reason, the cast titanium hubs prepared under Phase II do not have adequate material properties for use as a UH-60 rotor hub. The casting vendor launched a cooperative program to investigate the nature and sources of foreign material which caused the excessive fatigue scatter. Results of the investigation identified sources in the process for most of the "low" fatigue failures which caused the excessive scatter. Therefore, implementation of the technology of a cast rotor hub for the Blackhawk was unlikely. In order to salvage the technology and available funds, it was mutually decided that the contract should be modified to cast a damper bracket for the rotor section of the Blackhawk. This will be reported on when completed.

## **BENEFITS**

The knowledge learned thus far will be applied to the Phase III portion of the effort.

## **IMPLEMENTATION**

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

## **MORE INFORMATION**

Additional information may be obtained by contacting Mr. Frank Hodi at AV 955-5475 or Commercial (617) 923-5475.

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Summary report, Dec 84, was prepared by Wally Graham, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 677 7753 titled "Noise Suppressor for Powder Type Recoil Mechanism Testing Machine (Powder Gymnasticator)" was completed by the US Army Armament, Munitions and Chemical Command in June 1984 at a cost of \$385,000.

**BACKGROUND**

Function firing and engineer testing of large caliber gun mounts and recoil mechanisms have been performed on the powder gymnasticators at Rock Island Arsenal for many years. Powder gymnasticators exercise the weapon component by exploding a small charge in an open test environment providing an attractive, economical alternative to live firing.

The primary drawback to the powder gymnasticators is the noise they produce.

**SUMMARY**

The objective of this project was to design and fabricate a noise attenuator which could be placed over the powder gymnasticator to reduce testing noise to a level which would be in compliance with state laws. This meant reducing the average peak noise level at a distance of 2000 ft. from the gymnasticator from the current 115 dB(A) peak to 56 dB(A) peak.

The project ran into a number of difficulties basically because prospective contractors did not comprehend the extremely harsh environment that the noise attenuator would be subjected to (pressures created by up to 23 ounces of powder, see figure 1). An acceptable design was, however, ultimately presented and a noise attenuator system was fabricated.



Figure 1 - Recoil Mechanism Being Exercised (US Army photograph)

The noise attenuator is made up of three main parts; a stationary buttress wall, a moveable shell, and an exhaust blower (see figure 2). The system measures approximately 43 feet in length, 12 feet in width, and is 8 feet high. The basic construction uses a lamination of 1/4-1/2 inch steel plate, 6 inches of white foundry sand, 1/4-1/2 inch steel plate, 2 inches of vinyl covered fiberglass, 4-6 inch air space and 1/8-3/16 inch perforated stainless steel plate.

The noise attenuator was tested. Although the noise level from the powder gymnasticator was not reduced to 56 dB(A) peak, it was reduced to a level that should be acceptable in light of new regulatory criteria for explosive blasting.



Figure 2 - Noise Attenuator (US Army photograph)

#### **BENEFITS**

This project was conducted to bring test procedure in compliance with state laws.

#### **IMPLEMENTATION**

The noise attenuator is being incorporated into the standard operating procedure for recoil mechanism and gun mount testing with the powder gymnasticator at Rock Island Arsenal.

#### **MORE INFORMATION**

Additional information and a copy of the final technical report is available from Mr. Jerroll Hansen, Rock Island Arsenal, AUTOVON 793-6745 or Commercial (309) 794-6745.

Summary report, Dec 84, was prepared by J. Sullivan, 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 677 7814 and 678 7814 titled "Synthetic Quenchants for Heat Treating Weapon Components" were completed by the US Army Armament, Munitions and Chemical Command in June 1980 at a total cost of \$128,000.

**BACKGROUND**

The common quenchants, water and oil, have been regularly used for many years in the production heat treatment of weapon components. These conventional coolants cause distortion and cracks in complex workpieces, or excessive post-machining warpage. Attendant problems are nonuniform or incomplete hardening because of poor or spotty heat transfer, quenchant loss from mechanical dragout, and health and safety hazards such as fire, smoke, soot, and fumes. Working control parameters were to be established for the application of these water-soluble quenchants to production heat treatment.

**SUMMARY**

The objective of the project was to evaluate the use of commercially available synthetic quenchants to replace most oil, water, and brine quenching at the Rock Island Arsenal heat treatment shop. Improvements regarding fire, safety, health, and a more uniform surface hardness were anticipated. In this project, the quenching applications of oil, water, and solutions of UCON A, UCON B, UCON C, and UCON HT in water were analyzed.

The heat treatment practices and schedules were analyzed along with the recent history of acceptance/rejection. Components that were typical, more frequently quenched, or more difficult to heat treat were selected. From these examples, four steels, SAE 4140, SAE 8740, gun barrel steel about 2 inches in diameter covered in Mil-Spec 11595D, and Class IV steel covered by Mil-Spec QQ-S-681, were selected for study. The latter is a statically cast steel. The others are normally used for wrought products and occasionally centrifugally cast tubing. The effects of applying UCONs C, HT, B, and A to the heat treatment of these steels were determined.

The contractor performed dilatometric tests on each of the steels. From this data temperatures were selected for austenitizing these steels as follows:

<u>Steel</u>	<u>Austenitizing Temperatures</u>
SAE 4140	1500 degrees F
SAE 8740	1550 degrees F
Class IV	1650 degrees F
Gun Barrel	1550 degrees F

The contractor devised a variation of the Jominy end-quench test procedure to evaluate quenchant selection for these steels. In this test, bars of steel one-inch in diameter are austenitized, then quickly placed in a fixture which causes one end face to be quenched over a flowing fountain of quenchant. Normally, water is the quenchant, but in this non-standard test, various concentrations of UCONs in water were used. Hardness tests were then performed at various distances from the quenched end. To supplement the data and to provide information on cracking tendencies, the Jominy bars were re-austenitized and quenched by immersing entirely into the quenchant. The surface hardness values from these immersion tests were used as the surface hardness values in later analysis. The hardness values at .125-inches from the quenched ends in the Jominy tests were also used in this analysis.

A testing device was fabricated to provide a quick, easy method for comparing heat extraction capabilities of different quenching media. It consisted of a wire heated by alternating current with the attached thermocouple junction. When the temperature stabilized, the power input, which was assumed to be equal to the heat extracted by the quenchant, was recorded as a function of the temperature. As expected, greater heat was extracted at higher temperatures. The hot wire device shows UCON C cools similar to brine when the component is above 1400 degrees F and similar to water when the component cools below 1200 degrees F. This makes it a desirable quenchant for the Class IV steel. The cooling capability of 30% UCON A is similar to water when the components are 900 degrees F or less. UCON C is a good quenchant for Class IV steel since it through hardens the steel and quenchant concentration affects surface hardness. The latter phenomenon allows surface hardness measurements to indicate the existence of an acceptable hardness profile throughout a component and also enables the heat treater to decrease the surface hardness if quench cracking ever becomes a problem.

SAE 4140 components about 1-inch in diameter should not be quenched in UCON's A or HT because of potential cracking and/or rapid loss in hardness near the surface. With SAE 4140 steel, UCON B at about 25% should yield a hardness profile near the surface similar to oil, but it is more difficult to perform quality control checks since the surface hardness remains relatively constant with concentration changes; whereas, the hardness gradient changes significantly.

SAE 8740 can probably be quenched in UCON HT and also possibly in concentrations of UCON B near 20%; however, additional tests on a variety of components would be needed for verification. Gun barrel steel about 1-inch to 2 1/2-inches in diameter is susceptible to cracking in UCON A. As expected, cleaner steels reduce the tendency to crack.

Attempts to replace common quenchant for heat treating a given steel, e.g., replacing oil with synthetic quenchant for oil hardenable steel grades, must include separate quenching trials for each alloy in a wide range of actual component configurations.

## **BENEFITS**

Limited control parameters have resulted from these projects; however, some benefits have been realized by reducing the amount of scrap material, by improving the quality control, and by reducing health and safety hazards. These benefits will be increased since work is continuing in a manufacturing support effort to improve Rock Island Arsenal's quench practices.

## **IMPLEMENTATION**

Based on the results of this project, the heat treatment shop has switched back to oil for most quenching of SAE 4140. Because quenching the long gun barrel tubes in oil presents a safety and fire hazard, quenching in UCON A between 27% and 30% has continued. Meanwhile, the performance of UCON's in quenching SAE 4140 and gun barrel steel is being compared with that of other synthetic quenchants in an ongoing manufacturing support effort.

## **MORE INFORMATION**

Further information may be obtained from Dr. Richard Kalkan, Rock Island Arsenal, AV 793-4627 or Commercial (309) 794-4627.

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Summary report, Dec 84, was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 681 7916 titled "Low Cost Mandrel Material" was completed by the US Army Armament, Munitions and Chemical Command in April 1984 at a cost of \$168,000.

**BACKGROUND**

The current mandrels used in swaging the 105mm, 120mm, 155mm, and 8" cannon barrels are made of solid tungsten carbide, which is very expensive. This material is brittle and subject to premature failure without warning. These failures cause not only the loss of the mandrel, but also the loss of the gun tube.

The requirements for a swaging mandrel are high hardness, high compressive strength, high wear resistance, high yield and tensile strengths, and minimum expansion and contraction caused by the constant heating and cooling from friction during the swaging process.

The swaging operation has been used at Watervliet Arsenal for approximately 20 years. Through the years, various tool steels have been tried and the solid tungsten carbide, presently used, has proven to be the best, although expensive, and not readily available in the large size required.

**SUMMARY**

The objective of this project was to develop a low cost swaging mandrel from a material that is readily available. The approach taken was to select a material for the core and exterior shell that would meet the structural requirement to produce an improved and less expensive swaging mandrel.

Marage 350 steel was chosen for the core material because the mechanical properties best met the requirements of the multitude of tool steels reviewed. Tungsten carbide coating was selected as the exterior shell as a result of tests made using sub-size mandrels. It exhibited the best characteristics for the swaging mandrel.

The 120mm and 105mm swaging mandrels were designed and constructed to evaluate their performance under production conditions. Five 120mm gun tubes were swaged consecutively with one mandrel. The mandrel was examined before and after each operation for scoring, flaking and shrinkage. The mandrel showed no adverse wear, shrinkage or any other signs of deterioration. All five tubes passed inspection by the Arsenal Manufacturing Division and were then finish machined and shipped as regular parts.

The results achieved show the tungsten carbide coated swaging mandrel to be a viable alternative to the solid tungsten carbide mandrel. The tungsten carbide coated mandrel is less expensive, and the coating wear can be measured so that the mandrel can be replaced before a catastrophic failure occurs.

#### **BENEFITS**

The total savings for ten years would be \$188,000.

#### **COST SAVINGS**

DESCRIPTION	105mm	155mm	8"
Solid Carbide Mandrel (presently used)	\$2,025	\$3,820	\$6,460
Carbide Coated 350 Marage Mandrel (new)	\$1,012	\$1,910	\$3,230
Cost Savings per mandrel	\$1,013	\$1,910	\$3,230

The amounts shown are based on 1979 dollars.

Another important benefit is that the coating wear can be measured and the mandrel replaced before a catastrophic failure can occur. The recoating of a thin layer of tungsten carbide on worn mandrels is much more cost effective than replacing the entire mandrel. The recoating reclaims the life of the mandrel at approximately one-third the total cost on a normal production order of mandrels.

The tungsten carbide coating of the mandrel eliminates the difficulty incurred in obtaining the large size monolithic block required for the solid tungsten carbide mandrel.

## **IMPLEMENTATION**

The tungsten carbide coated swaging mandrel will be implemented at Watervliet Arsenal when the conventional solid tungsten carbide mandrels, presently being used, are no longer of any value. The two tungsten carbide coated mandrels produced have been turned over to Watervliet Arsenal Operation Directorate for use on the production line.

## **MORE INFORMATION**

Additional information may be obtained by contacting Mr. V. Colangelo, AV 974-5827 or Commercial (518) 266-5827.

Summary report, Dec 84, was prepared by Rolf Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project **680 7927** titled "Generation of Base Machining Surfaces" was completed by the US Army Armament Research and Development Center in March 1983 at a cost of \$35,000.

**BACKGROUND**

To reduce the cost of manufacturing breech rings, the parts are produced in near net form. The near net shape must then be inspected and laid-out prior to machining. This process is usually accomplished on a layout table with the operator developing a model for the finished part. There are many problems associated with the layout phase. The operator must anticipate the stock conditions over the entire part while only being capable of laying out the part one surface at a time. The operator must make a value judgement while manipulating the part, weighing as much as 1500 pounds. Using the standard layout method can lead to variations in modeling that are hard to detect and cause manufacturing problems as the part is processed. The solution to the problem is a system that will permit the layout of the part to be done accurately and without manual manipulation.

**SUMMARY**

The project titled "Generation of Base Machining Surfaces" is a two year funded program, with this particular project designed to determine the engineering requirements of the system and to evaluate various technologies that meet the requirements. An engineering analysis of current layout procedures defined ten (10) "major" criteria (elements) that determined the specifications of the system, see table 1. The major criteria covered areas of part definition, quality, handling, inputs and outputs. Each element was then studied in detail to determine the optimum effect they will have. The study resulted in a fundamental description of the mandatory and detailed technical requirements. The system is called the Stock Verification Machine (SVM). The layout method uses the forging surface as the reference surface.

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| <ol style="list-style-type: none"><li>I. Part Definition and System Flexibility</li><li>II. Floor Space Reduction</li><li>III. Reduced Handling</li><li>IV. Improved Quality</li><li>V. Operating Time</li><li>VI. Part Inspection Criteria</li><li>VII. Layout Sequence</li><li>VIII. Operator Inputs</li><li>IX. System Inputs</li><li>X. System Outputs</li></ol> |
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Table 1 - Ten Major Criteria

The machine to be designed will separate the forgings into two groups. The first group will consist of those forgings the machine can layout, the second group will be the forging the machine cannot layout. This represents an important advantage of the machine; the manual effort can be concentrated on the forgings that require multiple degrees of freedom for layout while the machine can layout the remainder. The contract to design and develop the SVM was given to Computer Technology Corporation and will be completed with the second year of funding.

#### **BENEFITS**

Upon completion, the following benefits are expected: a 50 hour reduction in operation time in the layout process, a 75% decrease in floor space required for layout stations, reduced handling, and an improved quality in the layout process.

#### **IMPLEMENTATION**

Computer Technology Corporation of Milford, OH will design and develop the machine. Upon completion (late 1984) the machine will be sent to Watervliet Arsenal for testing and eventual implementation.

#### **MORE INFORMATION**

Additional information may be obtained by contacting Brian Rose, Watervliet Arsenal, Watervliet, NY 12189, AUTOVON 974-5590 or by obtaining the final technical report "Generation Base Machine Surfaces" from the US Army Armament Research and Development Center, Watervliet Arsenal.

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Summary report, Dec 84, was prepared by F. Stonestreet, 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 7928 titled "Robotized Benching Operation" was completed by the US Army Armament, Munitions and Chemical Command in March 1983 at a cost of \$113,000.

**BACKGROUND**

Past investigations pertaining to benching operations on breechblocks and rings have shown the current methods were unsafe for the operator and excessively time consuming. The operation took approximately 4 hours depending upon weapon and component with a considerable amount of time spent on grinding radii on the ends of internal segmented threads. In addition, there are various edges and surfaces on the outside of the breech ring which had to be ground. While performing these operations, the worker used a high speed air driven grinder. Because of the geometry of the component, visibility is poor. The combination of the air exhaust stream and the worker trying to improve his view, resulted in too high a frequency of eye injuries even though full face shields are used. A method was needed to relieve the worker from these hazardous working conditions.

**SUMMARY**

The thrust of this project was to determine the feasibility and requirements for implementation of a robot to perform the benching operations. It is anticipated that an industrial robot will not only eliminate the hazardous aspect of this particular benching operation, but will also reduce the metal grinding time.

Due to the intricate maneuvers required in grinding operations addressed in the project, the initial survey of the robotics market resulted in eliminating robots which were either pneumatically or hydraulically powered. The confined workspace, tolerance, material hardness and minute movements are factors which make an electric robot suitable for the task. The areas to be ground are within an eight inch diameter approximately six inches deep where one is attempting to put a series of .050 of an inch radii (+ .010 inches).

Even with an electrical industrial robot having the required precision and movements, initial testing did not prove feasibility of this robotic grinding application. Feasibility testing utilized ASEA's 5-axis Robot, IRB-6. Testing revealed that the normal method of "teaching" a robot, by using the "teach box", could not be used for this application.

The nature of the cutting action involved in metal removal by grinding imposes significant loads on the mechanism supporting the cutting tool. These loads cause deflections in the supporting member which are stored as strain energy much like the energy in a compressed spring. The mechanical

stiffness of the robot and this stored up energy caused abrupt tool movements which led to tool breakage and/or resulted in very poor workmanship. In most cases, the results were so poor that gouges were noted on either side of the thread, while the sharp edge to be ground remained untouched. This resulted in the requirement for a sixth axis to help resolve the problem.

The grinding tool had to be small, powerful, and have a tool holding method which permits rapid changing. The shape of the cutting tool must be carefully considered in order that it may be properly positioned and to assure the desired geometry is imparted to the workpiece.

The control unit, an integral part of the robot system, needed augmentation. It needed sufficient "intelligence" so that the user can direct the robot motions along a very complex and difficult-to-define path. The geometric definition of the cutter location is even more difficult to define using manual computation methods. Therefore, a computerized method of providing motion control information is a system requirement.

The consulting firm, ESI, proposed a system configuration to meet all of the benching operation requirements. This system consists of:

- (1) ASEA 6 KG Industrial Robot, IRB-6 with 5-axis of motion.
- (2) ESI built sixth axis to hold air driven grinding tool permitting tool positioning in 0.5 degree steps over a range of  $\pm 45$  degrees.
- (3) Chicago-Pneumatic No. CP-9107 grinding tool.
- (4) A computer system with CPU, disk storage, printer, graphics display and system console.
- (5) The Robot Programming Language (ROPL) will be written in Pascal.

The work on this effort is continuing under the second year of funding in YMT 681 7928.

## **BENEFITS**

Because the effort is ongoing, no benefits have yet been realized. Upon completion of the effort, the benefits anticipated are:

- (1) A reduction of 50 percent of the direct labor cost.
- (2) Elimination of hazardous work.
- (3) An increase in product quality from fewer component rejections.
- (4) Adaptation of robot to other repetitive or hazardous tasks for cost savings because of robot flexibility.

## IMPLEMENTATION

The system configuration developed in this project was finalized. ESI was contracted to build and test the system in MMT 681 7928. Figure 1 shows the robotic system currently under evaluation.

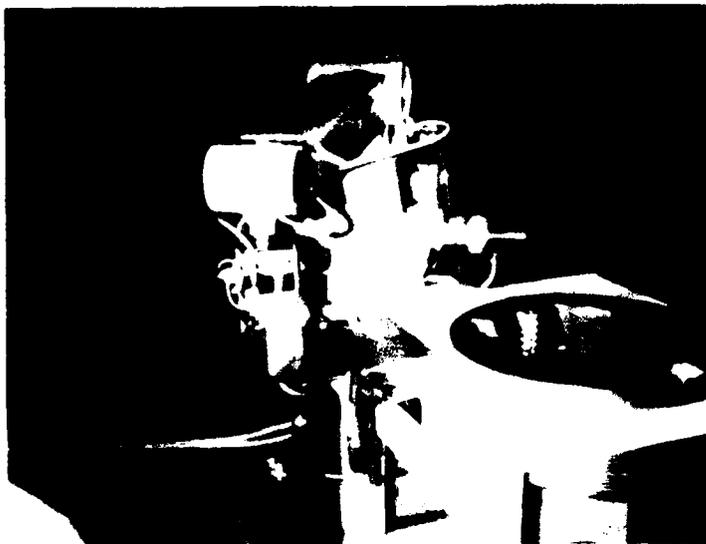


Figure 1 - Prototype Robotic Benching Operation

## MORE INFORMATION

For additional information contact Mr. Victor Montuori, AMCCOM, AUTOVON 74-5507 or Commercial (518) 266-5507. A letter final report is available (ARADCOM letter, DRDAR-LCB-SE, 30 September 1982, subject: Final Technical Report.)

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

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

Project 682 7940 titled "Synergistic Platings with Infused Lubricants" was completed by the US Army Armament, Munitions and Chemical Command in December 1964 at a cost of \$175,000.

**BACKGROUND**

The development of rapid fire weapons has resulted in increased wear in many of the moving parts. Present dry film lubricants, as well as greases or oils, tend to wear off with use and, therefore, require frequent reapplication to reservoirs. Such maintenance or built-in reservoir systems are not practical. The environment to which armaments may be exposed include dirt and moisture. Therefore, the coating must resist wear from the abrasive cutting action of dirt and it should be resistant to corrosion in wet environments. There is a requirement for a hard, self-lubricating coating for sliding surfaces.

**SUMMARY**

This project was directed toward advancing the technology to a stage where armament components can be coated for field tests. Non-destructive tests, process controls and quality assurance methods were to be optimized.

Control of the bath was done by conventional analytical procedures. A dual anode system was used to control the chemistry of the bath. With this dual anode system, 60 percent of the DC was used to deposit nickel and 40 percent was needed to deposit a combination of phosphorous and hydrogen. The technique for applying the coating was to electroplate an alloy as a "spongy" (porous) layer, heat treat to harden this alloy, then impregnate the pores with a solid lubricant. Several carbon and graphite powders were considered to induce porosity. Darco and Nuchar activated carbon powders were found more effective than graphite powders. The particle size selected was in the range 44-75  $\mu\text{m}$ . Heat treatment of the alloy was conducted at 400°C to harden the alloy. Quantimet-QT-M was used to measure present surface view on a screen. Open dot charts used in electroplating were used to determine porosity. Porosity to seventy percent surface void was found adequate to hold the lubricant.

A plating facility was designed, built, and delivered to ARDC. The facility consisted on a 300 liter polyethylene tank equipped with dual anodes; one for soluble nickel anodes and one for insoluble, platinized-titanium anodes. It also contained a make-up tank and a centrifugal sump pump for circulating and circulating the solution to keep the carbon particles in suspension. Figure 1 shows a schematic diagram of the facility.

Pumping tests of PBX-0280 slurry was conducted with a recessed impeller pump. The objective was to prove that explosive slurry can be pumped to the belt filter in a continuous mode of operation without particle size degradation. Evaluation showed that excessive pumping (1 hour or more) in a recirculating loop does result in particle size degradation. However, no particle size degradation occurred in all evaluations after 1/2 hour of pumping in the loop. It is felt that particle size degradation would not occur when the material is pumped from a storage tank to a filter. In this case, the material passes the pump only once instead of circulating for an hour in a loop through the pump as in the test.

The pilot Wolverine dryer was reactivated during the project effort. Lubrication, belt replacement and operational checkout of the exhaust fan, heater and dryer motors were completed to bring the dryer to operational status. The dryer will be evaluated during the FY83 project.

### **IMPLEMENTATION**

The scale-up of batch processes for LX-14-0 and PBX-0280 have been implemented at HSAAP. The implementation of dewatering technology with Eimco belt filter for Comp C-4, LX-14-0, PBX-0280 and W-109 precoat is planned as part of Holston AAP Comp C-4, Modernization Project 586 2054, Holston AAP HMX Special Production Project 587 2999, and Holston AAP RDX Special Products Project 586 3000.

### **BENEFITS**

Increasing the batch sizes for LX-14-0 and PBX-0280 resulted in a cost savings of \$265,000 and \$241,000, respectively, based on FY83 production quantities. The use of the Eimco belt filter for dewatering will increase process efficiency.

### **MORE INFORMATION**

Additional information on this project is available from Mr. W. Auyung, ARDC (Dover), AV 880-4123 or Commercial (201) 328-4123.

Summary report, Dec 84, was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

explosive was then filtered and dried. The process developed had an optimum batch size of 2,000 pounds. This process was developed by increasing the water/MEK ratio from about 5/1 for the 500-pound batch size to about 9/1 for the 2,000-pound batch size, and increasing the aging temperature from 60°C to 72-76°C.

LX-14-0 was produced in 550-pound batches in a water slurry process similar to the PBX-0280 process with minor variations. However, LX-14-0 has less stringent granulation requirements compared to PBX-0280 and therefore encountered less difficulties in scaling up the process to 4,000 pounds/batch.

The direct coating processes for PBX-0280 and LX-14-0 eliminated the lacquer preparation step in the current processes by adding ground Estane to an RDX or HMX, water and MEK slurry. The ground Estane was dissolved in the slurry. The processes were very similar to the current processes except for the dissolution of Estane. All process parameters were comparable to that of the current processes. A cost study on the direct coating process for PBX-0280 indicated that savings were marginal due to the extended digestion period for the Estane to dissolve. Therefore, it was decided that the production of PBX-0280 by the direct coating process would not be pursued. The direct coating of the LX-14-0 with the ground Estane appeared to be uniform and bulk density varied by less than 2 percent. Cost evaluation of the direct coating process for LX-14-0 indicated a cost savings of about 2 percent. A considerable investment was necessary for laboratory and end item testings to qualify the process. In view of the limited savings and the large costs for end item testing, it was decided that this effort would be discontinued.

Dewatering evaluations of direct-coated LX-14-0, PBX-0280 (regular production grade material) and W-109 precoat were completed using the pilot Eimco filter. All three (3) products filtered well. Moisture analyses for LX-14-0, PBX-0280 and W-109 precoat ranged from 9-11%, 15-20% and 9-11%, respectively. The granulation of the LX-14-0 and PBX-0280 was unaffected by the filtration operations. Initial filter leaf tests were completed for direct-coated LX-14-0, PBX-0280 and W-109 precoat. These tests used the same type of filter cloth as that used during the dewatering evaluations. Moisture content of the samples were somewhat lower than that of actual filtration data. This difference can be attributed to the higher vacuum levels obtained during the filter leaf tests. The dewatering study indicated that Eimco belt filter can be used effectively for the dewatering operation of the LX-14-0, PBX-0280 and W-109 precoat.

The Nautamix-Mixer Dryer was received and installed at Holston AAP. The Nauta equipment provided a thorough mixing action followed by a drying cycle. When drying was completed, the discharge was rapid with a clean separation of explosives from the vessel walls. Only a small amount of explosives remained attached to the top of the auger blade. However, tests with Composition C-4 indicated a lower heat transfer than the currently used equipment. Therefore, the Nauta equipment was a less efficient dryer than the current tilt kettle with horseshoe agitators.

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

MMT Project 581 4449 titled "Process Improvement for Composition C-4 and PBX Explosives" was completed by the US Army Armament Research and Development Command on October 1983 at a cost of \$290,000.

**BACKGROUND**

This project is a continuation of the effort to improve the present processes for manufacturing composition C-4 and PBX's. During the FY78 project, the process for C-4 was modified by using nominal Class 1/Class 5 RDX. This resulted in a cost savings and was implemented into production operations at Holston AAP.

Additional work was planned in this project to investigate areas of new or improved technology in the manufacture of PBX explosives.

**SUMMARY**

The main objective of this project was to improve the present processes for manufacturing PBX's by increasing the throughput of product with modernized equipment and modification of the present processes. This involved investigating present methods and applying new technology to coating, drying, and finishing PBX compositions.

Six areas were investigated under this project, to include scale-up of batch sizes for LX-14-0 and PBX-0280 coating operations; development of the direct coating processes for LX-14-0 and PBX-0280; dewatering of LX-14-0, PBX-0280, and W-109 precoat with the Eimco filter; pumping tests for PBX-0280 explosive slurry; the installation and evaluation of the Nauta blender/dryer; and the reactivation of the Wolverine dryer.

Original efforts to increase the batch sizes of LX-14-0 and PBX-0280 were initiated by MMT Project 580 4037. This project completed the technical and cost evaluations of the process changes. These changes were implemented in regular production beginning the fourth quarter of 1982. The original process of coating PBX-0280 in production consisted of adding an Estane/methyl ethyl ketone (MEK) lacquer to an RDX/water slurry. This caused the RDX and Estane to agglomerate and form granules. Quench water was added to harden the granules and prevent growth. The MEK was removed by distillation and the PBX

(NEPs) similar to those obtained during initial development. The instrument furnished by AADCO was expressly designed to provide a convenient method for handling and artificially aging a propellant sample while automatically analyzing for evolved oxides of nitrogen by chemiluminescent detection. (See figure 2 below).

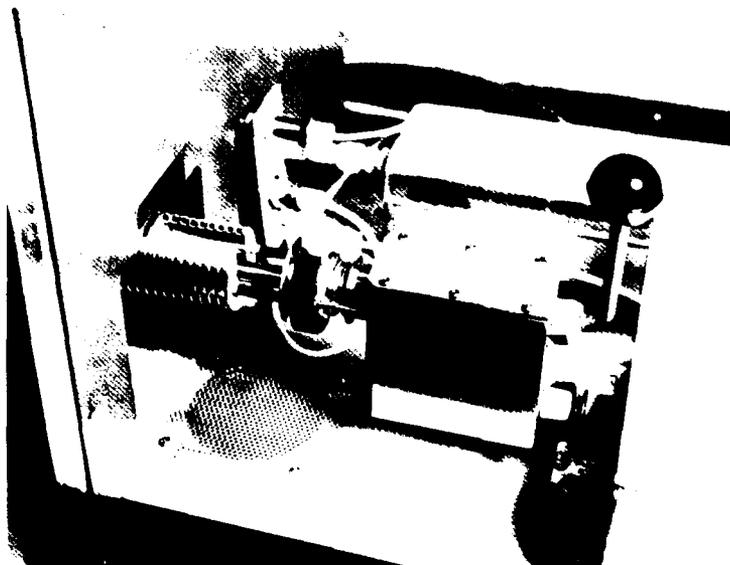


Figure 2 - Prototype Propellant Stability Analyzer

#### **BENEFITS**

Changing the testing and quality assurance programs presently being used for the batch method of manufacture to the new techniques and QA plan for the continuous process for processing 2.4 million pounds of M1 propellant can save approximately \$600,000 per year.

#### **IMPLEMENTATION**

The MMT results were implemented by revisions to MIL-STD-286 and MIL-STD-652. This action established an automated laboratory test for propellant acceptance which result in a reduction of test time and cost.

#### **MORE INFORMATION**

Additional information may be obtained by contacting D. Hansen, US Army Armament, Munitions and Chemical Command, AUTOVON 880-2856.

Summary report, Dec 84, was prepared by F. Stonestreet, Manufacturing Technology Div., US Army Industrial Base Engineering Activity, Rock Island, IL 61299

Considering equipment cost, as well as application needs, an inexpensive image analyzer from the Leity Company was chosen for extensive evaluation. The results of this evaluation demonstrated that the equipment chosen did satisfy Radford AAP's automated production line requirement for a rapid control and acceptance method. A laboratory investigation was conducted with the Leity Simplex Measuring Microscope with a closed circuit TV system was purchased. Figure 1 shows that system.

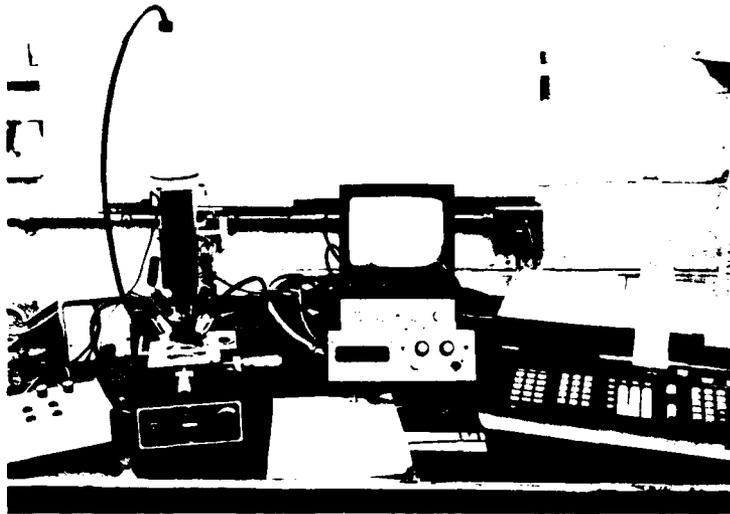


Figure 1 - Simplex System

When utilizing the Simplex Measuring Microscope, combinations of eyepieces and objectives were selected to provide the largest possible image of the grain's cross-sectional area on the TV monitor without exceeding two-thirds of the screen width. The magnified image on the TV monitor was obtained with the use of a tele-microscope. Two electronically generated filar lines on the TV monitor were positioned on the propellant features with the numerical distance between the two lines visually displayed on the electronic micrometer. By depressing a single button, the dimension on the micrometer was electronically entered into the programmed desk calculator for later computation.

#### Procedure for Rapid Assessment of Propellant Stability Prototype & Propellant Stability Analyzer

A feasibility study was conducted to determine if the chemiluminescent technique could be used as a rapid and suitable replacement technique for the "German" stability test. The results of the feasibility study indicated that the chemiluminescent technique would properly measure the shifts in  $\text{NO}_x$  levels.

After a review of several design packages and unit cost estimations, the unit contract was awarded to AADCO Incorporated. This instrument was found to meet the design specifications and to generate  $\text{NO}_x$  evolution profiles

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

MMT Projects 57T 4302 and 576 4302 titled "Acceptance Criteria for Continuous Single Base Propellant" were completed by the US Army Armament, Munitions and Chemical Command in the 4th quarter of FY 79 at a cost of \$506,000.

**BACKGROUND**

Prior to the completion of these MMT projects, the establishment of acceptance and homogeneity limits was heavily dependent on ballistic testing. The testing and collection of data using proven techniques generally requires extensive production output. To eliminate the Army's dependency on ballistical testing, two MMT projects (ref: 57T 4302, 576 4302) were initiated to establish nonballistic acceptance and homogeneity limits for M1 propellants produced on the Continuous Automated Single Base Line (CASBL). These limits were to be established for other propellants which were not evaluated in the original "Autocap" (MMT 573 4186).

The objectives of this project were to continue the effort initiated under the previous project (Autocap), to minimize acceptance testing, and insure acceptability of additional M1 formulations currently used by the Army.

**SUMMARY**

The effort initiated in the "Autocap" project, for the developing of new, rapid, and automated testing techniques and equipment was continued. The activities of these projects were slightly different from the work performed for "Autocap" in that rapidity of sampling-testing was the major consideration. Rapid sampling and testing are necessary on the CASBL so that both qualitative characteristics and process parameters can be determined and controlled to assure maximum probability of successfully making a quality single-based propellant.

In the Autocap program, several efforts were undertaken, such as the computerization and programming of the closed bomb and gas chromatograph for internal ballistic and green chemical analysis. Also, feasibility studies were performed on physical measurement and propellant stability.

Under these projects improvement in equipment and techniques developed under Autocap and implementation of the feasibility studies were carried out. This summary will highlight the more significant studies which took place.

Rapid Granule Measurement

For physical measurement of propellants to be manufactured in the new modernized facilities, new testing equipment, techniques, and specification changes were required. For this study, several pieces of equipment were considered.

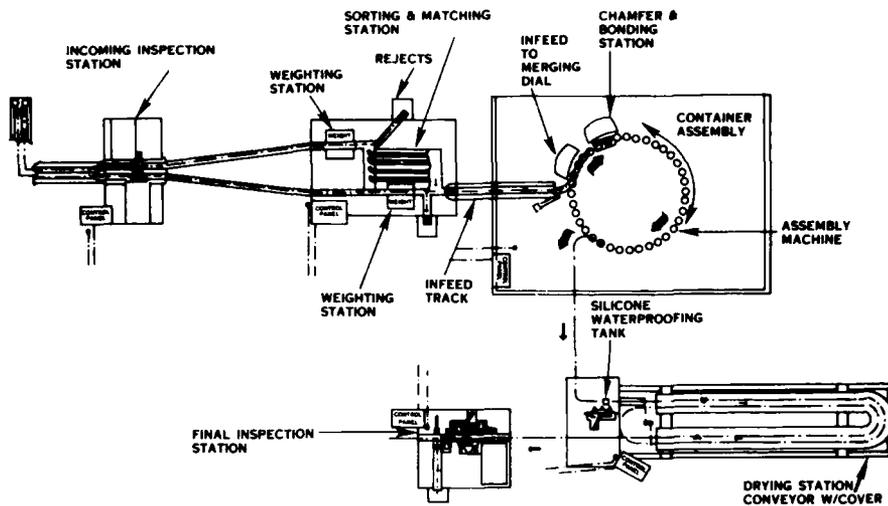


Figure 1 - Mortar Increment Container Assembly Equipment Layout

**BENEFITS**

The prototype slurry vacuum forming manufacturing/assembly system can reduce labor requirements from 20 operators to 6 operators with a reduction in item cost of 50-75%.

**IMPLEMENTATION**

The prototype lines to be built and tested will be made available to the private sector thru competitive part buys. This project will expand the Army's production base and eliminate dependency on a single source of supply.

**MORE INFORMATION**

Additional information concerning this effort may be obtained from Peter C. Bonnett, US Army Armament Research and Development Center, AUTOVON 880-5839 or Commercial (201) 724-5839.

Summary report, Dec 84, was prepared by F. Stonestreet, 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 4062 and 580 4062 titled "Automated Manufacturing Systems for Mortar Increment Containers" was completed by the US Army Armament Research and Development Center in August 1982 at a cost of \$1,393,000.

**BACKGROUND**

In the past, mortar increment containers have been manufactured on a developmental basis and by manual methods keyed to small quantities. As part of the Army mobilization requirements, private companies would be required to produce large quantities of containers, and the manufacturing capabilities of these companies are inadequate to meet the Army's needs. The current manufacturing base also creates high costs for the mortar increment containers. A high production and cost effective system must be developed to meet the mobilization needs.

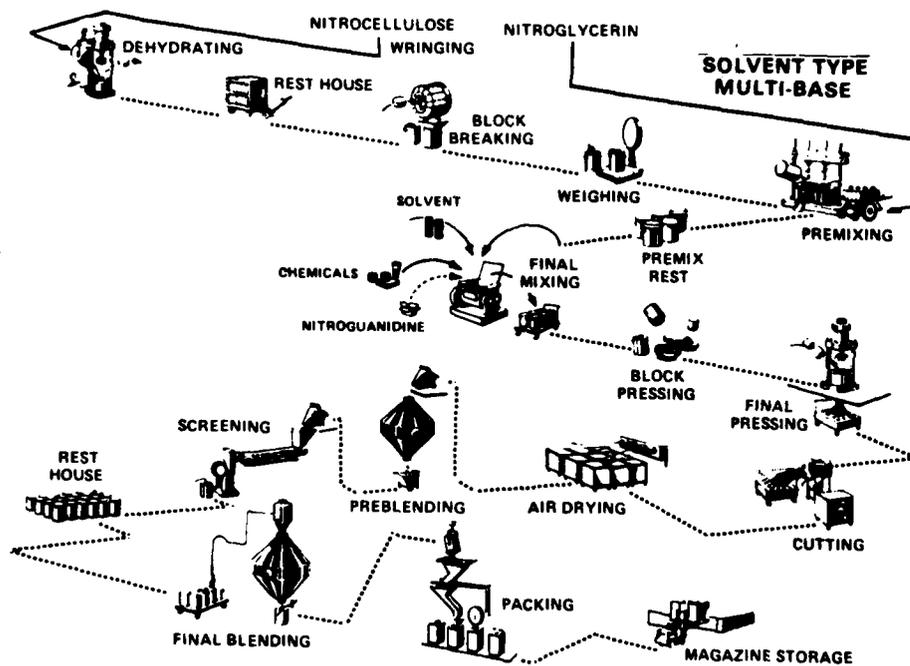
**SUMMARY**

The goal of the 1979 and 1980 effort was to provide a complete technical data package to be used in the development and fabrication of an automated manufacturing system for mortar increment containers. The manufacturing system consists of two subsystems; the part forming system and the assembly system. The part forming system can be either a slurry vacuum forming system or a paper molding system with either one capable of being used in conjunction with the assembly system.

The slurry vacuum forming system consists of three modules or parts; part forming, punch and trim turret, and inspection turret. As the name implies the system uses vacuum technology to form the container half. The container half is transferred from the first module, processed (cut and trim) and then transferred to the third module where it is inspected to strict quality standards. The container half is then transferred to the assembly system (see figure 1). The last two transfers are accomplished using robot technology. The paper molding system also consists of three modules; modules two and three are identical to modules two and three for the slurry vacuum forming system. The first module differs in that the station consists of 32 sets of male dies on which the container half is molded thru various stages. The container half is then transferred to the assembly system.

The assembly system interfaces the halves, making sure that they meet quality standards. The halves then go to a weigh, sort and match subsystem that is designed to reject halves not meeting a pre-established weight requirement. The halves are then assembled, bonded waterproofed, and inspected. A prototype of this automated manufacturing system can demonstrate significant reductions or even eliminations of many labor intensive operations.

# MUNITIONS



## CONVENTIONAL PROPELLANT MANUFACTURE

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

MMT Project M81 6390 titled "Program Implementation and Information Transfer" has been completed by the US Army Materials and Mechanics Research Center in December 1983 at a cost of \$250,000.

**SUMMARY**

The purpose of this project was to improve the dissemination of the results of the Army's Manufacturing Methods and Technology Program by publishing various technology transfer aids. The end products of this project include manufacturing technology transfer aids such as the Manufacturing Technology Journal, NTIS Manufacturing Technology Notes, Manufacturing Technology films and exhibits.

There is no technology developed by this project, rather this project supports wider dissemination of technology developed under other MMT efforts.

This is a continuing effort with current funding and planned out-year funding.

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

## **BENEFITS**

The project is in the development stage at present and benefits will not be realized until the total work effort is completed. A sharp decrease in time required to stamp a tube naturally will lead to a cost savings and an increase in production. In addition, the new system will remove the operator from the direct stamping process thereby eliminating a hazardous condition.

## **IMPLEMENTATION**

Upon completion of the follow-on project, the system will be proved out at the Watervliet Arsenal Production Facility.

## **MORE INFORMATION**

Additional information concerning this project may be obtained by contacting V. Montuori, Watervliet Arsenal, Watervliet, NY 12189, AUTOVON 974-5507.

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Summary report, Dec 84, was prepared by F. Stonestreet, 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 8151 titled "Portable Engraving System (CAM)" was completed by the US Army Armament, Munitions, and Chemical Command in March 1984 at a cost of \$96,000.

**BACKGROUND**

Gun tube identification is usually done by two different methods; stamped manually with a hammer, and alphanumeric stamp or engraved using a milling machine. The first method is time consuming and hazardous and the second method is very costly. A safer, faster and more cost efficient method is needed to perform the gun tube identification task.

**SUMMARY**

In an effort to solve the problem of an engraving system that is portable and efficient, three methods were studied. The first was the use of a laser to engrave the identification. However, it was determined that laser marking lacked portability. Chemical etching was investigated next but it did not provide the required penetration into the tube metal. The standard engraving method of stamping was determined to be the best but a portable system was unavailable, therefore, one had to be designed.

The system to be developed with follow-on funds incorporates a two-axis screw controlled X-Y mechanism with a pneumatically driven high speed carbide grinding burr. The system will use state-of-the-art computer technology to control and command the engraving unit. The operator's role in the engraving task is to line up the unit onto the gun tube and begin the engraving process. The entire process of locating, clamping and engraving will take only a few minutes. Figure 1 depicts how the system is set-up for use.

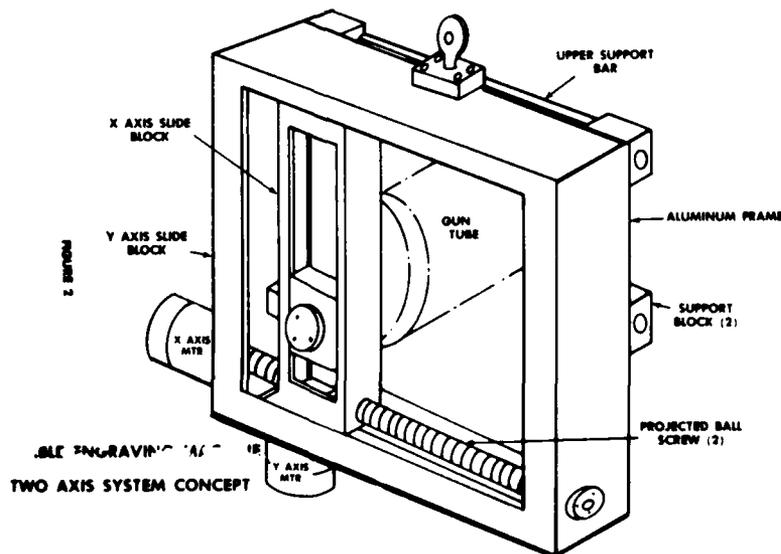


Figure 1 - Portable Engraving Machine

ME-32

## **IMPLEMENTATION**

Qualification testing (test firing) for coated weapon components will be carried out. These components include M16 components such as pin-bolt cam, hammer assembly, and key bolt carriers; and M60 operating rod assemblies. Upon completion of a successful testing phase, engineering change proposals will be initiated and executed. The acceptance of the ECPs will constitute the implementation phase of this program.

## **MORE INFORMATION**

Additional information may be obtained by contacting R. Jackson/M. Mankabadi, ARDC, AV 880-5746 or Commercial (201) 328-5746.

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Summary report, Dec 84, was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

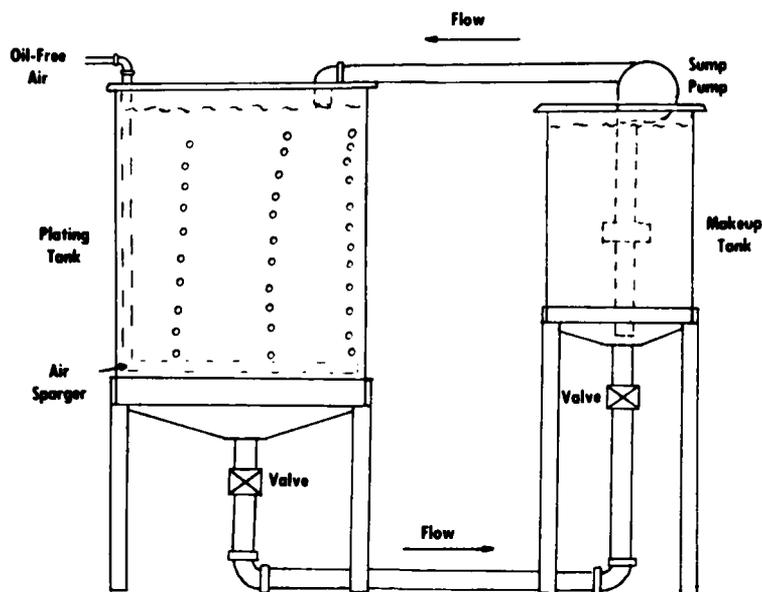


Figure 1 - Schematic Diagram of Plating Facility

Steel panels made of 1010 steel were evaluated after coating with two layers. The first layer was 12  $\mu\text{m}$  of nickel phosphorous without pores. The second layer was 13  $\mu\text{m}$  with pores which were formed by suspending the carbon particles and then impregnated with either nylon epoxy or teflon.

Weight loss measurements were made after 100 hours exposure in the salt spray test. Based on the weight loss measured, the nylon-epoxy lubricant provided additional corrosion protection to the alloy electroplate. The corrosion weight loss of the nylon-epoxy coated panels was about one-tenth of that for unfilled surfaces and about one-fifth of that for teflon impregnated surfaces.

Wear test samples show that teflon has the lowest friction and the lowest average coefficient. However, nylon-epoxy impregnated coating had slightly lower average scar width and average weight losses than the teflon filled coatings. The nylon-epoxy system is the preferred system.

#### **BENEFITS**

This program has established an approach for applying a lubricant-impregnated, nickel-phosphorous alloy coating on military hardware in a pilot scale facility. The coating has excellent wear resistance.

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

MMT Project 580 4508 titled "Process Improvement of Pressable RDX Compositions" was completed by the US Army Armament Research and Development Command in June 1983 at a cost of \$505,800.

**BACKGROUND**

This project is a continuation of the effort to improve the standard processes for manufacture of the pressable A compositions (A-3, A-4, A-5, and A-7). A previous review of the standard manufacturing processes for these products indicated that Holston AAP's production capabilities were severely limited by outdated coating, filtration and drying techniques.

An FY79 MMT project was completed on improving the current Wolverine Jet-Zone dryers located on line 1 at Holston AAP. In addition, a new type dryer, the Wyssmont Turbo dryer was recommended for use with future A compositions. This project concentrated on improving the coating and filtering processes for the A compositions.

**SUMMARY**

The primary objectives of this project were to evaluate process improvements for coating the A compositions, develop pilot filtration data and optimize the filter medium in order to design a filtration facility for the A compositions.

Initially, new slurry coating processes were proposed for each of the A compositions. The new process for the Comp A-5 involved the use of nominal Class 1 RDX in place of Class 3 RDX. Batches of A-5 were produced, tested and met the pressed density range and requirements of the specification. The sensitivity tests for the batches were also acceptable. The Comp A-5 produced by the new process exhibited a finer overall particle size distribution than the A-5 produced by the nominal Class 3 RDX process while still meeting all current product specifications. In addition, the Comp A-5 (nominal Class 1 RDX) had less residual solvent (cyclohexanone) than the standard process Comp A-5 (nominal Class 3 RDX).

The new processes for producing Comp A-4 and Comp A-3 involved the coating of RDX particles with wax dissolved in n-octane. The standard process produced a wax coating on the RDX particles from a water slurry. The Comp A-4 contained 91 + .07% RDX and 9.0 + 0.7% wax; whereas, the Comp A-3 contained 97 + 0.5% RDX and 3.0 + 0.5% wax. Several batches of both A-4 and A-3 compositions were prepared by the new process. The results indicated that the

RDX had a more uniform wax coating and the compositions were less sensitive to impact than standard compositions. Both compositions met all product specifications.

Based on the results with the new A-5, A-4, and A-3 composition processes, it was recommended that the results be used in the design of modernized facilities. However, since filtering of these compositions was a critical step, optimizing the filtering operation was programmed.

Previous efforts indicated success with the use of horizontal traveling belt vacuum filters made by Eimco for filtering Comp A-7 from water slurries. Therefore, an Eimco pilot filter facility was installed at Holston AAP to conduct an evaluation of the new A-5, A-4, and A-3 compositions. The filter measured 1 foot (0.3m) wide by 12 feet (3.6m) long with an effective filtration area of 10 square feet on the filter's vacuum deck. A layout of the equipment, including the Eimco Extractor, is shown in figure 1. Batches of explosives (A-3, A-4, and A-5) were dumped into the charging hopper located on the discharge end of the Eimco filter. Filtered water was then metered into the hopper to flush the explosives to a self-priming pump. The explosive slurry was then pumped into one of the three feed tanks mounted on the mezzanine level above the Eimco filter. The belt filter was started and the explosive slurry pumped from the feed tanks onto the filter belt. The slurry feed rate was varied to obtain product moisture data at various feed rates and vacuum conditions. The resulting dewatered product was reslurried and pumped to one of the two feed tanks not in use.

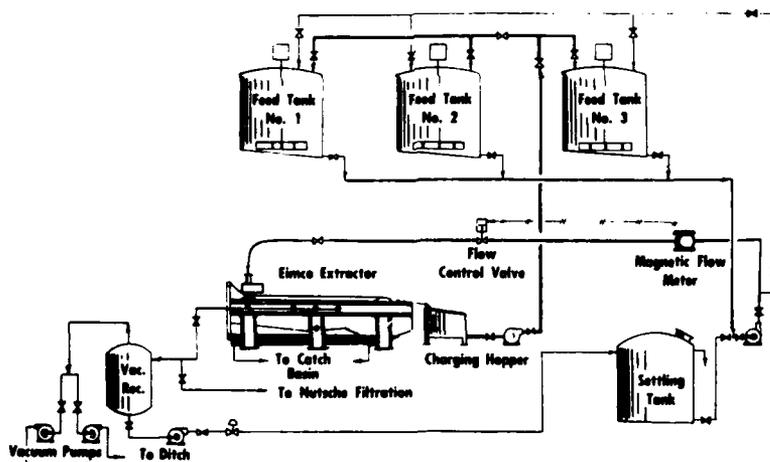


Figure 1 - Eimco Extractor

The batch filtration cycle previously described was repeated 2 to 3 times for each batch of explosives charged to the system. During the operations, process data was obtained on product moisture, feed rates, vacuum, and cake thickness. Based on the results of the filtration studies, the continuous filtration of the A Compositions was successfully demonstrated on a pilot scale with the Eimco filter. A design criteria for production scale units was established. In addition, the studies indicated that a polypropylene filter be used for Comp A-5 and that a polyester filter be used for Comp A-3 and A-4.

#### **BENEFITS**

A process was developed for manufacturing Composition A-5 utilizing nominal Class 1 RDX. The new process produced Comp A-5 with finer particle size distribution and less residual solvent (cyclohexanone) than the standard process. A n-octane/wax process was developed which resulted in a more uniform product coating and decreased impact sensitivity. In addition, the use of the Eimco filter to continuously filter the A compositions was successfully demonstrated.

#### **IMPLEMENTATION**

The process changes developed by this project will be implemented at Holston AAP.

#### **MORE INFORMATION**

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

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Summary report, Dec 84, was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 574 6571 titled "Engineering in Support of the Mortar Ammunition Metal Parts Modernization Program" was completed by the US Army Armament Research and Development Center in October 1979 at a cost of \$1,010,000.

**BACKGROUND**

A new mortar projectile metal parts manufacturing line was established at Riverbank Army Ammunition Plant. It was decided that the line was to have 60mm XM720 production capability. The existing method of manufacture of XM720 was unsuited for the new metal parts production line therefore, it was necessary to develop a process that would be compatible with the new line equipment and also meet all the technical data item requirements. Additional requirements were the investigation of the feasibility of eliminating or combining certain known operations, studies determining the adequacy of key equipment already installed, analysis of the effects of using powder metals and alternate wrought steels on metal parts and alterations of thermal treatment processes.

**SUMMARY**

The project was divided into eight phases to meet the above requirements for the XM720 60mm projectile, see figure 1. The first phase of the project involved processing 50 billets of AISI 1340 Steel in an effort to optimize die to punch flow relationships and meet hardness requirements. A new billet weight was achieved that resulted in a net savings of 6 oz/part. The second

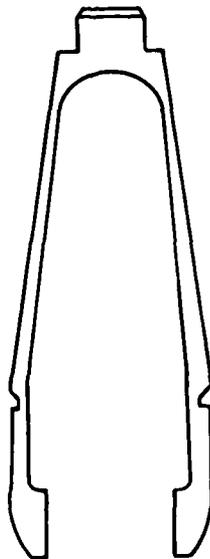


Figure 1 - 60MM XM720 Mortar Projectile Body

phase of the project was to demonstrate the mass producibility of the process. Five hundred billets were processed using the results of the first phase. The process proved to be highly reliable with a 99.2% acceptance rate. Further analysis of hardness and microstructure effects on fragmentation seemed necessary. In the third phase, seven different heat treatment cycles were performed and compared with parts not heat treated. All heat treated parts were successfully processed through a cold coining operation while the parts not heat treated broke or split during coining operations. This phase demonstrated the feasibility of a reduced heat treating cycle. The fourth phase of the project involved a study of alternative material for metal parts. Using the process developed in the first and second phases, parts were produced using AISI 1040 and 1541 steels. The parts were compared with the 1340 steel for fragmentation and mechanical properties. It was decided that AISI 1340 steel would be the best material for the metal parts.

The fifth phase was to determine whether or not there existed a need for purchasing new hydraulic presses. Tooling was modified for use in an existing 800 Ton press and again modified for use in a 1600 Ton press. In both cases it was determined that the two existing presses could fulfill the production requirements. It was decided that elimination of the profile operation, a machining operation that is prior to invert nosing, would reduce tooling costs; this was the goal of the sixth phase. Upon processing 100 pieces of AISI 1340 steel, it was determined that the profile operation could be eliminated. The seventh phase was to investigate the feasibility of combining the iron operation and the cold coin operation. One hundred pieces were processed up to the cold coin operation and then processed through a combined iron and cold coin operation. Upon inspection of finished parts, it was determined that the combined operation was not feasible; therefore, the seventh phase was terminated. The next and final phase was a material study using powdered metal preforms. The government supplied 62 powdered metal preforms to be processed. The tests demonstrated that there was no significant difference between wrought steel projectiles and powdered metal projectiles. This comprehensive study proved that the process as developed and refined is a production ready method of manufacture, adoptable to powder metal and eliminates unnecessary production steps.

#### **BENEFITS**

The results of this program have led to reduced costs due to the following: optimization of tooling, elimination of unnecessary operations, reduced thermal treatment requirements, lower scrap rates and improved coin tool life. Savings per part are estimated at about \$0.15; savings in equipment purchase (see fifth phase) is estimated to be over \$1,750,000. The net estimated savings on heat treatment equipment is over \$4,000,000.

#### **IMPLEMENTATION**

The process has been completely implemented at the Riverbank Army Ammunitions Plant for the production of both 60mm and 81mm mortar projectile metal parts.

**MORE INFORMATION**

Additional information may be obtained by reading the final technical report "Engineering in Support of the Mortar Metal Parts Modernization Program" or contacting Charles Sallade, US Army Armament Research and Development Center, Dover, NJ 07801. AUTOVON 880-6509 or Commercial (201) 724-6509.

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Summary report, Dec 84, was prepared by F. Stonestreet, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

MMT Project 578 6693 titled "Ball Propellant Deterrent Coating - CAM Related" was completed by the US Army Armament, Munitions and Chemical Command in March 1981 at a cost of \$167,000.

**BACKGROUND**

Previous R&D efforts identified the mechanism of deterrent coating and established a limited model for predicting the placement of deterrent in the propellant grain. Under a related effort, an overall mathematical model of the deterring process was outlined. Neither model has been demonstrated on production equipment.

**SUMMARY**

The purpose of this project was to join the results of the previous efforts and complete the mathematical model of the deterring operation. A review of prior open literature articles and Government reports identified two models for predicting the depth of penetration of dibutylphthalate (DBP) in ball propellant grains. The first model related the amount of DBP added and other chemical and physical characteristics to the depth of DBP penetration for a fixed processing time and temperature. Quantitative data from laboratory experiments supported the proposed model. The second model included, along with the DBP effect, a time dependency which together would predict the depth of penetration of the DBP in the ball propellant grains.

Neither model, however, had dealt with the effect of temperature on the rate and ultimate depth of DBP penetration. Furthermore, although the first model included the initial solvent (ethyl acetate) concentration in its formulation, no specific experimental studies were conducted to verify this portion of the model. Finally, no studies were conducted to determine what effect the particle size of the DBP in the emulsion, which is added to the propellant water slurry in the coating process, might have on the rate of DBP adsorption and the overall processing time.

As a result of these findings, it was decided to conduct further experiments: One established the relationship between agitation speed and the average DBP globule size in a water-DBP emulsion, followed by a companion experimental series to quantify the relationship between the volume concentration of DBP in the water-DBP emulsion and the resultant DBP globule size. The volume concentrations ranged from 25 to 50 percent to encompass the 37.5 percent concentration typical of production operations. The results of these tests showed that the volume concentration was a more reliable means of controlling the DBP globule size in the emulsion.

Following these preliminary experiments, two deterrent coating runs were conducted to establish if the DBP globule size would significantly affect its rate of adsorption by the propellant grains. It was established that the DBP was adsorbed more rapidly from the emulsion having the smaller average DBP globule size, but not significantly enough to be considered further in the context of the batch deterring methods in current use.

Next, an experimental plan was developed to evaluate the effect of temperature and added DBP on the depth of penetration of DBP in the propellant grains. Subsequently, a Scope of Work was prepared and contract awarded for the modification of an existing 5-gallon reactor and the improvement of the existing control system so that the results of the model development phase could be verified on a pilot plant scale. The design is complete and the process flow diagram is shown in figure 1.

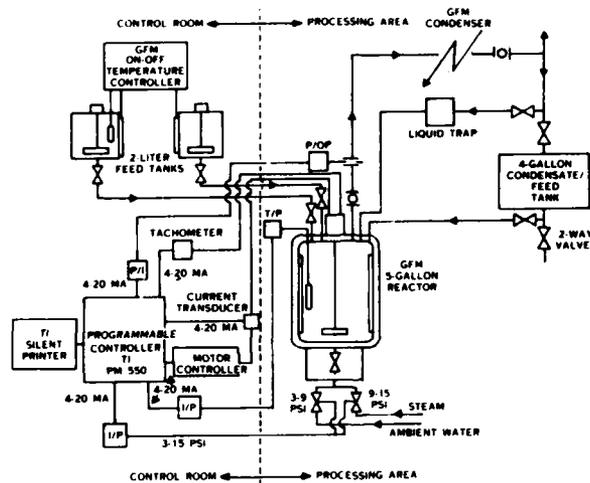


Figure 1 - Process Flow Diagram

## BENEFITS

Benefits will ultimately accrue in that a new preblend facility will not be required in the Ball Propellant Modernization Facility Project planned for Badger AAP. This would have cost in excess of \$500,000.

The avoidance of preblending will streamline ball propellant operations and the deterring operation will no longer be sensitive to operator influence. Hence, annual operating costs of \$600,000 can be avoided.

## **IMPLEMENTATION**

The experimental plan is being carried out in the FY79 portion of the program. The pilot plant system will verify the results of the model development phase of the program.

Eventual implementation of the project results will occur under the Badger AAP Ball Propellant Modernization Facility. This project, originally planned for the mid 80's, has been postponed to the 1990's time frame.

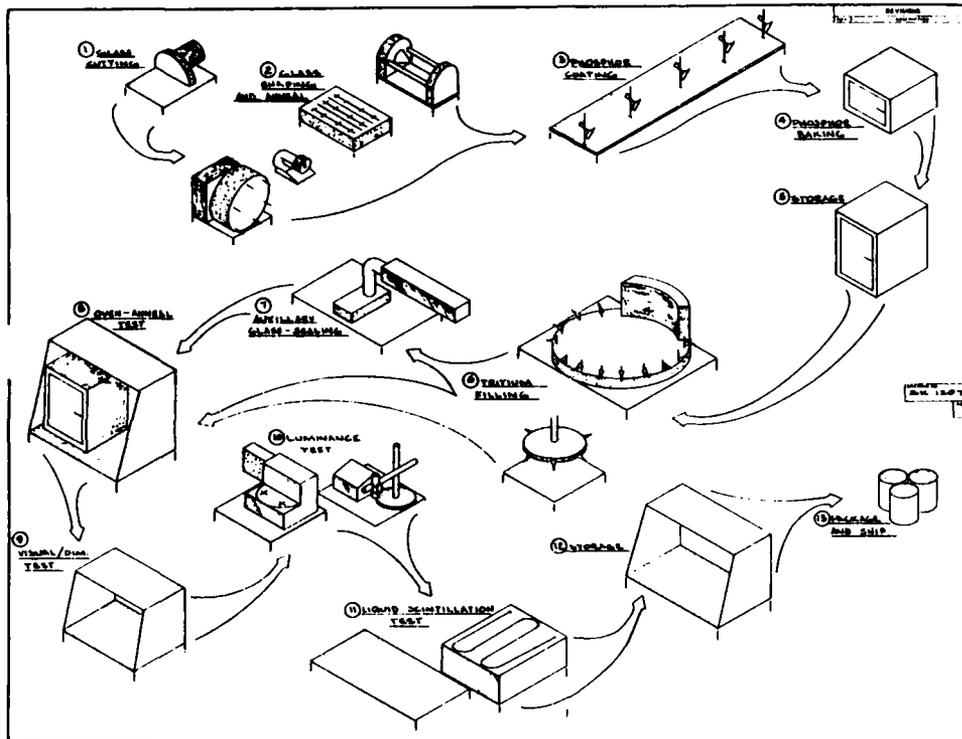
## **MORE INFORMATION**

Additional information may be obtained by contacting either Mr. Joel M. Goldman or Dr. Lillian Chen at AMCCOM (D), AV 880-6930 or AV 800-2693 or Commercial (201) 328-6930 or (201) 328-2693, respectively.

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Summary report, Dec 84, was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

# NON-METALS



SELF-LUMINOUS LIGHT SOURCE PROCESS

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

AMT Projects 177 7108 and 181 7108 titled "Manufacturing Techniques for Transmission Shaft Seals" were completed by the US Army Aviation Research and Development Command in March 1983 at a total cost of \$235,000.

**BACKGROUND**

Elastomeric lip seals are, in general, a low-cost, effective means of sealing transmission shafts where the pressure difference is moderate. However, where the input shaft speed is high, as in advanced helicopter transmissions, high surface velocities may result in early failure of the simple lip seal. This leads to early removal of transmissions for replacement. Since carbon rubbing surfaces perform much better than lip seals at higher surface velocities, NASA-Lewis designed a seal that would retain most of the low-cost advantages of an elastomeric lip seal and would yield high performance by incorporating carbon rings as the rubbing surface. A design constraint for the hybrid elastomeric seal was that it must be a direct replacement for presently used lip seals.

**SUMMARY**

The purpose of this manufacturing program was to develop the manufacturing technology for a NASA-invented, hybrid elastomeric seal employing segmented carbon rings carried in an otherwise elastomeric lip seal structure. Specific objectives were to develop processes and techniques for fabricating the carbon ring segments and molding the elastomeric element to accommodate the segments, and means to assemble the seal components. A representative cross section of the seal evaluated in this program is illustrated in figure 1.

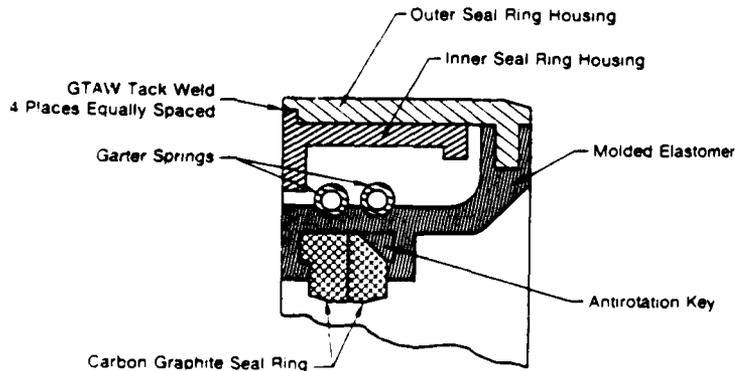


Figure 1 - Cross Section of Hybrid Elastomer Seal

The seal components consist of an outer seal ring housing to which is bonded an elastomer seal body. The seal body incorporates internal cavities sized to accept the segmented carbon graphite seal rings. Six antirotation stops are molded into the elastomer: three equally spaced for the oil-side carbon ring segments, and three equally spaced for the air-side segments, with one set offset 60° from the other. Two garter springs and an inner seal ring housing used for garter spring containment complete the seal assembly. Each assembled seal includes two three-segment, carbon graphite seal rings placed back-to-back. All segments are fabricated as a set.

The seal rings were manufactured using normal production tooling capable of providing acceptable piece parts in production lot quantities of 500 to 1000 total seal sets. The only difficult seal component to manufacture was the molded elastomer. In reviewing the design from the standpoint of manufacturing technology, it was concluded that the carbon segments were too slender and fragile to survive the rubber molding process if they were to be included in the mold. The approach taken was to mold precision pockets. The additional requirement that the carbon not adhere to the rubber after molding was easily met by this technique. A mold that would provide geometrically acceptable parts while accounting for the fluorocarbon shrinkage proved very difficult to produce and required several trial and error builds until a mold meeting this requirement was produced. The final mold design, capable of producing production lot quantities of molded parts, consisted of a single-cavity multipart injection mold. The natural variability of the shrink rate for molded fluorocarbon precluded maintaining the precise tolerances included on the piece parts drawings. Tolerances closer than +0.25mm (0.01 in.) generally could not be maintained. The normal variations which occurred in the molded parts examined in this program were easily accommodated by the flexibility of the elastomer.

The garter springs were made from AISI type 304 stainless steel wire. They were cut to length at assembly to ensure proper spring tension. Each seal component was inserted prior to assembly. Normal inspection-room metrology techniques were used and no special gages or fixturing were employed. Agreement between requirements and components was found to be good, with the exception of one area. This was the inability to hold the precise tolerances specified for the molded elastomer. Seal assembly was accomplished with a specialized fixture. The fixture includes a main body to which is keyed a removable lower seal ring indexer. The indexer contains three equally spaced separators for accurately positioning three adjacent carbon ring segments. After all six carbon ring segments are installed in the fixture, the seal ring clamp, also keyed to the main body, is positioned to retain the carbon ring. The upper seal ring indexer is then installed. The upper indexer, keyed to the ring clamp, also contains three equally spaced separators to orient properly the second group of three carbon ring segments. When assembling a seal, the seal's molded component, pressure side down, is lowered over the fixture until its seal ring retention lip passes over the carbon rings. The fixture is then inverted, the lower indexer removed, and the retention lip eased over the carbons. The fixture is inverted again and with some slight up and down motion of the elastomer, the upper indexer is removed. When the

bons are fully captured by the elastomer, the ring clamp is disassembled the seal removed. The springs are installed using another fixture. With bon rings installed, the seal is placed on the fixture; the garter springs then rolled over the fixture and into their proper positions in the seal.

Two seal sizes, 63.5mm and 139.2mm in diameter, were fabricated and embled. Samples of these seals were submitted to static and dynamic ts. The static tests, with the exception of widely varying leakage rates, e generally acceptable, but the dynamic test results were unsatisfactory. e seals exhibited excessive leakage, high friction torque, and high wear es. In addition, the mating wear surface (runner) displayed severe wear. s performance was attributed to test conditions that substantially exceeded ual conditions in a helicopter engine or transmission. These conditions e high differential pressure, surface velocities up to three times greater, l excessive oil impinging on the seal carbons. Additional work on hybrid ls performed in another program employed wind-back grooves in the carbon lling ring bores which resulted in zero leakage under similar testing ditions. However, time and cost constraints prohibited the incorporation this design change in a moderated testing program. Future tests are eduled after this program in a OH-58 helicopter transmission test on the IA-LEWIS 500-hp test stand.

#### **IEFITS**

The hybrid seals developed in this program were projected to be more ensive than the contemporary seals but would be beneficial in eliminating e three extremely costly seal replacements necessary between transmission l engine overhauls.

#### **PLEMENTATION**

Implementation of the hybrid seal is dependent upon the conclusion of the l-scale OH-58 helicopter transmission ground test. If the OH-58 seal is ccessful, implementation is possible on the OH-58 and UH-1 helicopters.

#### **LE INFORMATION**

A detailed technical report entitled "Hybrid Elastomeric Seals," AVRADCOM hnical Report TR 83-F-8, March 1983, is available from Mr. Fred Reed, US y Aviation Systems Command, AV 693-3079 or Commercial (314) 268-3079.

mary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing hnology Division, US Army Industrial Base Engineering Activity, Rock and, IL 61299-7260.

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

Projects 179 7113 and 180 7113 titled "Composite Rear Fuselage (CRF) Manufacturing Technology" were completed by the US Army Aviation Research and Development Command in July 1981 at a total cost of \$1,210,000.

**BACKGROUND**

The existing rear fuselage of the Blackhawk helicopter is a moderately sized, semi-monocoque, metallic structure. It is shown in figure 1. The foot-high, 8-foot-wide, 9-foot-long airframe section contains 1203 detail parts, 88 subassemblies, and 17,000 fasteners. Compound curvature in this section of the fuselage results in costly forming operations for skins and structural members, and the riveted construction makes the manufacturing operations highly labor intensive.

Preliminary IR&D studies conducted by the producer of the Blackhawk, Sikorsky Helicopter, showed that the rear fuselage parts count and associated labor could be substantially reduced by changing from metal to composite construction. The design approach used in these studies, however, relied heavily on the ability to cocure large complex structures for which manufacturing methods had not been proven. The need to develop these methods was recognized by government and industry at the first AVIATION MANTECH conference. At this conference, the airframe panel gave the proposal to conduct this work the highest priority of all programs considered.

**OBJECTIVE**

The major thrust of this effort was to develop and demonstrate cost saving manufacturing methods for building primary airframe structures with composites. This effort consisted of a manufacturing and component design phase and a manufacturing demonstration and component testing phase. This report will summarize the manufacturing and component design phase. The Composite Rear Fuselage (CRF) was designed to replace the metal rear fuselage between Stations 379 - 385 (figure 1) without changes in performance, external configuration, and interference requirements.

Design goals for the CRF, relative to the aluminum baseline, were to lower acquisition cost by 35%, lower weight by 10%, improve reliability, maintainability and repairability, improve ballistic survivability, and to improve pilot safety.

Although the basic structural arrangement was controlled by the existing interference requirements, design flexibility existed in the detail design of the individual composite skin panels, bulkheads and frames.

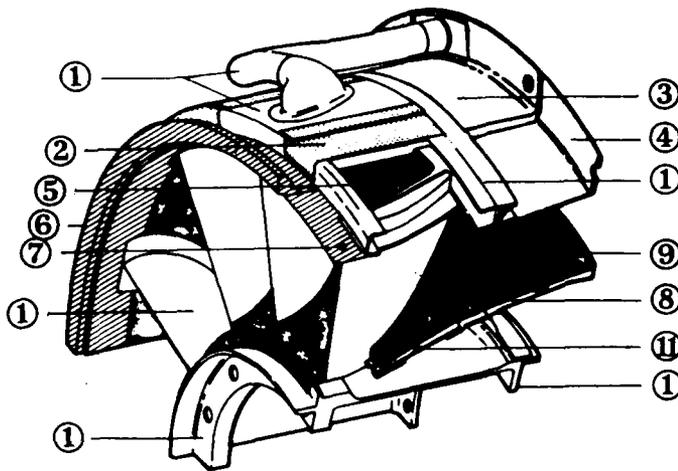


Figure 1 - Finished T700 Composite IPS Swirl Frame Assembly

TABLE 1				
T700 Composite Frame Components				
Part No.	Title	Material	Lay-Up Pattern	Thickness
1	Vanes, Rings & Cylinder	410 Stainless Steel	N/A	N/A
2	Skin, Outer	GI/GR/PMR15	0,+45,0,-45,0	0.53
3	Support Flange, Aft	GI-Gr/PMR15	0°, +45,0,-45,0 GI/Gr/GI/Gr/GI	.053
4	Flange, Aft	GI/Gr/PMR15	0,+45,0,-45,0 GI/Gr/GI/Gr/GI	.053
5	Panel Flow-path Outer	Al/GI/PMR15	(7) ply All 0°Oriented	.055
6	Flange, FWD	GI/PMR15	(0,45-0 <sub>3</sub> ,45,0) <sub>4</sub> (GI/G/GI <sub>3</sub> /G/GI) <sub>4</sub>	NA
7	Ring Flow-path, Outer	GI/PMR15	(0,45,0 <sub>2</sub> ,-45,0) GI/G/GI <sub>2</sub> /G/GI	.048
8	Skin Flow-path, Inner	Al-GI/PMR15	Ply	.055
9	Support, Inner, Aft	GI/PMR15	(0 <sub>3</sub> ) (GI) <sub>2</sub>	.024
10	Skin Manifold Inner	GI/PMR15	(0 <sub>2</sub> ) (GI) <sub>2</sub>	.026

\*Gr=Graphite fabric T300-3K-8HS  
 GI=Glass fabric 7781-A1100  
 PMR15=Polyimide resin  
 Al= Aluminized glass fiber

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

Projects 179 7200, 180 7200, and 181 7200 titled "Composite Engine Inlet Particle Separator" were completed by the US Army Aviation Research and Development Command in November 1983 at a cost of \$1,001,000.

**GROUND**

The Inlet Particle Separator (IPS) is the forward structure of the T700 copter engine. It consists of the initial section of the air inlet system provides attachment structures and interfaces for the mount attachment, engine support, nose-mounted gearbox, and inlet duct attachment. The IPS captures and exhausts overboard approximately 90% of all sand and dirt entering the engine intake.

This project benefited from previous R&D and IR&D programs. In these programs, the front frames for the FIDI engine (B-1 bomber), the YJ101 engine, the QCSEE engines were fabricated of composites, and were tested successfully. Weight savings of 25 to 35% were achieved. Most importantly, these programs established the overall fabrication, composites process development, and supporting design engineering bases necessary to conduct this program.

**MATERIALS**

This effort established production processes for the swirl frame of the inlet particle separator. A hybrid design approach was followed in view of the structural, anti-icing and other T700 requirements. The resulting design consisted of a metallic vane and hub subassembly integrated with the polyimide/glass, aluminized glass, or graphite composite components to form a rugged, low-cost frame structure satisfying all engine requirements.

A quarter section segment of the annular IPS swirl frame is shown in Figure 1. The various parts are keyed to table 1 in which the parts are named, the composite material and layup pattern are presented. The thickness of parts is also given. The composite matrix material, a polyimide, was selected to meet the heat and flame retardation requirements of the T700 engine. Aluminized glass cloth was required in the flowpath panels to meet the de-icing requirement.

s cost estimate showed that the redesigned components manufactured by the i-automated process would be more expensive than either the redesigned rs assembled manually or the currently planned production doors. The SAMS rs were estimated to be 81 percent more costly than the production doors, le the redesigned doors assembled manually would cost 35 percent less than production doors. This finding was the primary reason for terminating the gram, with the conclusion that the SAMS process is not an efficient one for ponents that require only a few layers of prepreg such as these doors. For ore complex structure, such as the wing skin of a fighter airplane that uires many layers of different sizes of prepreg plies laid down with many ament orientation angles, automation results in significant cost savings.

#### **EFITS**

Although the objectives of the program were not achieved, a side benefit ulted. The doors designed in this project for semi-automated production e found to be less expensive to produce than the existing door designs.

#### **LEMENTATION**

Partial implementation of the project results is being considered. An ort is currently underway to implement the UFD and WPD door designs eloped in this project, but the manual layup technique rather than the i-automated technique investigated in this project will be used to ufacture the doors.

#### **E INFORMATION**

Additional information is available from Mr. Fred Reed, AVSCOM, AV -3079 or Commercial (314) 268-3079. A technical report is also available: ni-Automated Composite Manufacturing System for Helicopter Secondary ctures" USAAVRADCOM - TR-82-D-3, Contract DAAK51-70-C-0014, August 1982, pages.

nary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing nology Division, US Army Industrial Base Engineering Activity, Rock nd, IL 61299-7260.

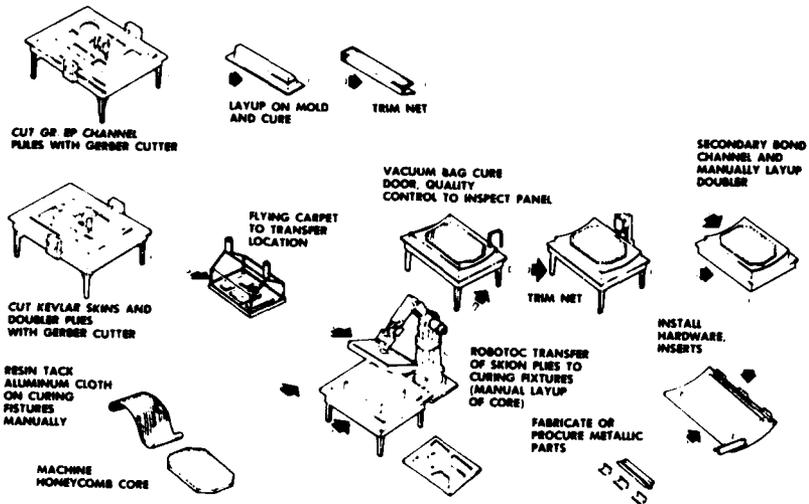


Figure 2 - Upper Fairing Door Fabrication Flowchart

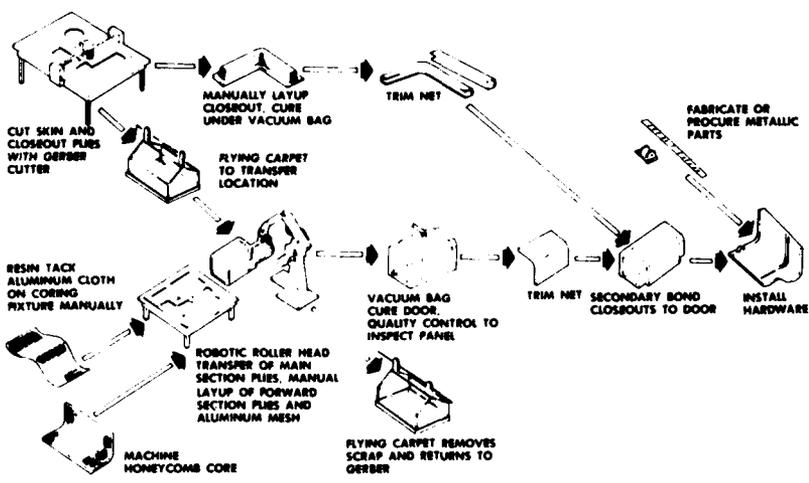


Figure 3 - Work Platform Door Fabrication Flowchart

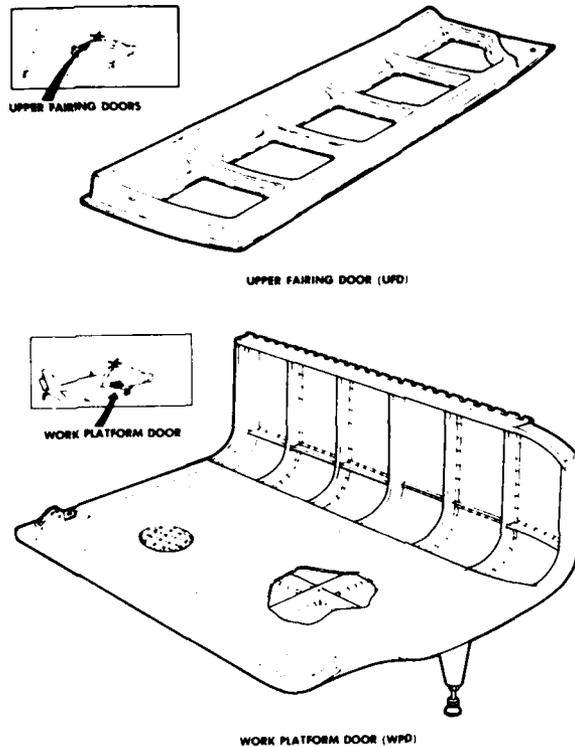


Figure 1 - UFD and WPD for the YAH-64 Helicopter

The design of the doors was modified to accommodate the IFACS SAMS process. From the skin-stiffened Kevlar configuration of the existing UFD, the design was changed to a Nomex honeycomb sandwich with Kevlar skins. This allowed the use of a standard robot pick-up head to transfer sheets of Kevlar prepreg from the transfer table to the door mold. The WPD changed from a aluminum skin/stringer/frame riveted design to a honeycomb sandwich with Kevlar skins. For this configuration, a new pickup head had to be developed for the robotic transfer machine in order to accommodate the high curvature of the WPD. This door has complex double curvature at its forward edge where it meets the engine inlet cowling. Laying up this shape is beyond the present capabilities of the robot, so that portion was planned to be a hand layup operation. The fabrication flow diagrams for the UFD and the WPD are presented in figures 2 and 3, respectively. Project work resulted in the fabrication of all the tooling for both doors. Only one pair of UFDs was built. At this point in the program, a comparative cost analysis was made to determine design to unit production costs (DTUPC) for the UFD/WPD built according to three processes:

- ° Manual fabrication of AAH production design.
- ° SAMS fabrication of redesigned components.
- ° Manual fabrication of redesigned components.

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

MMT Projects 178 7183, 179 7183, 180 7183, and 181 7183 titled "Semi-Automated Composite Manufacturing Systems for Helicopter Fuselage Secondary Structures" was completed by the US Army Aviation Research and Development Command in August 1982 at a cost of \$743,600.

**BACKGROUND**

The US Navy and Air Force have independently sponsored the development of semi-automated manufacturing systems (SAMS) at Grumman Aerospace Corporation, Milledgeville, GA, and Northrop Corporation, Hawthorne, California. The purpose in developing SAMS capability was to lower production costs, increase production rate, and improve quality. The objective of this program was to establish the suitability of SAMS for fabricating secondary structural components of the YAH-67A Advanced Attack Helicopter (AAH).

**SUMMARY**

The effort was initiated with an inspection of candidate secondary structures (such as doors and fairings) on the AAH to determine which of these would yield the greatest benefits if semi-automated fabrication processes were applied to supersede the conventional composite hand lay-up or sheet metal assembly processes. The aft pair of Upper Fairing Doors (UFD) and the right hand Work Platform Doors (WPD) were chosen. The location of these doors on the helicopter, and their shape and design, are shown in figure 1. The MMT doors were to be interchangeable with the existing doors on a form/fit/function basis, but the design and materials were to be variable in order to accommodate the chosen fabrication process.

The prime contractor, Hughes Helicopter, Inc., selected Northrop to be the fabrication subcontractor for the effort because its geographical location would result in better communications and cost effectiveness. The Northrop SAMS facility is named the "Integrated Flexible Automation Center (IFAC). This facility is housed in an environmentally controlled clean room. It consists of an automated Gerber knife table that cuts flat patterns of prepreg material under computer control, transfer tables, and a computer controlled robot that transfers the cut plys from the tables and positions them into the curing mold.

In addition to detailed discussions on these methods and analysis techniques relating to them, the application of these methods to the quality control of epoxy matrices in fiber reinforced composites, and the determination of the extent and nature of in-service exposure conditions (degradation, hydrolysis, weathering, and aging) on composites is presented. The effect of conditions of cure on the weathering stability of epoxy resins is also discussed.

Extensive tables of band assignments for EPON 828, methyl anhydride, and the spectral changes occurring during the crosslinking between these species in curing catalyzed by benzyldimethylamine is presented. Also presented in table form is a listing of tentative IR absorption assignments for DGEBA, DGEPP, DGEBF cured epoxy resins and absorption variations during degradation. An extensive bibliography is also provided.

### **BENEFITS**

This project resulted in a comprehensive state-of-the-art review of the principle physicochemical characterization techniques being applied for characterizing resins, cured resins, cure progression, and cured composite environmental degradation. This review will benefit current workers in the field, and serves as an excellent, in depth introduction to students of this aspect of composite technology.

### **IMPLEMENTATION**

Implementation of project results will be accomplished with the distribution of the handbook entitled "Quality Control and Nondestructive Evaluation Techniques for Composites."

### **MORE INFORMATION**

The results of this project have been published in AVRADCOM report TR83-F-6 titled "Quality Control and Nondestructive Evaluation Techniques for Composites, Part II: Physicochemical Characterization Techniques - A State-of-the Art Review" dated May 1983. Additional information is available and can be acquired by contacting Dr. Richard J. Shuford, Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts, on AV 955-5572 or Commercial (617) 923-5572.

Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

Part VII - Thermography - A State-of-the-Art Review

Part VIII - AH-1 - Composite Main Rotor Blade Quality Control, Mechanical Tests and NDE Methods

This summary report summarizes Part II, "Physiochemical Characterization Techniques - A State-of-the-Art Review".

Since the physical, chemical, and ultimate mechanical properties of high performance, fiber reinforced epoxy composites are dependent on the degree of cure of the epoxy matrices, a knowledge of curing process and composition of the epoxy matrices is essential. A schematic representation of the degree of polymerization versus glass transition temperature is shown in figure 1.

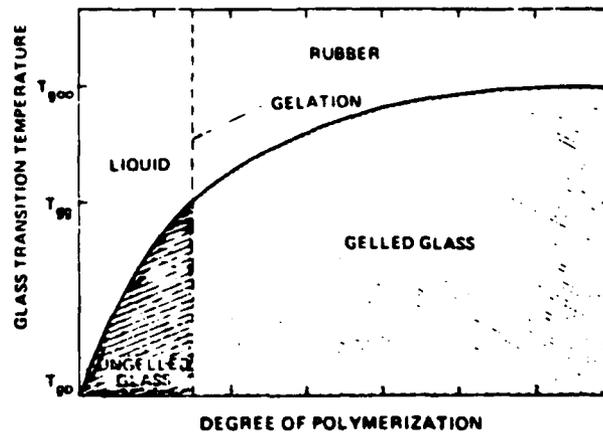


Figure 1 - Glass Transition Temperature Vs. Degree of Polymerization for a Thermosetting System

The objective of this project is to review the most important physiochemical characterization techniques used to date (1983) for establishing degree of cure and the composition of the matrix epoxy in fiberglass epoxy composites.

The project first discusses the role of epoxy matrix - the transfer of stress from the fiber to the finished composite in glass and graphite fiber composites - in meeting performance requirements. The three major types of epoxy resins of commercial significance, epichlorohydrin-bisphenol A, epoxy novolak, and epoxidized polyolefin resins, are compared in terms of meeting performance requirements, processing requirements, economic preference, and mechanical performance. In addition, shelf life of prepreps of these epoxies, ease of field repair, and heat resistance requirements of epoxies are detailed.

The project, after detailing the role of epoxy matrices and the requirements they must meet in fiberglass and graphite fiber composites, presents detailed discussions of the analytical methods for determining extent of cure and degradation of epoxy resins.

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

MMT Project 178 7119 titled "Non-Destructive Evaluation Techniques for Composite Structures" was completed by the US Army Aviation Research and Development Command in May 1983 at a cost of \$96,000.

**BACKGROUND**

The incorporation of structural composites in Army helicopters, missiles and ground vehicles is accelerating. This trend will reach its culmination in the next generation helicopter, the LHX. The LHX entire airframe, the main rotor blade, and the tail rotor blade will be constructed of composites, and the transmission and engine will contain composite parts as well. Many manufacturing problems will need to be solved, including quality control techniques.

At this time, a large number of non-destructive testing (NDT) techniques have been developed and are being used on composite structures of widely varying configurations and materials. Unfortunately, however, this technology is scattered among laboratories, contractor plants, and in various literature. A major step forward in advancing the present NDT state-of-the-art would be to centralize this technology and make it available to the manufacturing community.

**SUMMARY**

The purpose of this project, and the total effort of which it is a part, is to compile a comprehensive manufacturing handbook devoted to non-destructive in-process inspection of composite structures. The handbook entitled "Quality Control and Non-destructive Evaluation Techniques for Composites" will be organized into eight parts as listed below:

- Part I - Overview of Characterization Techniques for Composite Reliability
- Part II - Physiochemical Characterization Techniques - A State-of-the-Art Review
- Part III - Liquid Chromatography - A State-of-the-Art Review
- Part IV - Radiography - A State-of-the-Art Review
- Part V - Ultrasonic Characterization - A State-of-the-Art Review
- Part VI - Acoustic Emission - A State-of-the-Art Review

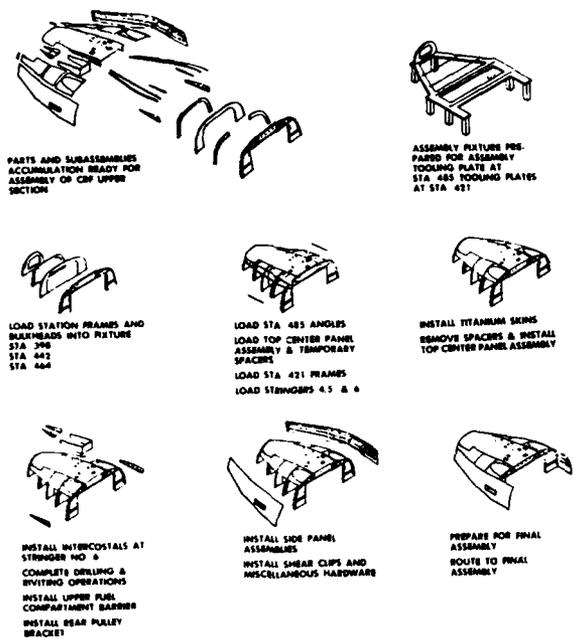


Figure 2 - Major Assembly of Upper Section - CRF

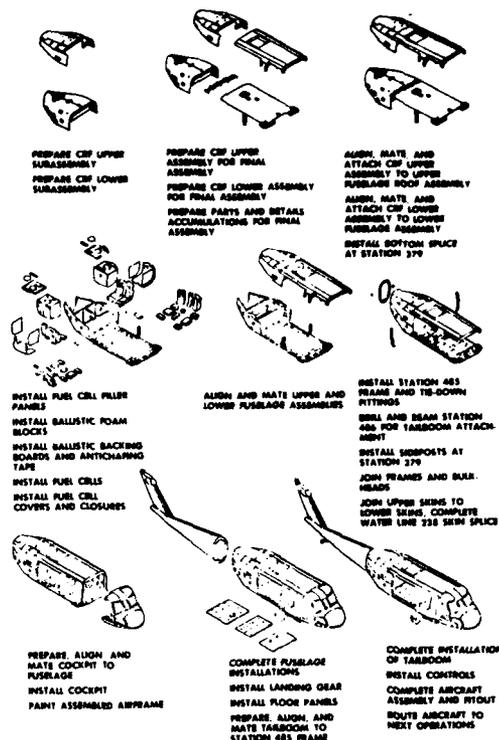


Figure 3 - Final Assembly - CRF/BLACKHAWK

## BENEFITS

The CRF is 38% more economical to manufacture than the current metal UH-60A rear fuselage. Total cost savings, if the CRF is implemented and 1064 units are produced, will equal \$19,100,000. Reduced manufacturing costs constitute \$13,600,000 of this amount. An additional benefit is a 10% weight reduction.

## IMPLEMENTATION

The CRF is currently undergoing flight qualification testing. If this test is successful, the CRF will be implemented in the current production run.

## MORE INFORMATION

A detailed technical report is available and can be obtained by contacting Mr. Thomas Mazza, Fort Eustice, VA, AV 927-2377 or Commercial (804) 878-2377.

Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

Where practical, the molds utilize non-tailored elastomeric blanket type bags, with mechanical seals, to minimize time and costs associated with the bagging operation. Frame molds have standardized bases and are loaded into a mobile stacking and handling rack. This permits efficient, high density autoclave loading and curing of a shipset of parts at one time. The fabrication sequence of the upper skin panel is depicted in figure 1.

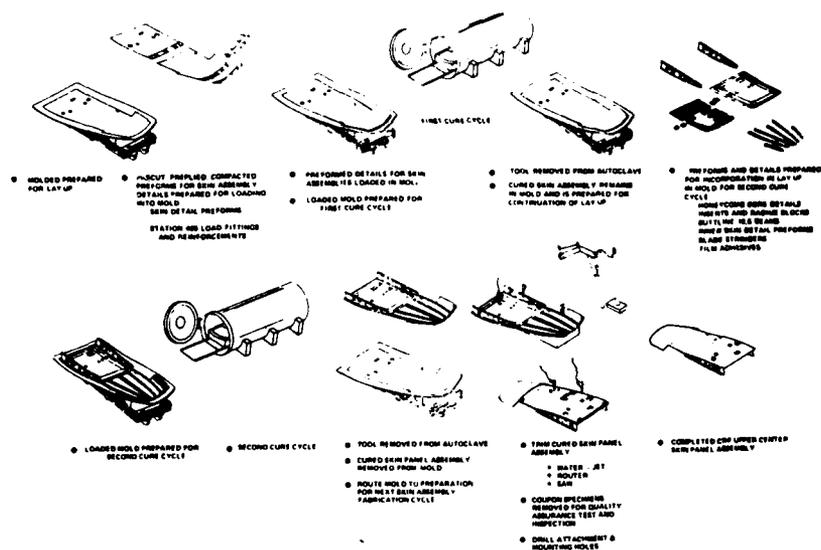


Figure 1 - Fabrication of Upper Skin Panel

After completion of the autoclave cycle, the cured parts and assemblies are trimmed to dimension by water-jet router or saw, and pattern drilled. These operations are performed with controlled, coordinated tools and templates. Finished parts are accumulated into kits for assembly. Joining is accomplished with titanium rivets.

The CRF upper and lower units are assembled independently on coordinated assembly tooling (figure 2). They are then joined to the mid-fuselage roof and floor assemblies, respectively (figure 3). Fuel cells, ballistic foam, backing boards, and cover panels are installed. The upper fuselage and lower fuselage assemblies are then joined in the final assembly fixture. The Station 485 frame is aligned and installed to complete the fuselage assembly.

Structural assembly of the CRF was demonstrated with subcomponent and full-scale static tests. In addition, a modular repair capability was also established.

This effort established the feasibility of fabricating large compound curvature airframe structures on steel shell molds. A practical size limit was determined in molding the lower skin panels, and producibility advantages from CAD/CAM, preplying, cocuring, thermal expansion molding, and the use of lightweight structural foam were also demonstrated.

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

MMT Projects 181 7113 and 182 7113 titled "Composite Rear Fuselage (CRF) Manufacturing Technology" were completed by the US Army Aviation Research and Development Command in May 1983 at a total cost of \$1,574,000

**BACKGROUND**

The major thrust of this effort was to develop and demonstrate cost saving manufacturing methods for building primary airframe structures with composite materials. The UH-60A Blackhawk rear fuselage was selected as the demonstration component because of its inherent complexity and labor intensive construction. Preliminary IR&D studies conducted by the producer of the Blackhawk, Sikorsky Helicopter, showed that the rear fuselage parts count and associated labor could be substantially reduced by changing from metal to composite structural materials. The design approach, however, relied heavily on the ability to cocure large complex structures for which manufacturing methods had not been proven.

**SUMMARY**

The major thrust of this effort was to develop and demonstrate cost saving manufacturing methods for building primary airframe structures with composites. This effort consisted of a manufacturing and component design phase and a manufacturing demonstration and component testing phase. This report will summarize the manufacturing demonstration and component testing phase.

The manufacturing plan established in this project is described below.

Prepreg materials and film adhesives are prepared and cut into ply detail shapes (patterns) by high-speed and automated cutting methods which include the Gerber Cutting System and steel rule die cutting. The resulting flat ply patterns are accumulated into kits of materials for each frame, bulkhead, assembly, and detail. The kits are routed to refrigerated storage from which they are drawn for lay-up on a first-in, first-out basis.

Kitted materials are distributed to the lay-up, fabrication, and assembly operations by means of transporters or parts wagons. Each kit contains all of the materials, parts, hardware and written instructions required for a specific operation or installation.

Extensive cocuring and cobonding are employed in fabrication of the composite structural components. In order to minimize tool turnaround and processing times, prepreg details are preplied, debulked, and preformed out of the molds on ancillary tooling wherever practical.

A comparison of the materials used in the CRF and the current metal rear fuselage is presented in figure 3.

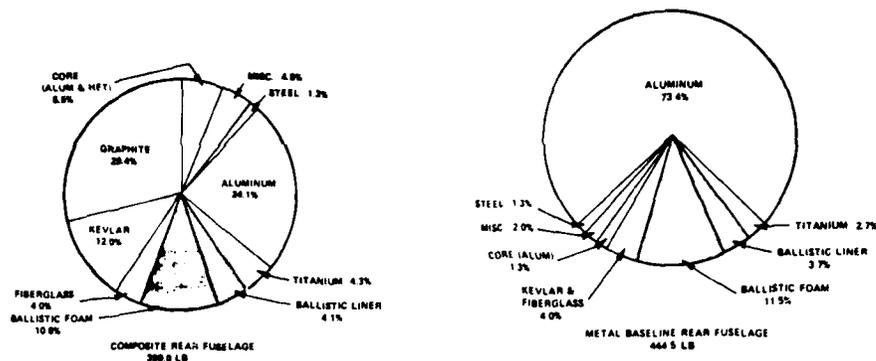


Figure 3 - CRF and Metal Baseline Material Usage

The manufacturing plan consisted of manual layup process using automated cutting technique, two step curing (skin and then skin and stiffeners), segmented upper and lower sections, steel shell tooling, and mechanical fastening of segments to form the final assembly.

**BENEFITS**

This work established the component design and manufacturing plan that will be the basis of the remainder of the effort.

**IMPLEMENTATION**

This work is the result of the first two years of a four-year effort. The results of this work will be the basis of the following two years of the effort.

**MORE INFORMATION**

Additional information may be obtained by contacting Mr. Fred Reed at AV 693-3079 or Commercial (314) 628-3079.

Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

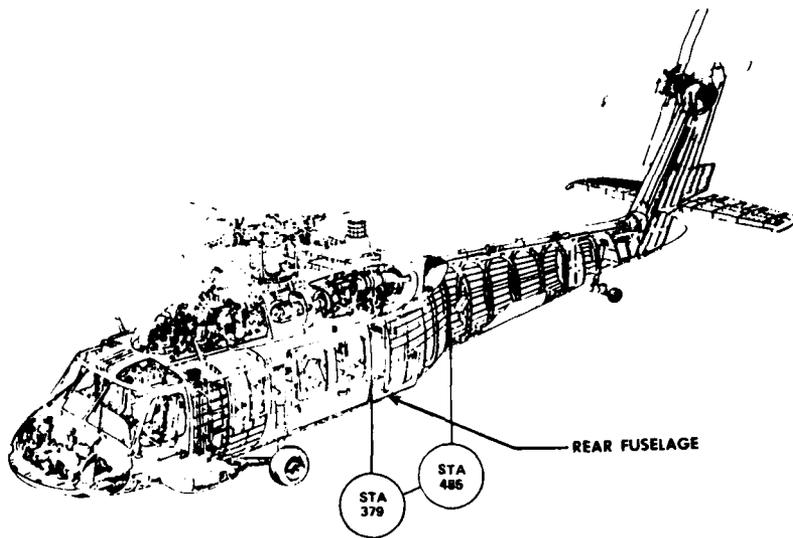


Figure 1 - UH-60A  
BLACKHAWK Helicopter,  
General Arrangement

Several different structural forms, stiffener geometries, and joint configurations were evaluated for each of the major structural elements of the CRF, with structural efficiency, manufacturing cost, and tool complexity used as the basis for selection.

The final design, depicted in figure 2, is a configuration containing both sandwich and stiffened skins. The skins are Kevlar. Longitudinal stiffening is provided by open sided square edged honeycomb strips with a graphite cap for most of the skin panels, and honeycomb sandwich where transverse loads must be counteracted such as in supports for the fuel cells and the multiple systems interface on the roof. "J" section stiffeners doubled as attachment angles and were specified for edge members where skin panel splices occurred. Closed hat section members, composed of graphite and a reticulated foam core were used where torsional stiffness is required. The scuppers around the fuel cell, as well as the skin of the fuel covers, are made of unidirectional E-glass. The frames (stations 421,464,485) are composed of graphite/epoxy. The corrugated bulkhead at station 442.5 is graphite epoxy with rigid ballistic foam filling in the corrugations.

To meet crashworthy requirements, it was decided to retain metallic structure for the station 379 frame, the bulkhead at station 398, and the floor "I" beams connecting these components. Titanium skins were retained in the appropriate area of the upper panel to shield against heat and flame emanating from the engine exhausts.

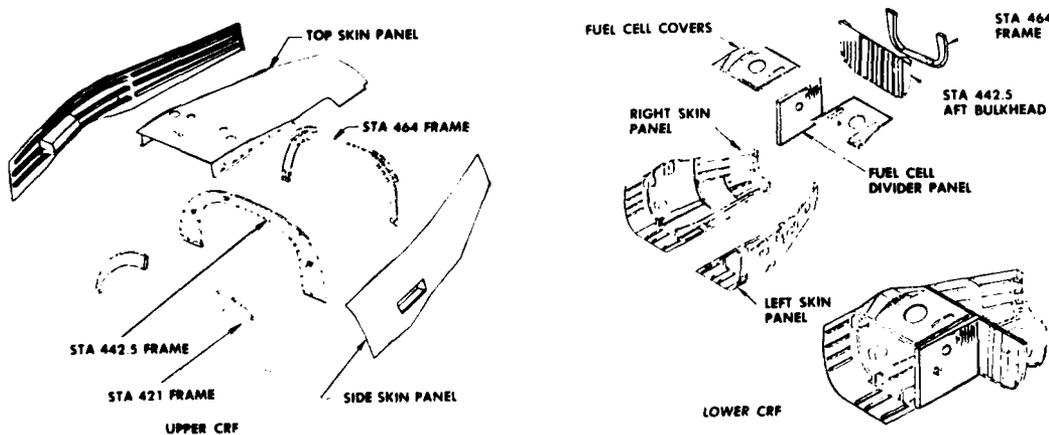


Figure 2 - CRF Final Design Major Composite Assemblies

The forming, processing, and curing of the parts is shown in figure 2. Four different types of processes were used:

1. High-pressure molding with matched metal dies in a hydraulic press.
2. Low-pressure molding using the vacuum bag autoclave technique.
3. Surface preparation of components for adhesive bonding.
4. Adhesive bonding using clamp-up tooling with high expansion RTV rubber for follow-up pressure.

Two types of tooling were used. Three components were made on steel male molds and cured by the vacuum bag autoclave method. Six components were made or heated steel matched dies designed for use on the hydraulic press.

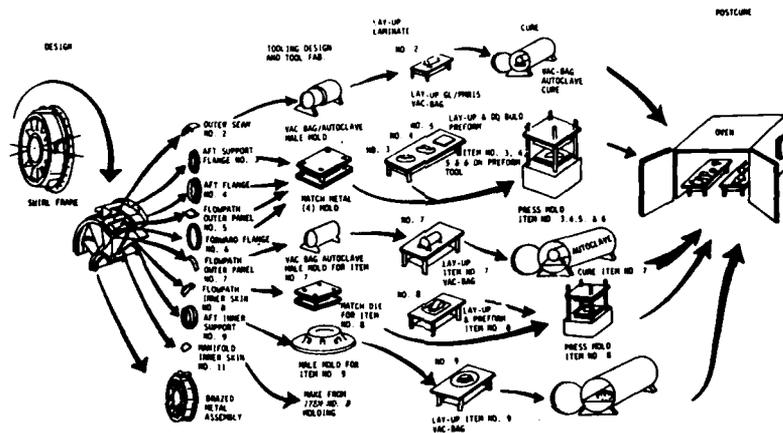


Figure 2 - Autoclave and Press Molding of Composite Parts

All of the composite parts are joined to the metal basic frame, which was formed by conventional techniques, by using adhesive bonding techniques. This was accomplished with clamp-up tooling in combination with RTV rubber for follow-up pressure. Following the final bonding cure, the frame assembly is final machined, "Sermetal" coated, and water wash spray pattern tested prior to final inspection.

Three IPS swirl frames were fabricated and evaluated in engine ground tests. The tests demonstrated that the IPS design and production process are successful.

**BENEFITS**

The composite IPS swirl frame resulted in 26% weight savings, and a projected savings of \$2,820 (1980 dollars) per frame.

## **IMPLEMENTATION**

Implementation of the IPS composite swirl frame is not planned on the T700 engine. Savings would result if implementation were immediate; however, the time and costs of qualification testing would eliminate any potential savings. The results of this effort are incorporated into the 5000 HP MTDE now under development, and will be implemented when that engine reaches production.

## **MORE INFORMATION**

Additional information is available from Mr. David Cale, US Army Applied Technology Laboratory, AV 927-2771 or Commercial (804) 878-2771.

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Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Projects 179 7243, 180 7243 and 181 7243 titled "Machining Operations on Kevlar Laminates" were completed by the US Army Aviation Systems Command in June 1982 at a total cost of \$264,000.

**BACKGROUND**

Kevlar is the trade name for an aromatic polyamide fiber developed by E. I. DuPont. This high strength, low weight reinforcement is presently being used in many structural and nonstructural aircraft applications. Kevlar reinforced laminates have presented the aerospace industry with machining difficulties due to their tendency to fibrillate or "fuzz" when machined with conventional tools. Considerable data has been generated in attempting to solve this problem. However, much of it is conflicting and applies only to specific applications. As a consequence, the cost of production has suffered due to ill-defined parameters such as feeds, speeds, and tool configuration.

**SUMMARY**

This effort was initiated to investigate/develop tooling and techniques needed to perform clean, efficient machining operations on Kevlar laminates. The investigation included two different Kevlar laminates, one with an epoxy matrix and one with a polysulfone matrix. The machining techniques investigated were drilling, cutting and trimming. The effort was performed in three phases. Phase I consisted of a technology survey and a tool vendors/developers survey. Phase II consisted of the evaluation of eight different types of conventional tools for Kevlar laminate machining effectiveness, and three state-of-the-art cutting systems. Production scale-up problems and techniques such as tool life, tool materials, special coatings, and coolants were studied in Phase III. Additionally, automation equipment was identified and production automation concepts were developed.

A DOD/NASA and HHI library literature search initiated the technology survey. This survey covered manufacturers' data, technical conferences, periodicals, and Government-sponsored studies. In addition, eight selected vendors were visited in order to determine the latest state-of-the-art in Kevlar laminate machining. The information collected covers tools, processes, and techniques.

In Phase II, the performance of tools identified in Phase I was verified and their capabilities and limitations were further defined. Selected tools were modified and evaluated for increased efficiency. In addition, state-of-the-art machining procedures were examined. Tools and equipment were evaluated for machining rate and quality on both epoxy/Kevlar and polysulfone/Kevlar laminates.

The results of the machining tests with conventional and modified conventional tools are presented in table 1. An example of a modified tool is the drill bit shown in figure 1.

Table 1 - Performance of Conventional and Modified Conventional Tools on Kevlar Laminates

TOOL DESCRIPTION	SIZE	SPEED	CUTTING RATE	EVALUATION	
				QUALITY	COMMENTS
Circular Saw Carbide Tipped	7" 40 Teeth	3500 SFPM	4 Mat'l 5 FPM	Good	Light fuzz downside only.
Birmingham Grit Edge Circular	10" Dia.	4500 SFPM	6 FPM	Good	Not recommended due to grit loading.
Cutoff Blade-Composition	10 Dia.	4500 SFPM		Poor	Generates heat and swells edges.
Band Saw Wavy Set	1/2" 32 Teeth	650 SFPM	4 Mat'l 2 FPM	Good	
Band Saw Knife Edge	1/2"	1000 SFPM	10 FPM	Good	32 plus 281 style dry woven Kevlar.
Band Saw Scalloped Knife Edge	1/2"	1000 SFPM	10 FPM	Poor	32 plus 281 style dry woven fabric.
Saber Saw - Bosch T118A	1 1/2" 20 TPI	191 SFPM	2 FPM	Good	
Saber Saw - Bosch T101P		191 SFPM	4 FPM	Good	
Saber Saw - Airtach AR3925		191 SFPM	2 FPM	Good	Special blade high cost.
Saber Saw - Bosch T130 Course		191 SFPM	1 FPM	Good	Grit coated blade for special applications.
Saber Saw - Knife Edge Bosch T18A	2 1/4"	191 SFPM	10 FPM	Good	2 plus 281 style dry woven fabric.
Scroll Saw					Not available.
Drill HSS Standard Twist	1/2" 135	600 RPM		Poor	Rejected.
Drill Solid Carbide Twist	1/2" 135	600 RPM		Poor	Rejected.
Carbide Single Flute Drill	1/2"	600 RPM		Poor	Rejected.
Turboflute Drill	1/2"	600 RPM		Poor	Rejected.
Countersink 2 Flute Standard		600 RPM		Poor	Rejected.
Weldon Countersink		600 RPM		Good	Overheats fast.
Router - Opposed Helical	1/2"	24,000 RPM	6"/min.	Good	Carbide bit breaks-diameter too small.
Router - Diamond Cut Carbide	1/2"	24,000 RPM		Poor	Rejected.
Hog Mill - Omcut	1"	4,000 RPM	6"/min.	Good	Suitable for heavy sections.
Bosch Nibbler Model 7501	14 GA	1460 Strokes per min.	2 FPM	Excellent	Clean and economical.
Circular Saw Carbide Teeth (Modified) Mod #1	10 60 Teeth	4500 SFPM	6 FPM	Good	No advantage over standard blade.
Countersink Serrated		600 RPM	N/A	Poor	Unsatisfactory finish.
HSS Twist Drill Modified		600 RPM	24 sec/in.	Good	Excellent with backup.
Solid Carbide Twist Drill (Modified)	1/2"	600 RPM	20 sec/in.	Good	Excellent for graphite composite.
Turboflute or Paraflute Drill (Modified)	1/2"	750 RPM	24 sec/in.	Good	Excellent with backup.
Router - Special Design	10" 60 Teeth	4500 SFPM	6 FPM	Good	
Circular Saw Carbide Teeth (Modified) Mod #2					More effective than standard.

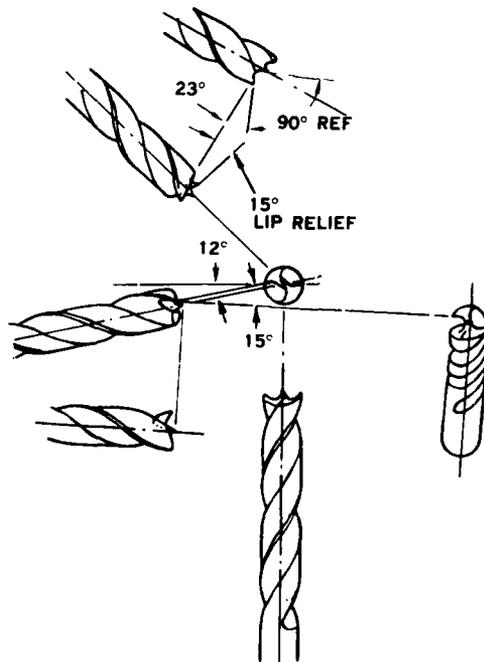


Figure 1 - Modified Drill Tip

Contrary to popular belief, Kevlar is not appreciably more difficult to machine than graphite or fiberglass. Although the Kevlar fibers are tough, they are easily cut by sharp tools with the proper cutting angles. It should be noted, however, that since heat over 350°F tends to permanently swell the edges of the cut, tools must be kept cool during the machining operations.

In Phase III, production scale-up, characteristics of hole drilling in relation to the quality, cost, and tool durability were evaluated. Tool life under normal operating conditions, tool life using special tooling materials, and tool life improvement when using coolants and special coating were evaluated.

Production application problems were also addressed and concepts were developed for production machining of complex aircraft components. Automation methods were studied and the integration of automated machining into labor efficient production lines was conceptualized.

The performance evaluation in the first phase of this effort showed that tools and equipment presently available have suitable quality and durability for incorporation into automated production lines.

Future composite production lines will reduce costly labor by the use of robotic handling, automated curing, and automated nondestructive testing. The automated machining contribution will be in the form of robotic trimming and drilling of sufficient accuracy such that trimming and drilling jigs will not be required.

### **BENEFITS**

This effort will aid the manufacturing engineer in the selection and modification of tools and machining parameters to produce Kevlar laminate components. This will reduce costs and improve quality.

### **IMPLEMENTATION**

Implementation was completed with the distribution of a technical handbook entitled "Design Guide Handbook Efficient Machining Methods and Cutting Tools for Kevlar Composite Laminates," November 1981.

### **MORE INFORMATION**

To obtain additional information, contact the project officer, Mr. Charles E. Stuhlman on AV 927-2377 or Commercial (804) 878-2377.

Summary report, Dec 84, was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project 173 8042 titled "Manufacturing Methods for Gradient Furnace Processing of Ceramic Armor and Structural Ceramics" was completed by the US Army Aviation Systems Command in December 1980 at a cost of \$135,000.

**BACKGROUND**

The growth of large single crystal materials opens up many possibilities for new applications of ceramics such as in the case of transparent armor, lasers, and laser windows.

Single crystals of sapphire have been made by many techniques, the best known probably being the Verneuil method for the production of jewels and bearings. Until recently, the largest crystals of sapphire were probably those obtained by the Czochralski technique where crystals up to three inches in diameter were grown.

At the Army Materials and Mechanics Research Center (AMMRC) a coordinated in-house effort has been underway to develop an improved approach to the growth of large, uniform, single crystals of sapphire. The original research and development work demonstrated the effectiveness of a crystal growth technique called the gradient furnace technique. An earlier MMT project designed, built and placed in operation a 20" I.D. gradient furnace with a capacity for potential crystal growth of up to 18".

**SUMMARY**

The objective of this project was to establish the manufacturing techniques to fabricate 12" - 18" diameter transparent single crystal armor and structural ceramic end items.

The gradient furnace technique essentially consists of solidification of a melt onto a preexisting seed crystal contained in a high temperature crucible and cooled through controlled temperature gradients to obtain nucleation and crystallization of the melt into a single crystalline form. A general schematic of the furnace used in this process is shown in figure 1.

The specific schematic showing the arrangement of the crucible and the material in the furnace is presented in figure 2. The seed crystal is placed in the crucible above a heat exchanger which prevents the seed from melting during solidification by directing a flow of helium gas, or other suitable coolant, against the crucible beneath the seed. The crucible was heated from the sides by a graphite resistance heater and the flow of helium gas through

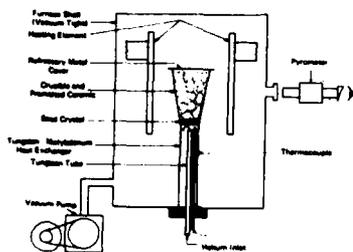


Figure 1 - Schematic of Gradient Furnace

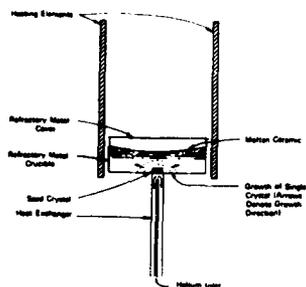


Figure 2 - Schematic of Arrangement in Gradient Furnace for Growth of Ceramic Single-Crystal Disks

the heat exchanger extracted heat from the crucible bottom beneath the seed. This cooling effect resulted in a temperature gradient which was the driving force for the radial growth of the crystal from the seed crystal. The temperature gradient can be controlled by adjusting the amount of helium flow through the heat exchanger.

As the temperature of the furnace was increased to 2250°C, helium was recirculated into the heat exchanger to maintain the seed crystal at a maximum temperature of 1,950°C. The temperature at the bottom of the crucible was continually monitored by a thermocouple. The temperature of 1,950°C, approximately 100°C below the melting point of  $Al_2O_3$ , was maintained constant during the melting of the sapphire. After the sapphire, as well as the surface of the seed crystal was completely melted, the helium gas flow was increased in order to raise the temperature gradient and start to solidify the new growth onto the seed crystal. The furnace was slowly cooled during the solidification process. The growth rate was approximately one centimeter per hour. Approximately 20 hours are required to grow an 8" diameter crystal. The sapphire crystal was cooled at a rate of approximately 20°C per hour.

In the work carried out, sapphire single crystals have been grown reproducibly in sizes of 6", 6 1/2" and 8" diameters. Sapphire single crystals 12" in diameter and clear to the outer diameter that were cracked have been produced also. These crystals were examined by neutron activation analysis and impurities were determined to be less than 10 ppm.

Sapphire ingots were cut into disks with diamond cutting wheels, and diamond core drills were employed to cut cylindrically shaped columns out of the sapphire ingots. Diamond was used as a cutting medium due to the hardness of the sapphire. The cylindrical pieces were sliced to provide seeds for growing sapphire crystals and disks for evaluation. It was necessary to polish the disks prior to optical, infrared, or x-ray examination.

Because of the long time and high cost of polishing sapphire by conventional methods, an alternative approach to optical transparency seemed necessary. To produce an optically transparent armor plate, it was decided to coat the rough-cut sapphire surface with smooth glass. The glass would adhere to the sapphire and produce an optically smooth surface. A lead-base glass was formulated which had the same refractive index as sapphire. The sapphire plates, which were not transparent due to the existing rough surface, were dipped into the molten glass, resulting in a smooth transparent coating. In addition, the glass coating could be further polished by standard soft polishing techniques using  $Al_2O_3$ ,  $B_4C$ , etc., affording a substantial cost saving without affecting the ballistic performance of the sapphire plate. Figure 3 shows the amazing clarity possible of a 6 1/2" diameter x 1/2" thick polished sapphire single crystal disk. Ballistic tests of the glass dipped into sapphires showed no deleterious effects, the same as for uncoated sapphire.



Figure 3 - A 6-1/2" Diameter X 1/2" Thick Polished Sapphire Single Crystal Disk

## **BENEFITS**

The processing technology of this project is ideal for transparent ceramic armor, scratchproof instrument windows, insulators, and structural ceramic materials for aircraft and vehicle applications. Also, this process can be used for materials other than sapphires. Towards the end of this project, successful preliminary work was carried out on making large laser windows out of YAG (yttrium aluminum garnet). Finally, there are intrinsic cost savings in the process since it is self-purifying during solidification. The pure materials solidify completely, forcing the impurities to the periphery where they can be easily removed by machining.

## **IMPLEMENTATION**

Though delayed, information on the results of this project have been forwarded to private industry and a number of DOD activities. Sapphire made by this technique has been used as windows by the Air Force to study exhausts from rocket engines. Also, single crystal sapphire was tested by TRW for laser applications. Scale-up to even larger size crystal need not stop at the 2" to 18" level. It is quite conceivable that scale-up can be extended further with the resolution of technological problems such as crucible fabrication and heat control.

## **MORE INFORMATION**

Additional information may be obtained by contacting C. Neckyfarrow, MMRC, AV 955-5526 or Commercial (617) 923-5526. Also, Technical Report TR O-F-4 titled "MMT Manufacturing Methods for Gradient Furnace Processing of Ceramic Armor and Structural Ceramics" was published in August 1980.

Summary report, Dec 84, was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

AT project 381 1042 titled "Production of Composite Radome Structures" was completed by the US Army Missile Command (MICOM) in September 1983 at a cost of \$755,000.

**BACKGROUND**

The currently qualified radome for the Pershing II is a two layer part. It consists of a short fiber reinforced fluoropolymer jacket (RT/Duroid 550M) and a separate inner shell of continuous S-2 glass/epoxy. The outer jacket provides optimum ablation characteristics and rain erosion resistance while the inner shell provides mechanical strength and stiffness. Both parts are precision machined and then attached together in secondary operations which require special etching and bonding procedures.

The purpose of this project was to eliminate these machining and bonding processes. Project work was accomplished by in-house effort at MICOM and contractual effort at Rogers Corporation, Lithonia, Georgia.

**SUMMARY**

Several potential constructions were studied through the fabrication and testing of samples during the first phase of the project. A two layer construction was still considered as the best design. The outer layer was RT/Duroid 5667, a low fiber content, short filament/polytetrafluoroethylene (PTFE) composite. The inner layer was RT/Duroid X074 which consists of S-2 glass strand in a PTFE matrix. Dielectric testing of flat plate samples demonstrated that this material had a dielectric constant under 3.5, which is superior to its epoxy/glass counterpart.

These materials were used to manufacture 1/3 scale Pershing II radomes. This led to the second phase of the project which included scale-up to full size parts, dielectric and mechanical characterization of these parts and estimates of production costs. Approximate dimensions of these parts were 14" L x 18" O.D. The cross-sectional drawing below shows the relative thickness of the ablative and structural layers.

Full-scale Pershing II and Patriot radomes were manufactured. The winding and ply-up procedures for the inner shell, the machining techniques, the attachment hole drilling techniques, and the inspection steps were common to both radomes.

The winding operation was done on an engine lathe. The circular inner layer was wound directly over an aluminum forming mandrel. Then, longitudinal fiber mats were hand-laid over the inner layer and another layer of circular windings was applied to form the outer layer of the inner shell. The S-2 glass used for the circular windings and mats were coated with PTFE resin and dried before use.

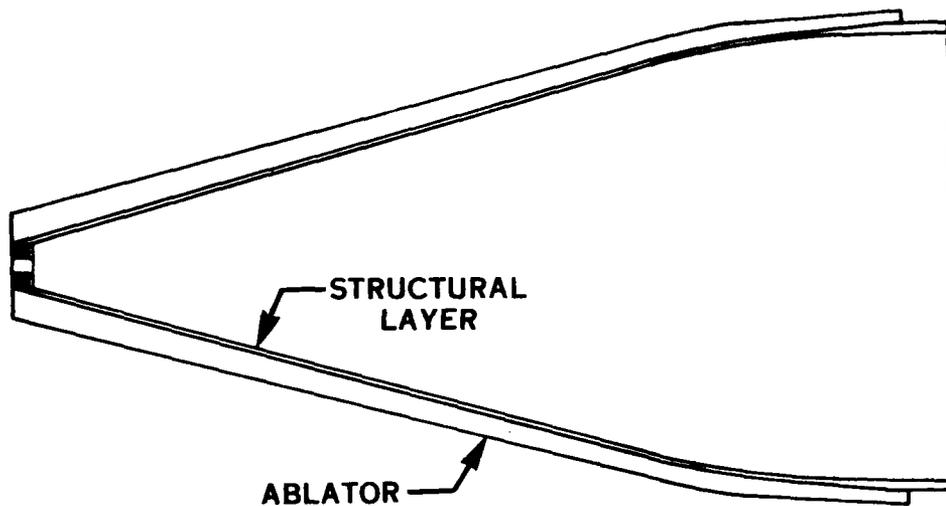


FIGURE 1 - RADOME

variations in the sequence of certain process steps were incorporated for remolding of the inner shell, ablator molding and sintering. The intent was to explore productivity improvements and to develop a better understanding of the process parameters.

Process A, the inner shell was densified (pre-molded) following the formation of the longitudinal mats. Latex bags were carefully drawn over the mats, set-up and sealed. Following evacuation, the packages were placed in a isostatic press (CIP) where pressure was slowly increased to 20 ksi and held for 5 minutes. The outer layer was then wound onto the densified inner shell.

Process B, the CIP operation was omitted. Since the undensified longitudinal mat reduced the slippage of the circular windings, a much higher tension was possible. The winding was begun at the radome base and worked toward the tip. Considerable reduction in mat bulk was accomplished during the winding.

A separately molded ablative jacket was placed over the inner shell and was supported by a sintering mandrel. The entire assembly was bagged and sealed in aluminum foil and fluoropolymer film. Before and during the curing, a vacuum of better than 20 inches of mercury was drawn on the inside of the assembly. Pressure applied to the outside of the part fully exceeded 120 psi. The autoclave was rated to 750 degrees F.

After curing was complete, the radome was left on the sintering mandrel and was chucked to a computer controlled lathe for outer contour grinding. The attachment holes in the Pershing II radome were then drilled. Hole locations were controlled by a drilling jig. Dimensional verification of the radome contour was done on a coordinate measurement machine.

## **FITS**

All fluoropolymer continuous filament reinforced radomes had excellent mechanical and electrical properties and the production cost was somewhat less than the current production radome.

## **IMPLEMENTATION**

The Pershing II Project Manager and the prime contractor have been kept abreast of results and have participated in program planning activities. At this time, however, it appears that this project was completed too late to utilize the radome in test flights. The project manager may not implement this technology because of reasons of uncertainty. The next implementation opportunity could occur during the 1989-1990 timeframe. An advanced ballistic missile interceptor could utilize this technology.

## **ADDITIONAL INFORMATION**

For additional information contact Mr. Phil Ormsby, MICOM, AUTOVON 4933 or Commercial (205) 876-4933. A technical report which covers the technology developed under contract DAAH01-81-C-B162 is also available. It is titled "Production of Composite Radome Structures" and is dated February 1984.

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This report, Dec 84, was prepared by G. Fischer, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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

t 382 1126 titled "Wound Elastomer Insulator Process" was completed Army Missile Command (MICOM) in December 1983 at a cost of

solid propellant rocket motors contain a rubber liner which the motor case walls from the burning propellant. Current methods for the insulators involve lengthy process periods. Costs, due to extensive labor and tooling requirements, are high. Engineering design changes are not implemented easily. Insulators for tactical and strategic motors are made by two processes. One process cures the green (uncured) elastomer to final dimensions in matched metal molds under heat and pressure. The cured insulator is then assembled on the case mandrel and bonded together using splice. The other method uses sheets of green stock which is cut to shape, wound on a special mandrel, stitched together and cured as a unit. The top is then ground to precise contour, removed from its mandrel and bonded to the case mandrel. Remaining procedures for both types of insulators are alike. The motor case is filament wound onto the insulator. A curing cycle is required to complete the composite case/insulator

Principal objective of the three-year MMT effort was to demonstrate a motor fabrication concept. In this proposed technique, a processor controlled tire winding machine could be used to extrude green elastomer to a precisely controlled thickness and immediately wind it onto a case mandrel. The insulator thickness would depend on the number of plies laid down. Instant insulator design changes could be made. After the insulator is wound, it would not be cured. Instead, the Kevlar/epoxy would be immediately wound over the insulator and then both the insulator and case cocured.

During this first year of project work, various insulator formulations were evaluated for ease of processing, physical properties, characteristics and adhesion to case and propellant. Subscale motor case evaluations were followed by the construction of a Pershing II first stage wound elastomer insulator process.

Two types of formulation were tested: an EPDM/silica formula and an HC (halogenated hydrocarbon) formula. These baseline formulas were modified to enhance susceptibility to microwave curing. Two preplasticized

Formulations were also evaluated to reduce plasticizer migration from the propellant in an effort to achieve a direct bond without using bonded bonding techniques. The test objective was to select an easily formulated formula that had equal or better properties than the current molded material.

Thermal processing tests showed that the use of microwave cure enhancers improved the cure rate. All formulas tested cocured well to the epoxy composite case material. Thus, the modified formulas were eliminated from further consideration.

Motor tests showed that the baseline formulations performed as well as those than the currently used molded material. The preplasticized formulations, however, had higher erosion rates.

Propellant/adaptor/adhesion tests showed that the bonds achieved by the modified materials were as good as those made by the molded control material. The preplasticized formulas could not be directly bonded as they were due to a soft propellant cure at the interface.

The preplasticized formulas were eliminated from further testing. The B-4C was chosen over the EPDM/silica because its char ratio was lower in the high gas velocity regions. It was then used to fabricate the first stage insulator. To demonstrate the wound elastomer process (WEI), the case was constructed according to Pershing II conditions except that premolded EPDM thrust reversal (TR) adapters were used. The case was wound over the uncured wound insulator, and the case/insulator/adaptor were cocured in one step.

When the mandrel was wrapped, a skive cutter removed the WEI at the top and bottom over the TR port locations. The premolded adapters were removed and the elastomer strip stock was stitched into the gaps remaining between the insulator and the adapter. This interface is illustrated by Figure 1. The case was overwound, making the insulator, TR adaptors and case a single unit. A standard Pershing II thermal/microwave cure schedule was used. The cure schedule cured the filament wound case. It also cured the elastomer and vulcanized the TR adapter to the WEI.

The assembly was prepared for burst testing at 77°F. The case burst at 1000 psi, the best ever obtained for any first stage case. The previous high burst was 700 psi. It was obtained with a case containing molded insulators.

#### CONCLUSION

The WEI technology will be further developed during the last two phases of the program - (2) design verification and (3) fabrication of project demonstrators. Additional investigations are needed to be sure that the TR adapter can withstand the static firing test. The fabrication of the Pershing II second stage with WEI also must be demonstrated.

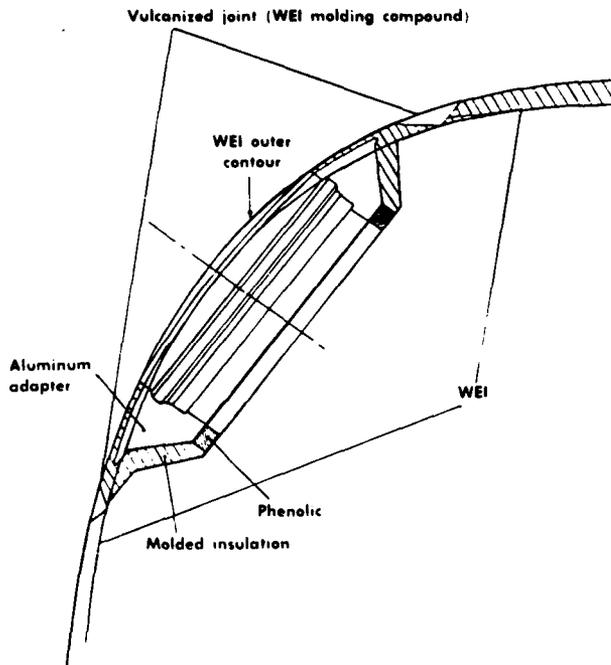


Figure 1 - Thrust Reversal Adapter

**MORE INFORMATION**

For additional information, contact Mr. Tom Shaw, the project monitor at MICOM, (205) 876-2147. An interim technical report summarizes the work done under contract DAAH01-83D-A009 between 15 November 1982 and 30 November 1983.

Summary report, Dec 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 Project 478 5019 titled "Storage Battery, Low Maintenance - Phase II" was completed by the US Army Tank-Automotive Command in February 1981 at a cost of \$160,000.

**BACKGROUND**

To resolve the major problem of military battery failure, container breakage, a prior year MMT project developed a new low maintenance battery. The prototype had a plastic case and a calcium alloy grid to be dry charged to greatly extend its "wet" storage life. The prototype batteries delivered at the end of the project were all of the 6TN size. This is the one used in all classes of tactical wheeled vehicles of the 2 1/2-ton, 5-ton, 10-ton truck sizes, and larger, as well as military adapted commercial vehicles. Before they can actually replace the present batteries, the new prototypes must be evaluated in the laboratory and tested in the field.

**SUMMARY**

The objective of this project was to conduct laboratory and field validation tests on the new 6TN prototype battery. Similarly, it was desired to provide the appropriate technical data and requirements for a Technical Data Package (TDP) for its procurement.

At the beginning, programmed laboratory performance tests were carried out on the 6TN prototype batteries. (See figure 1). As indicated, it approximates a cube of about 10 1/2 - 11" on a side.

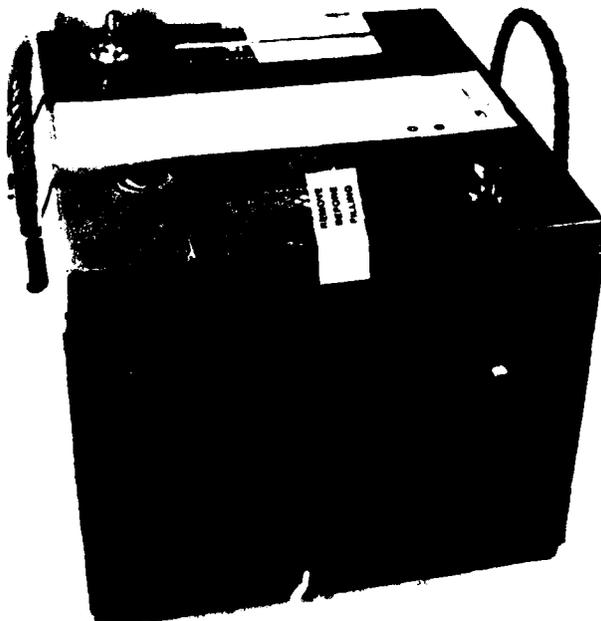


Figure 1 - Prototype 6TN  
Storage Battery

Shortly after the lab tests began, field evaluation tests were initiated at the Cold Regions Test Center (CRTC). Early battery leakage problems required prototype modifications. Modified samples were then submitted to both CRTC and Yuma Proving Grounds (YPG). Testing continued for roughly another year. Upon completion, draft specifications for the low maintenance battery were prepared.

After finalizing, the performance specifications were submitted to all the Services and industry contacts for their comments. Several questions arose and were subsequently satisfactorily resolved, and the specifications were published. The designation for the new battery is the 6TL (L is for low maintenance).

### **BENEFITS**

The new battery will provide the military with the dry-charged capability in a low maintenance battery for long term storage and ease of shipment. The battery, in its new plastic container, will decrease breakage and increase battery life expectancy.

The results of the development of the dry-charged, low maintenance, plastic container battery is applicable to military vehicle batteries of the 2 1/2 ton trucks, and larger, as well as all track vehicles.

With implementation of the 6TL low maintenance battery into the supply system, total battery procurement will be reduced by reason of a reduction of production quantities required. Battery life will be increased by at least six months. Maintenance will be reduced since the addition of water and routine maintenance will be virtually eliminated.

### **IMPLEMENTATION**

Implementation is being carried out by the Qualified Producer List (QPL) system. Thus far, there is only one qualified producer for the 6TL. As soon as a second is added, a QPL list will be issued. At that time, competitive bidding will be possible for the new battery and the 6TL will enter the supply system as a replacement for the 6TN.

### **MORE INFORMATION**

Additional information may be obtained from Mr. Joseph H. Reinman, TACOM, AV 786-5035 or Commercial (313) 574-5035.

Summary report, Dec 84, was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Projects T80 5019 and T81 5019 titled "Storage Batteries, Low Maintenance - Phase III" were completed by the US Army Tank-Automotive Command in July 1981 and May 1983 at costs of \$30,000 and \$130,000, respectively.

**BACKGROUND**

Earlier projects of this effort developed (Phase I), tested and evaluated (Phase II) a new 6TL low maintenance battery for use in military heavy equipment and combat vehicles, of 2 1/2 tons and over, as well as military adapted commercial vehicles. The new prototype has a plastic case, a calcium-alloy grid, and it is dry-charged to extend its "wet" storage life.

In recent years, low maintenance batteries using calcium-alloy grids and plastic containers have been developed commercially for a wide market. However, they do not meet military requirements and specifications. Prior to this Phase III, no work was done for developing a similar battery for tactical vehicles up to 2 1/2-tons.

**SUMMARY**

The purpose of this project was to develop a dry-charged, low maintenance, plastic container storage battery in the current 2HN configuration for Army tactical vehicles. This is the size battery used on all military vehicles smaller than 2 1/2 tons. Physically, it is about the same height and length but half the width of the larger 6TN or 6TL batteries, which are almost a cube of 10 1/2 to 11-inches on a side.

The basic element size of the current 2HN - 5 1/4" was retained and adapted for the plastic prototype. The design settled upon was low-antimony positive grids, calcium negative grid and envelope separators. Originally, a calcium positive grid was tested but it proved to be more sensitive to deposit formation and required increased electrical input to achieve the same results.

Since the major cause of battery failure is container breakage, the major concern was to have a plastic container and cover with high impact resistance. Evaluation of several materials revealed the optimum choice to be Hercules Profax #8523 high impact polypropylene copolymer resin. Containers and covers were molded in temporary molds and the cover was heat sealed to the container using Bielomatic heat sealing equipment. The cells were connected through the partition using high voltage welding systems.

The container is designed with reinforcing ribs to further improve impact and vibration resistance. Overall dimensional requirements were complied with.

The new prototype is made with hybrid construction and is dry-charged. Hybrid construction caused no problems during the dry-charge process and activated well at temperatures as low as 30°F.

All 50 prototype batteries, like those shown in figure 1, have been manufactured and delivered to the Government. They are now designated the 2HL.

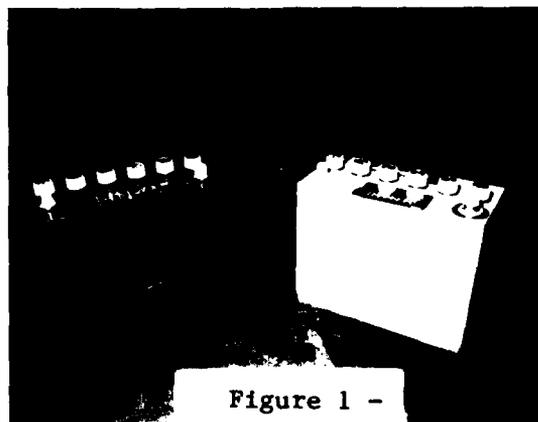


Figure 1 -  
Prototype 2HL Battery (Right)  
Developed to Replace the 2HN (Left)

#### **BENEFITS**

The new battery will provide the military with the dry-charged capability in a low maintenance battery for long term storage and ease of shipment. The battery, in its new plastic container, will decrease breakage and increase battery life expectancy.

The results of the development of the dry charged, low maintenance, plastic container battery is applicable to military vehicle batteries of all military vehicles up to 2 1/2-tons.

With implementation of the low maintenance battery into the supply system, total battery procurement will be reduced by reason of a reduction of production quantities required. Battery life will be increased by at least six months. Furthermore, maintenance should be reduced, since the addition of water and routine maintenance will be virtually eliminated.

No patent rights are involved in this project.

## **IMPLEMENTATION**

This project was finished with the delivery of the prototype batteries to the Government. Laboratory testing and field evaluation of them is being carried out under a follow-on project (482 5019).

## **MORE INFORMATION**

Additional information may be obtained from Mr. Joseph H. Reinman, TACOM, AV 786-5035 or Commercial (313) 574-5035. An interim Technical Report published in May, 1983, covered materials and physical characteristics, electrical performance, and physical performance data on the new prototypes.

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Summary report, Dec 84, was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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

MMT Project T80 5045 titled "Spall Suppressive Armor for Combat Vehicles (Phase II)" was completed by the US Army Tank-Automotive Command (TACOM) in May 1983 at a cost of \$86,000.

**BACKGROUND**

The detonation of an impacting HEAT or a near-miss HE projectile can shatter a lethal volume of spall from the interior surfaces of aluminum armored vehicles. Many spall suppressive materials had been evaluated, but the greatest reductions in lethality were achieved by using KEVLAR 29 panels spaced a short distance away from the interior surface of the aluminum.

This project, the final year of a 2-year program to develop the technology required for the installation of the spall liners, was conducted through in-house effort at TACOM and contractual effort at FMC Corporation, Ordnance Division, San Jose, CA.

**SUMMARY**

During the first year of the program, investigations were centered on the construction and installation of prototype armor kits for the M113A1/A2 Armored Personnel Carrier. The most critical areas of personnel vulnerability were determined and studied for the integration of the best ballistic protection. The KEVLAR 29/PVB - Phenolic panels were attached to the sponsons by track mounts (similar to sliding doors) and attached to the ramp and ceiling by bolting. Three complete kits were manufactured by the contractor. One kit was sent to Yuma Proving Grounds and installed as shown in figure 1.

During the second year of the program, this kit was road tested for 6,000 miles as follows: 2,000 miles paved, 2,000 miles level cross country, and 2,000 miles gravel. During the 15-month testing period, the ambient temperature varied from 35°F to 118°F. Upon removal, the panels had not become bent nor distorted and showed negligible wear.

At the contractor's test range at Hollister, California, the kit was installed in a battle damaged M113. The vehicle was combat loaded with various items of personal gear, rations, night sighting equipment, NBC equipment, and small arms ammunition of various calibers. Five HEAT rounds (approximately 3.5 inch diameter) were statically detonated into the hull at various locations around the vehicle. The roof was attacked by two M42 bomblets. Results indicated that the system performed its function by reducing the fragment spray. The jet and the slug penetrated completely but the fragments were contained. The sliding door liners on the sponson contained all of the stowed items placed therein. The theoretical crew casualty level was reduced from 11 to 2.

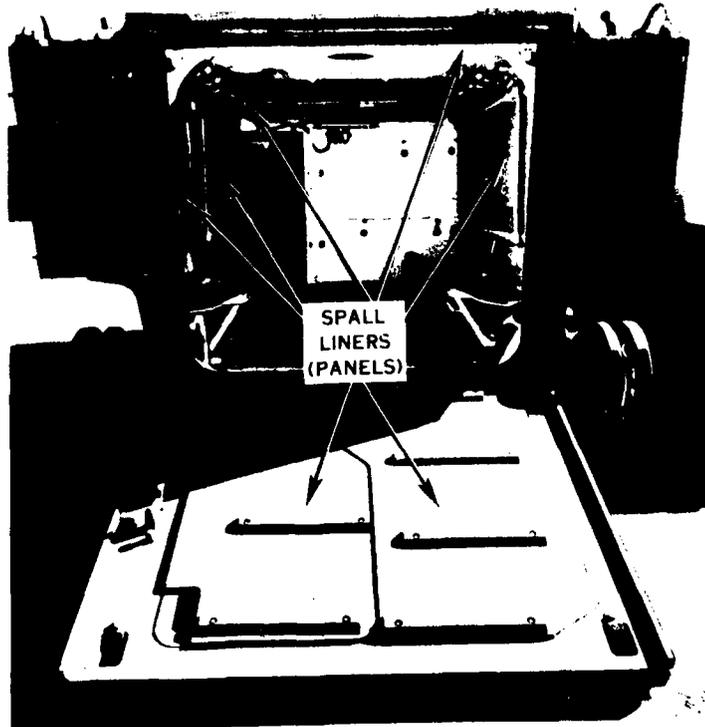


Figure 1 - Carrier Interior and Exterior

#### **BENEFITS**

No manufacturing benefits were derived from this project since most of the work was devoted to the installation and evaluation of armor kits. However, the work that was accomplished did result in the delivery of three complete sets of armor and installation hardware.

#### **IMPLEMENTATION**

Support from the Training and Doctrine Command (TRADOC) has recently been secured. If TRADOC selects the spall liner system for the M113, they will request Department of Army funding approval. The first implementation could involve a phased retrofit of 4,000 vehicles at the Red River Army Depot beginning in FY 86. The estimated cost for each spall kit is \$12,000.

#### **MORE INFORMATION**

Additional information on this project is available from Mr. Avery Fisher, TACOM, AUTOVON 786-6478 or Commercial (313) 574-6478. The final technical report is Number 12853, "Development and Test of Installation Methods for a Spall Liner System."

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)**

MT Project E82 3592 titled "Improved Graphite Fiber Reinforcement, Phase II" was completed by the US Army Belvoir Research and Development Center (BRDC) in May 1984 at a cost of \$257,000.

**BACKGROUND**

Aluminum components of military assault bridges are prone to excessive flexion during vehicular crossings. To correct this problem, the materials for future bridging systems need to be upgraded to improve stiffness. Existing aluminum structures will be replaced or augmented by graphite reinforced organic or metal matrix composite structures. Currently available commercial grade graphite fiber could be used; however, a higher strength, high modulus fiber would further enhance operation and reliability. With an improved fiber, for example, the clear span of a bridge could be lengthened by 33 percent and its service life prolonged.

Phases I and II of this project were completed under funding provided in FY78 and FY79 thereby completing this project to the point where a pilot plant for graphite fiber production was in place. The pilot plant was separated into two lines: one line for two oxidation ovens and the other for the carbonizer and two graphitizers. The 1400°C pre-graphitization furnace and the 2400°C graphitization/boron treatment furnace are shown in figure 1. The 1400°C furnace appears on the right hand side of the figure.

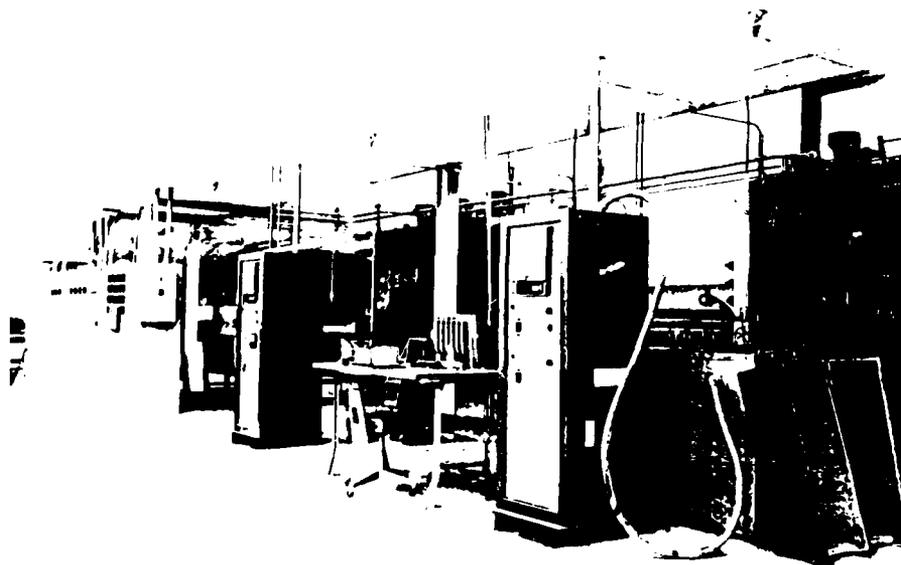


Figure 1 - Pilot Line (Graphitization Furnaces)

Preliminary optimization of fiber processing conditions during Phase II achieved an average tensile strength of 550,000 psi at a tensile modulus of  $60 \times 10^6$  psi. This graphite fiber was prepared from commercially available PAN precursor which was additionally drawn until the filament diameters were reduced to 6-8 microns. After relatively conventional oxidation, carbonization and graphitization, diborane gas was used as the source for a boron strengthening treatment during final graphitization. The finished fiber contained 3-4 micron filaments.

Phase II was conducted to complete the process optimization. This was accomplished through in-house effort at BRDC and contractual effort at Fiber Materials, Inc., Biddeford, Maine.

## SUMMARY

Conditions for the oxidation of drawn PAN fiber were established. Although there was no clear relationship between oxygen content and tensile strength or modulus, the highest strength/modulus fibers were made from oxidized fiber that had 11.0 to 12.5% oxygen by weight. The oven temperatures were set at 266°C and 275°C for the first and second oxidation ovens, respectively. At an oxidation line speed of 1.4 ft/min., a total residence time of 2-1/2 hours was available in the hot zones. Oxidation remained as the rate limiting step of the entire process. In a 24 hour period, the ovens were able to produce 6 pounds of 6,000 filament oxidized fiber. The 6 pound output yielded 3 pounds of graphite fiber.

Pre-carbonization studies involved the effect of temperature, nitrogen gas flows and residence time. The furnace had four heating zones. Optimum conditions were reached when the heating elements of the first three zones were off and the temperature of the last zone was set at 680°C. The residence time was one minute.

The data generated from the optimization of the carbonization process showed that fiber strength goes through a maximum in the range of 1300°C to 1500°C, and then there is a progressive lowering of strength with increasing temperature. There was no distinct relationship between temperature and resulting modulus.

Graphitization temperatures ranging from 2450°C to 2825°C were evaluated. The highest tensile values were achieved by processing at 2500°C-2600°C. However, the modulus values began a gradual decrease in the 2450°C - 2600°C range. The best combination of mechanical properties occurred at 2500°C and a graphitization residence time of 1/2 minute. Graphite fiber processed at the selected pre-carbonization and carbonization conditions and at 2500°C had an average  $54.4 \times 10^6$  psi modulus and a  $528.9 \times 10^3$  psi tensile strength.

Boron treatment studies were conducted on the optimized fiber. The diborane caused soot and hard deposits inside the graphitization furnace which interfered with gas flow, caused fuzzy accumulations and eventually disrupted production. Some improvement in modulus was gained by boron treatment at the expense of tensile strength.

## **NEFITS**

The routine production of improved graphite fiber has been demonstrated at a rate of three pounds in 24 hours. Definition of the process conditions required has also been established.

## **MPLEMENTATION**

The results of this project will be implemented by the preparation of military specifications governing the procurement of high strength/high modulus graphite fiber.

## **DRE INFORMATION**

Additional information on this project is available from Mr. Frank Harris, BRDC, AUTOVON 354-5471 or Commercial (703) 664-5471. The final technical report from the contractor is FM1-1990, "Optimization of the Pilot Production Process for Improved Graphite Fiber", dated December 1983.

Summary report, Dec 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)**

TT Project **E84 3800** titled "**Non-Gum Elastomer Hoses**" was terminated by the Belvoir Research and Development Center in June 1984 at a cost of \$15,300.

**BACKGROUND**

Present hose manufacturing techniques rely on the use and availability of gum rubbers. This technology, using gum rubbers in the sheet or extruded form, "hand build" hose, has changed very little over the past 50 years. As a result, hose performance has been limited in (1) low temperature flexibility, and (2) compatibility with a wide range of fluids. This restricted performance range is due to the limited characteristics of the gum rubber compounds which are available.

Elastomers such as polyurethane, polyethylene, polyvinyl chloride, and thermoplastic rubbers offer improved low temperature and compatibility characteristics. However, they are generally available only as castable, liquid, or one-shot coating. It was desired to perfect a manufacturing technology to use these elastomers.

**SUMMARY**

Liquid or castable (Non-Gum) elastomers were expected to yield hoses with improved performance characteristics, especially in the low temperature range. Also, there was a likely possibility of lowering the cost of hose production.

A contract package was prepared and processed up to the point of solicitation release. Then, money for this project was withdrawn in order to fund a higher priority program. All work on this project was terminated as of June 1984. In the event of expected further funding reductions, this effort will not be pursued in future years.

**FOR MORE INFORMATION**

Additional information may be obtained by contacting the Belvoir Research and Development Center project engineer, Mr. Charles Browne, AV 354-5781 or Commercial (703) 664-5781.

This summary report, Dec 84, was prepared by Wayne Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299-7260.

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