US Army

ManTech Journal

Guidelines for Defense Contractors

Volume 8/Number 2/1983

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Volume 8/Number 2/1983

Contents

ABOUT THE COVER:

The dramatic photograph on the cover of this issue of the U.S. Army ManTech Journal depicts what may be a dying breed of skilled workmen in the Army's industrial base operations. The welder shown is working currently at Rock Island Arsenal on field components, but when the Arsenal's Project REARM is completed in 1987, much of the welding this workman is doing will be done by computer controlled robot devices and automatic welding equipment planned for installation.

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Comments by the Editor


RAYMOND L. FARROW

Several items of high interest to our readers are contained in this issue of the U.S. Army ManTech Journal. Reports on two important guidance conferences highlight the contents of the magazine and point up the fact that the Army's mantech activities are continuing to attract a large number of industrial participants who have responded to our needs for development work in specific areas. The system of conducting these conferences in order to offer Army guidelines on needed manufacturing technology work has been highly successful for all concerned in the past and will continue to be an extremely effective way of attaining Army production goals and efficiencies.

The first of these conferences discussed is the FY85 MM&T Guidance Conference conducted by the U.S. Army Munitions Production Base Modernization Agency last November in Dover, New Jersey. This fifth annual conference was attended by over 125 representatives of private industry as well as 150 Government personnel, who followed the theme "Technology Investment—Key to Industrial Preparedness". This stressed both the need to invest in the development of technology and the need to implement the technology that is developed onto the factory floor. The need for proposals in the area of Army munitions, including large and small caliber, chemical, and product assurance formed the heart of the conference, with some interesting insights into the perspectives of the Air Force and Navy, along with those of MTAG and DARCOM—particularly, the thrust toward industrial productivity improvement, or IPI. MMT opportunities in current production also were discussed by the Army's Rock Island Arsenal representative.

A second important guidance conference is discussed in the article on the U.S. Army Aviation Research and Development Command's Army Aviation Manufacturing Technology Conference III held in Williamsburg 7-11 March of this year. Panels on Metal Airframe, Nonmetal Airframe, Propulsion, Rotor, Drive, and Aircraft Subsystems heard over 170 proposals on manufacturing technology projects emphasizing Propulsion and Subsystems. Over 220 attendees participated in the five day conference, representing 57 industrial firms and 9 Government agencies. Some of the Army's most outstanding mantech accomplishments have resulted from proposals encouraged by these guidance conferences, and advances in coming years certainly will be profoundly affected by these two conferences and those that are forthcoming thru other agencies.

As has become our practice over the past several issues of the U.S. Army ManTech Journal, this issue contains a multitude of brief reports on the status of ongoing projects, each giving the name of the Army project engineer and his telephone number for ease of contact by our readers who may have a special interest in that given topic.

The Tank Infantry Systems Division of the U.S. Army Armament Research and Development Command has completed a project on automated pre-encapsulation inspection of integrated circuits which is highlighted in one article in this issue. Although such an automated inspection system as yet is unavailable commercially, a thorough survey was made of firms working on systems that might prove feasible. These include image comparison techniques, image understanding, laser optic technologies, acoustic microscopy, and electro-optical pattern recognition. Further work is planned that will make a best buy prediction possible.

Composite dies for high energy rate forming are discussed in an article in this issue on a project done in-house at the U.S. Army Materials and Mechanics Research Center. High temperature alloy and titanium parts for helicopters now can be formed in half the time and for half the cost of other methods used previously.

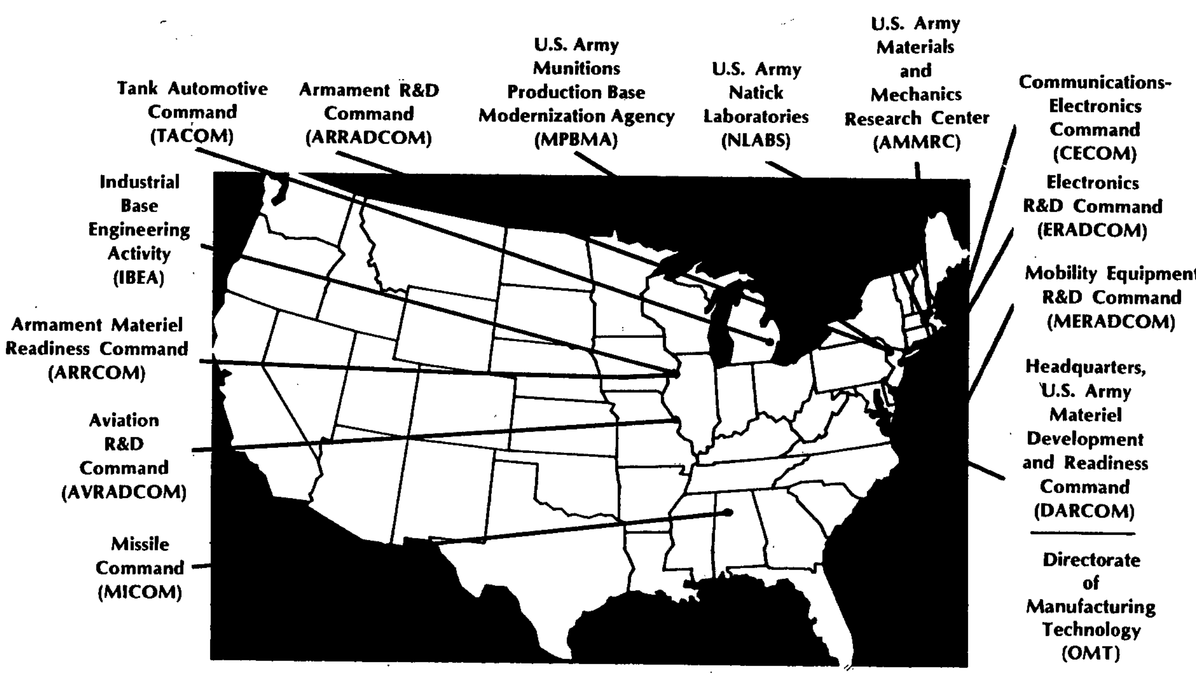
The self cleaning action of normal inertia welding is lost during the welding of rotating bands on projectiles, so this problem was attacked by a project carried out by the Large Caliber Weapon Systems Laboratory of the U.S. Army Armament Research and Development Command. Our article on projectile banding via inertia welding details the results of this successful project, in which the parameters required for cleanliness of surfaces were determined for effective bonding on rotational axes.

Improved visibility and ballistic capability for tanks were achieved by the U.S. Army Tank-Automotive Command during a mantech project on lightweight armored vehicle vision blocks, as described in our article in this issue of the U.S. Army ManTech Journal. The work reviewed the performance and design data required to meet a specified threat level, then new designs of vision block were fabricated and tested which enhanced crew performance in the field.

The applicability of aluminum-steel transition strips formed by explosive bonding in the joining of heavy plates of dissimilar metals has been verified during a mantech project by the U.S. Army Tank-Automotive Command. This Army ManTech Journal article details the procedures that were used to prove this technique feasible for the first time on such heavy components.

Batch processing requirements for fabrication of Nd:YAG laser rods were satisfied by the results of a manufacturing technology project sponsored by the U.S. Army Electronics Research Command; development of the critical tool to accomplish this objective—a polishing fixture—is described in our article. Design and fabrication of this tool has brought the cost of individual Nd:YAG laser rods down to a realistic production value.

DARCOM Manufacturing Methods and Technology Community



5th Annual Conference at Dover

FY 85 Munitions MMT Conference

By

Rex Powell

Munitions Production Base Modernization Agency

The U.S. Army Munitions Production Base Modernization Agency hosted its 5th Annual Manufacturing Methods and Technology (MMT) Guidance Conference at ARRADCOM Headquarters on November 9, 1982. The conference concentrated on technology needs for the FY85 Munitions MMT Program and was attended by 125 representatives of private industry as well as 150 Government personnel.

The theme of the conference was "Technology Investment—Key to Industrial Preparedness", which stressed both the need to invest in the development of technology and the need to implement the technology that is developed onto the factory floor. Results of the conference will mean more extensive industry participation in the MMT program and better planned and executed MMT projects.

Key Points Emphasized

Col. Henry Thayer gave the Welcome and Introductory Remarks, which centered around the Munitions Production Base Modernization program and planning guidance for MMT. This latter topic focused on six key points: support of facilities modernization program, provision of improved processes for existing facilities, evaluation of new processes for future facilities, improvement of project justification/screening and selection, broadening of industry participation in planning, and improvement of program execution and implementation.

MM&T program execution will be improved through the following initiatives:

- Terminate/Complete Old Projects
- Continually Measure Effectiveness
- Weed Out Losers and Accelerate Winners
- Don't Overload Contractor Capability
- Shorten Execution Times

NOTE: This manufacturing technology conference that was conducted by the Munitions Production Base Modernization Agency was funded by the U.S. Army Armament Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The MPBMA Point of Contact for more information is Bill Donnelly, (201) 724-2011.

- Validate Benefits at Project Completion
- Reward Quality Performance
- Assure Implementation of Results
- Transfer Technology to Industry/OGA
- Reward Quality Performance.

Col. Thayer closed with a challenge to industry (and everyone) to reduce production costs, reduce facility costs, improve producibility, increase productivity, and improve product quality.

Motivation Increase

A program overview of facility modernization and expansion delivered by Mr. Charles Osiecki centered on the TOA Overview, program thrusts, other service support, and the FY84 and FY85 plans.

The DARCOM perspective for industrial productivity improvement (IPI) by Mr. Charles Kimsey proposed a strategy to reduce acquisition costs by increasing contractor motivation to maximize manufacturing efficiency. The objective of the IPI program is to increase profits to contractors (with performance incentives, for example) while reducing cost to the Government. Specific programs involving such companies as General Dynamics and Avco Lycoming were reviewed.

The MTAG perspective by Mr. John Kaschak discussed its mission, structure, responsibilities, and involvement with industrial associations and societies.

PROCESS OPPORTUNITIES AND IMPLICATIONS

U.S. Army

The Army's major **large caliber** munition R&D thrusts as discussed by B. W. Busheyare to defeat armor, counter battery fire, and interrupt movement and deployment of troops and armor. The principal munition systems are (1) tank fired kinetic and chemical energy projectiles, (2) artillery delivered precision or "smart" projectiles for counter battery fire and the defeat of armor, and (3) ground emplaced artillery or air delivered antipersonnel and antitank mines to inhibit movement of troops and armor in both forward and rear areas of engagement.

In **small caliber** munitions, the emphasis is on increased penetration of helmets through the addition of steel penetrators to the conventional ball bullet and caseless amunition wherein the propellant is molded around the projectile. Although not a new concept, new binder materials have been developed to overcome the cook-off and other problems that previously prevented the successful development of caseless ammunition. Other areas of emphasis are on plastic bank ammunition for the .50 caliber weapon and on low cost, limited range training ammunition for cannon caliber weapon systems. High-length-to-diameter kinetic energy penetrators are being designed and fielded for .50 caliber through 30 mm weapon systems. also, multipurpose fuzeless, armor penetrating high explosive projectiles for these weapon systems are under development. In these projectiles, the explosive charge is sensitized upon firing to respond to a shock and/or heat stimuls for initiation upon penetration of the target. The last small caliber item is a Command Adjusted Trajectory (CAT) projectile for application in the air defense role. The projectile upon firing is tracked by the firing crew or another command crew which sends commands to the onboard projectile control system to modify the trajectory to intercept the target. This project is in the prototype design phase. Each of these small caliber programs has definite manufacturing technology needs; however, the emphasis of this presentation was on large caliber munitions.

Small caliber munitions were further discussed by Mr. William Dietrich. Near term requirements are for a 25 mm long rod penetration, .50 caliber robot launched AP projectiles (SLAP), .50 caliber plastic blanks, .50/5.56 caliber short range training ammunition, plastic links, and plastic packaging. Also discussed were improvements of existing facilities and future implementation of programs (e.g., maneuvering projectiles and caseless weapons systems).

Chemical munitions was presented by Mr. T. J. Abbott of the Chemical Systems Laboratory. This laboratory is responsible primarily for deterrent agent and munitions systems and the smoke screen agents and munitions systems. As far as MMT programs are concerned, there is a need to prove out new and/or improved manufacturing, handling, and load, assemble, and pack techniques.

In the deterrent area, lethal binary chemical munitions have a high visibility within the DOD. Work is centering around a VX munition along with a treatment process to handle waste by-products which will result from these facilities.

Product assurance by Mr. Gus Sylvestro discussed PAD responsibility in inspection technology, status of some of the current PAD MMT programs, planned PAD MMT programs, and principle MMT testing needs.

PAD responsibility in inspection technology centers on development, coordinatioin and management of overall ARRADCOM program in inspection technology. They provide the single point of contact for all product assurance considerations to MPBMA and also manage and provide Level II chairmanship for ARRADCOM materiel testing technology (MTT) programs. In addition, they provide test technology in the following areas of specialization: ultrasonics, optics, radiology, radar, eddy current, magnetic particle, magnetic flux leakage, image processing, and propulsion.

Principle MMT needs are for:

- Modernization of closed bomb laboratory at RAAP
- NDT inspection of combustible cartridges
  Case for 120 MM tank system
  Increment containers for 60/81 MM mortar
- Reliable and cost effective test for acceptance of primers
- A digital image amplification X-ray system for inspection of mortar rounds
- Automated inspection of small arms cartridge links
- Acceptance of stick propellant produced on an automated line
- Base separation and void measurement by microwaves
- Improved data acquisition and ballistic tracking of SMART projectiles
- Automated pre-cap visual test
- Nondestructive testing of electrical connections.

PAD MMT programs for FY85 will provide reliability, safety, and cost effectiveness by exploiting the following technologies and automation techniques:

- Real-time image amplification radiographic system incorporating automated digital signal processing techniques
- Automated image processing system to eliminate human judgment in interpretation of visual defects
- Swept frequency radar to detect voids and base separation in cast high explosive fillers
- Thermal wave analysis to determine bond strengths.

U.S. Air Force

J. Reginald Lewis of the Armament Division discussed the Air Force munitions R&D thrusts. Their current product line includes small caliber ammo and guns, support equipment, aerial targets, cluster weapons, guidance kits—TV, IR, laser, air-to-air missiles, and surface attack weapons. Examples of advanced and full scale development efforts and exploratory and advanced development efforts were given. Requested future manufacturing technology projects include advanced broadband radomes, 30 MM APFSDS projectile and sabot diverter, 30 MM augmented lateral effects projectile, RAUFOSS technology ammunition, solid state accelerometer, seeker gyro and inertial reference unit, tactical ring laser gyro, WASP injection molded electronic enclosures, thermal battery production improvement, and cast bulkheads/Tailcone—TMD.

Mr. Harvey Burnsteel discussed the Navy's ammunition activities, which presently feature participation in several programs with the Army which are discussed in that service's presentation.

CURRENT PRODUCTION MMT OPPORTUNITIES

Mr. Dennis Dunlap (ARRCOM-RIA) began his presentation on MMT opportunities with ongoing production with some areas in general program management which need to be improved upon. To improve program visibility, our implementation record, technical reports, end of project presentations, MMT accomplishment charts, and auditable benefits must be improved. Improving productivity was also discussed in relation to indirect labor, test/inspection methods, direct labor, and robotics, CAD/CAM.

One key point to remember is that our production base procedures must be involved from the beginning.

Proposals have been received from GOCO facilities in four areas—(1) metal parts; (2) propellants and explosives; (3) load, assemble, and pack; and (4) environmental protection. They have been forwarded for consideration of MMT funding **Metal parts include** pre-impregnated fiberglass for M483 MPTS, torque and centralizing assembly machine, application of industrial robots in MPTS operations, warm shearing of billets, automatic inspection for rotating band chemistry, automatic tool wear compensation, automatic inspection for fiberglass content, and automatic inspection of M42/M46 grenade bodies.

Propellants and Explosives include pilot plant for NC components, automatic attrition mills for pulping houses, improved laboratory analysis techniques, nitroguanidine production process optimization, screw extrusion of solventless propellant, and use of crude RDX/class in composition B.

Load, assemble, and pack center around improved sewing systems and automatic printing for bag manufacturing, vibratory loading system for propellant charges, digital checkweigh scale, improved loading of base ignited charges, application of industrial robots in LAP operations, automatic indexing and pouring machine for melt/cast explosives, M483 LAP improvements, electrical tester for RAAM lenses, automatic marking of wirebound boxes, and automatic inspection of M42/M46 grenades.

Environmental protection encompasses feasibility of filtering GN reactor effluent, treatment of mechanical roll waste water, diethylphtalate (DEP) decomposition, cyanide removal from waste calcium carbide, treatment/disposal of contaminated sludge, improved pollution monitoring in wastewater streams, and improved treatment processes for wastewater streams.

Some current MMT needs include prototype 50 caliber linking equipment, improved 50 caliber bullet manufacturing, improved process for 7.62 MM manufacturing 16 inch propellant charge loading improvements, automated process for FASCAM, NDT of RAP delay column assemblies, improved process for primer mix nitration, and pretreatment reduction of pink water RDX content.

Where the Dollars Will Be Spent

Project proposal requirements, program schedule, and thrusts were presented by Mr. Rex Powell MPBMA. As can be seen in Figure 1, the MMT program was at its highest funding level in FY76 and since has dropped considerably. However, funding is projected to rise by FY85 and surpass the FY76 peak. The FY70-83 funding of $377 million (Figure 2) shows that about the same percentage of the available funding has and will be spent in the same technical areas during the FY82-84 period (Figure 3).

The MMT thrusts in products will focus upon seekers and sensors, electro/optical, RDF/high technology division munitions, insensitive explosives/propellants

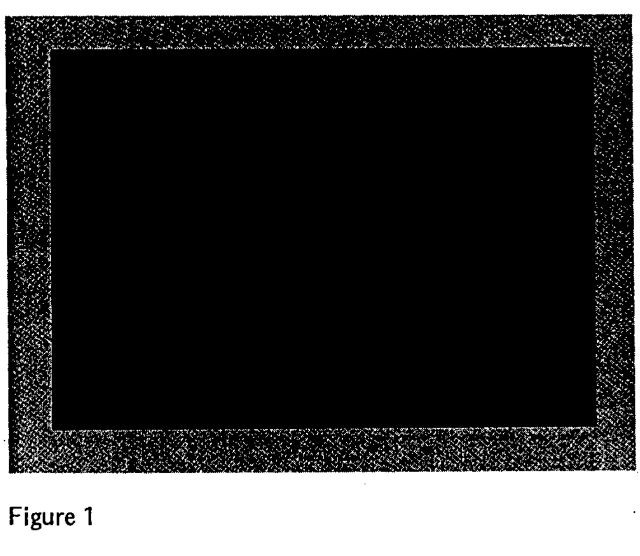


Figure 1

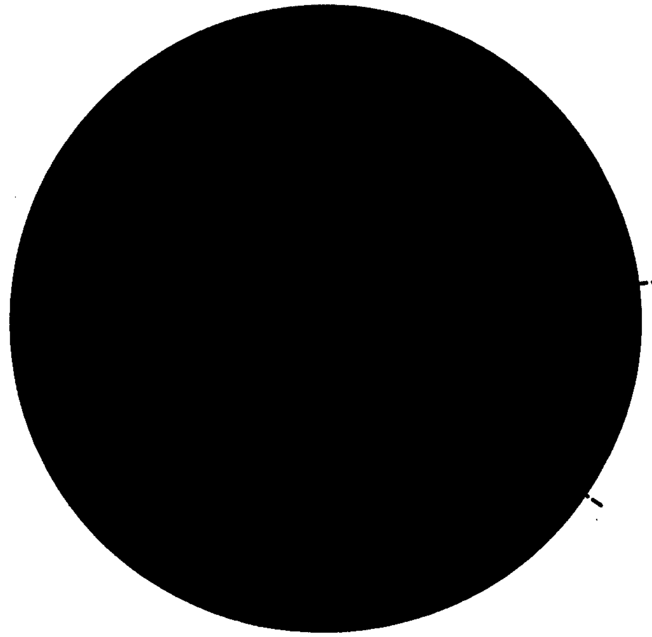


Figure 2

(stick/combustible case and PBX's and RDX/HMX), fuzing—that is compatibility with auto firing, product improved munitions (PIP's), critical materials/substitution, kill mechanisms (SFF, liners, penetrators), micro-initiation/detonation, chemical munitions, gun hardened microelectronics, and mobilization/surge/sustainability policy.

Concerning process equipment, the important areas will be flexible machining robotics, microprocessors and software, advanced assembly and joining technology, automated fabrication and inspection, microelectronics and miniaturization, and composites/plastics), nondestructive testing, advanced metal forming, joining and cutting, optical recognition (fiber optics/lasers), CAD/CAM-computer integrated manufacturing, automated batch processes multiproduct production, industrial modernization incentives programs, regulatory compliance technology, and unit processes (drying and separation).

A summary proposal format to use with MM&T programs also was suggested. It included seventeen key points to consider, ranging from the proposal identification code through the statement of the problem, the proposed solution, facilities, and funding.

What's Needed

METAL PARTS

Mr. Kal Kolis discussed what areas need to be studied in conjunction with the Metal Parts Division. For **tanks,** current items are bare extrusion of billets (DU), ion vapor deposition for DU cores, improved heat treat technology, and chip recycling/waste disposal. For **artillery**, activity will center on adaptation to existing machines, machine tool monitoring and changing, automated inspection for rotating band chemistry, and automated inspection for fiberglass content.

Cannon's (20 mm to 40 mm) will require high volume, low cost manufacture of ogive assemblies, manufacture of sabots and fins for high L/D APDS projectiles, process to assemble fuzes to projectiles, and high speed assembly of impact switches.

The **mechanical thrust** will be aimed at manufacturing technology for self-forging fragment liners, cost effective assembly of base to projectile, high speed test of self forging fragment liners, and automated assembly of parachute devices.

Electronics has a wish list broken down into three areas: manufacturing processes, automated assembly, and automatic testing. **Manufacturing processes** include low noise, high gain bandwidth transistors, gunn, mixer and varactor 35 GHz diodes, photolithography—MMW circuit boards, and leaded chip carriers. **Automated assembly** encompasses MMIC IF pre-amp/amp (integrated chip), MMW components on MMIC circuit boards, IR focal plane detectors and transducers, and electronic modules and sensors.

Finally, **automatic testing** includes MMIC subassemblies with RF sensor systems, microprocessor chips, IR transducers, and boresighting—IR focal plane to MMW antennas.

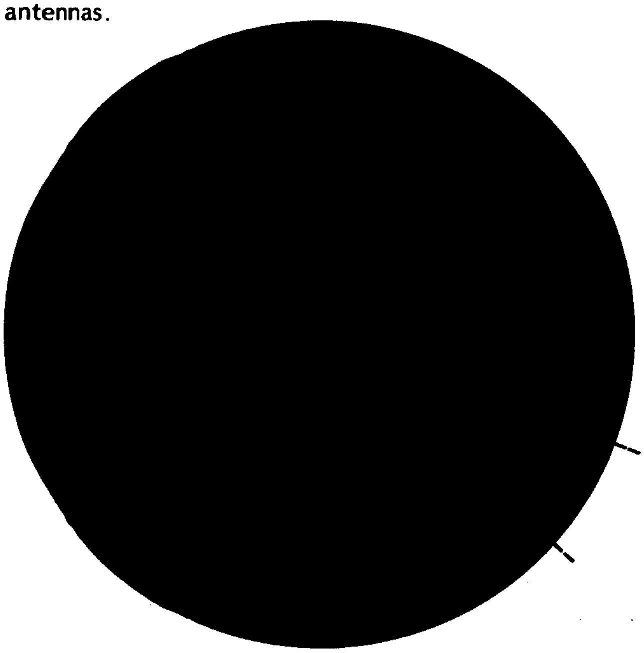


Figure 3

PROPELLANTS AND EXPLOSIVES

Suggested MMT efforts for propellants and explosives were presented by L. Laibson, T. Caggiano, and R. Koppenaal. Areas of interest dealing with wastewater include the pilot plant evaluation for treating detonator wastewater at Kansas AAP, solar aquaculture wastewater treatment, ball powder wastewater abatement, nitroguanidine wastewater treatment, and nitramine propellant wastewaters abatement. Other areas are improved boiler efficiency, air pollution abatement for coat and glaze operations at Badger AAP, manufacture of ultrafine nitroguanidine, process analysis of ROX/HMX slurry, improved manufacturing processes for HMX and EAK explosives, and improved controls for TNT lines—just to name a few.

LOAD, ASSEMBLE AND PACK

Opportunities targeted for load, assemble, and pack by A. Siklosi, D. Muller, P. Corradi, and F. Miksis included plastic bonded explosives (PBX), LAP of 120 mm tank ammunition, cost effective safety, LAP of 75 mm ammunition, improved process technology for chemical munitions, and M483 explosive charge loading improvement.

More Details Available

It is impossible to fully cover all the topics discussed at the FY85 MM&T Munitions Production Base Guidance Conference and the specific needs of the various MPBMA divisions. For example, the Metal Parts Division alone lists over 40 pages of needed future MM&T effort. Included in these listings are program title, funding period, specific technology, related/prior MMT effort, and point of contact.

If your firm is interested in participating in the Army's munitions effort, it is strongly suggested that you obtain a copy of the Conference Proceedings to see where your capabilities fit in. Copies are available from:

The Department of the Army
U.S. Army Munitions Production Base
Modernization Agency
Dover, New Jersey 07801

Less Parts Not Always Cheaper

Army Aviation III Conference Report

By

Bruce Park
Project Engineer

U. S. Army Aviation Research
and Development Command

More than 220 attendees from 9 government agencies and 57 industrial firms participated in the U.S. Army Aviation Research and Development Command's Manufacturing Technology Conference III at Williamsburg, Virginia March 7-11. The meeting at which over 170 proposals were presented by participants, served as an interface between helicopter representatives from all three military services and industry.

Propulsion Leads Categories

A breakdown of proposals for each category follows, with the most highly judged one(s) from each panel to be selected for consideration for funding at a later date.

Airframe, metal	27	Chairman: Allen C. Haggerty
Airframe, nonmetal	33	Chairman: James J. Kenna
Drive	15	Chairman: Alan H. Smith
Propulsion	49	Chairman: Frank E. Pickering
Rotor	15	Chairman: Peter C. Ogle
Subsystem	42	Chairman: Reginald Waller
Total	181	

The total above is greater than the total number of proposals due to the fact that some were presented to more than one panel.

Full Professional Support Given

Conference support was provided by the Hampton Roads Chapter of the American Helicopter Society and the Applied Technology Laboratory at Ft. Eustis, Virginia. The conference sponsor was the American Helicopter Society, Richard Stoessner, President. Actual conference support was provided by the Applied Technology Laboratory, with Jim Waller and Bob Powell serving as points of contact.

Production Engineering Early

The Keynote Address during the opening session was given by General Donald Keith, DARCOM Commander.

NOTE: This manufacturing technology conference that was conducted by the American Helicopter Society was funded by the U.S. Army Aviation Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The AVRADCOM Point of Contact for more information is Robert Vollmer, (314) 263-1625.

The synopsis of General Keith's address was to challenge the audience to accomplish the transition of programs from the research and development stage to production in a more efficient and cost effective manner. General Keith stated that there have been disappointments in achieving this objective from both industry and government due to higher priorities. To solve this problem, General Keith stated that both government/industry engineers will be brought into the acquisition process early and will stay throughout development. Adequate amounts of PEP and MM&T money will be obtained to make sure this objective is achieved.

Number of Components A Cost Factor

Mr. Ralph Alex, Ralph P. Alex and Associates, presented the luncheon address. Mr. Alex traced the evolution of the helicopter and noted than many of the MANTECH responsibilities of today were handled immediately on the shop floor using any materials and tools which were available. Mr. Alex also stated that less helicopter components in a helicopter system is not necessarily good. Costs for helicopter systems are minimized when there is a moderate number of components in a helicopter. Helicopter costs rise as the number of components are increased to a very large number or decreased to a small number.

Secretary of Defense Support

Mr. John Mittino, Assistant Under Secretary of Defense for Production, discussed government funding and support for the MM&T and IPI programs. Mr. Mittino stated that at the Office of the Secretary of Defense level there is strong support for these programs. Efforts in Congress are being made by his office to assure adequate funding. This effort continues in lieu of an FY83 funding cut in the Army MM&T program.

Top Proposals Considered

Titles of outstanding proposals from each panel (not in any order of significance) include the following:

Airframe, metal:
- Isostatic Forging of AH-64 Shock Strut
- Powdered Metal Parts
- Improved Low Cost: Superplastic Formed Titanium Structures
- Aluminum Powdered Metal Forgings & Extrusions
- Sheet Metal Work Center
- Group Technology for Sheet Metal Fabrication
- High Integrity Hot Isostatic Pressure Cast Aluminum Parts

Airframe, nonmetal:
- Assembly Level Joining of Large Composite Structures
- Thin Composite Laminate Cutting Methods
- Fiber Reinforced Thermoplastic Structures
- Vacuum Impregnation of Large Co-Cured Composite AF Structure
- Advanced Thermoplastic Composite

Drive:
- Production Fabrication of Overrunning Clutch Spring
- Corrosion Resistant Helicopter Structures
- Ballistic Tolerant Helicopter Bearings
- Laser Hardening of Heavily Loaded Gears
- Powdered Metal Gear Steels

Propulsion:
- Unmanned Machining Cell
- Real Time Statistical Process Control for N/C
- Microwave Frequency Eddy Current Crack Detection
- Improved Coating for Turbine Wheels Using AEP
- Resistant Spot Welding Adaptive Control

Rotor:
- Simplified Tail Blade Fabrication
- Composite Hub Production
- Automated Main Rotor Blade Tracking
- Advanced Composite Rotor Hub CH-47D
- Single Curve Cycle Tail Rotor Blade

Subsystem:
- Automated High Volume Inspection Station
- Automatic in Process Fault Isolation for Digital Hybrids
- Laser Soldering of Printed Wiring Boards
- Low Cost Design and Production of Millimeter Wave Components
- Hand Held Automatic Power Crimper

These proposals are being evaluated, and selection of those considered for future funding will be announced in the near future. Contractors who presented the proposals are not identified.

Automated Pre-Cap IC Inspection

Could Other Methods Do the Job?

A recently completed study by Columbia Research Corporation for the U.S. Army Armament Research and Development Command's Tank Infantry Systems Division was aimed at examining the feasibility of an automated inspection which can perform a 100 percent internal visual inspection of integrated circuits during production. The importance of such a system is realized when one becomes aware that scatterable mines, such as the remote anti-armor mine (RAAM) and the modular pack mine system (MOPMS), use large scale integrated circuits in their electronic fuzes.

The 100 percent visual inspection prior to encapsulation (pre-cap) is necessary for safety reasons, and it also would eliminate the use of microscopic examination and the subjectivity of human error.

GARY NIEMIC is a Project Engineer at the U. S. Army Armament, Munitions, and Chemical Command (AMCCOM – formerly ARRADCOM) at Dover, N. J. There he has been actively involved with the design, development, and evaluation of test instrumentation used on various armament systems while assigned to the Instrumentation Engineering Branch of the Product Assurance Directorate. Systems he has acquired experience on include mines, missiles, and large and small caliber ammunition.He has worked at Dover for the past six years after receiving his B.S.E.E. in Biomedical Instrumentation and his M.S.E.E. in Computer Systems from New Jersey Institute of Technology.

The Current Technology

Of thirteen large companies who currently make integrated circuit components for such purposes, none uses an automated system. They perform either a destructive visual inspection on a sample basis or use microscopic examination. About two years ago, experiments with a video system were conducted by one company; it was found to be very useful for training and for group viewing on marginal decisions; however, it did not improve the inspection process sufficiently to justify its cost and therefore was discontinued.

Engineering Studies and Evaluation

To allow a more comprehensive and objective evaluation of the alternative inspection procedures and of the positions taken by the various commercial vendors, Columbia conducted engineering studies of the specific requirements of Test Method 2010.4. This included an in-depth investigation of the requirements and implications of visual inspection as defined by MIL-STD-883B along with a comparison with the requirements of MIL-M-38510 for military JAN microcircuits.

For example, MIL-STD-883B (Method 2010.4) requires inspection of microcircuits under optical magnifications as indicated. There are 15 different types of defects each with descriptions of the accept or reject criteria: thin film resistor contact area, dielectric isolation defects, balling of die attach material, beam lead die faults, beam lead bond area and location, bonds at metallization exit, bond dimensions, bonding pad area, passivation and diffusion

NOTE: This manufacturing technology project that was conducted by Columbia Research Corporation was funded by the U.S. Army Armament Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ARRADCOM Point of Contact for more information is Gary Niemic, (201) 724-5603.

faults, MOS gate alignment, MOS scratches and voids, scribing and die defects (cracks), termination ends, scratches, and voids.

The inspector must scan the enlarged (magnified) chip image looking for flaws or defects. This scanning process is an orderly one which proceeds, for instance, from left to right and top to bottom, looking across some imaginary row and at each imaginary column within each row. At each stopping point of the visual scan the inspector must make a series of discriminations. These are shown in Figure 1.

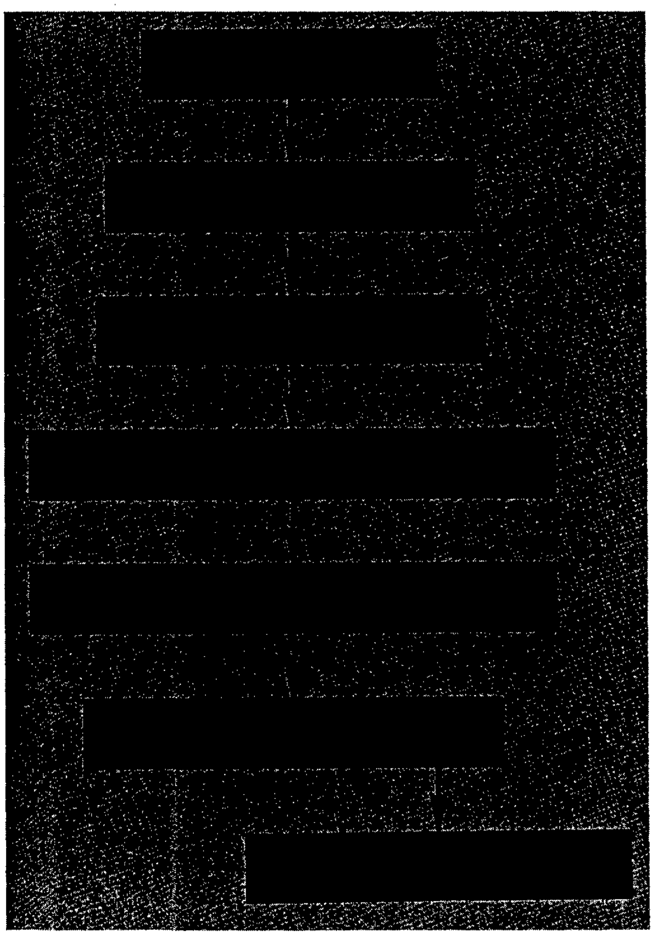


Figure 1

Human Factors Important

Studies have been conducted in the area of how many discriminations a human can make in a given period of time. The conclusions are that one can make from 10 to 20 mental discriminations per second. These are cognitive processes related to the perception of retention of simple stimuli such as those listed in Figure 1. The variance is a function of fatigue. At the rate of 20 discriminations per second, the operator tires very rapidly. It has been concluded that an effective sustained rate of 18 discriminations per second is reasonable and quite achievable in practice, with breaks for relaxation. A trained inspector could inspect one chip every 3 minutes, in accordance with MIL-STD-883B, Method 2010.4. This does not, however, account for the time required to position and repeatedly reposition the chip in the field of view of the microscope.

Another factor which must be considered when evaluating the human visual inspection is that not all of the defects are going to be detected. Two operators examining the same chip will detect different defects. Even the same operator looking at the same chip on two different occasions often will record different findings.

Current Instruments and Systems

MICROSCOPES

Several microscope systems currently available were investigated. Each has accessories available to tailor it to specific applications. Three of these special features would seem to be particularly useful in performing the pre-cap visual inspection:

- **Nomarski Differential Interference Contrast (DIC).** Nomarski DIC is a specialized illumination attachment available on some of the microscope systems. This attachment highlights slight variations in surface quality. It does this by utilizing differences in grey color density or in interference colors. In this manner, the Nomarski DIC can indicate scratch depths and peak-to-peak heights.

- **Video Compatibility.** Some of the microscopes already are compatible with closed circuit television (CCTV). Others have phototubes for camera attachments and could conceivably be adapted for CCTV use. A trinocular arrangement allows for simultaneous CCTV and binocular viewing, with the majority of the light being fed to the video monitor.

- **Automatic Transporters and Sorting Systems.** Two inspection stations, the CI-750 by Applied Materials and the Series 3000-I by Adcotech, automatically transport the ICs to and from the station. In the CI-750, this is accomplished by means of belts, while in the Series 3000-I, the ICs are tube fed. In both systems the operator indicates whether to accept, rework, or reject an IC. The sorting is then performed automatically and the information is stored in the system memory for later recall. The potential for damage to the ICs diminishes as the amount of handling decreases. The Applied Materials CI-750 is compatible with the Olympus microscope while the Adcotech Series 3000-I is video compatible.

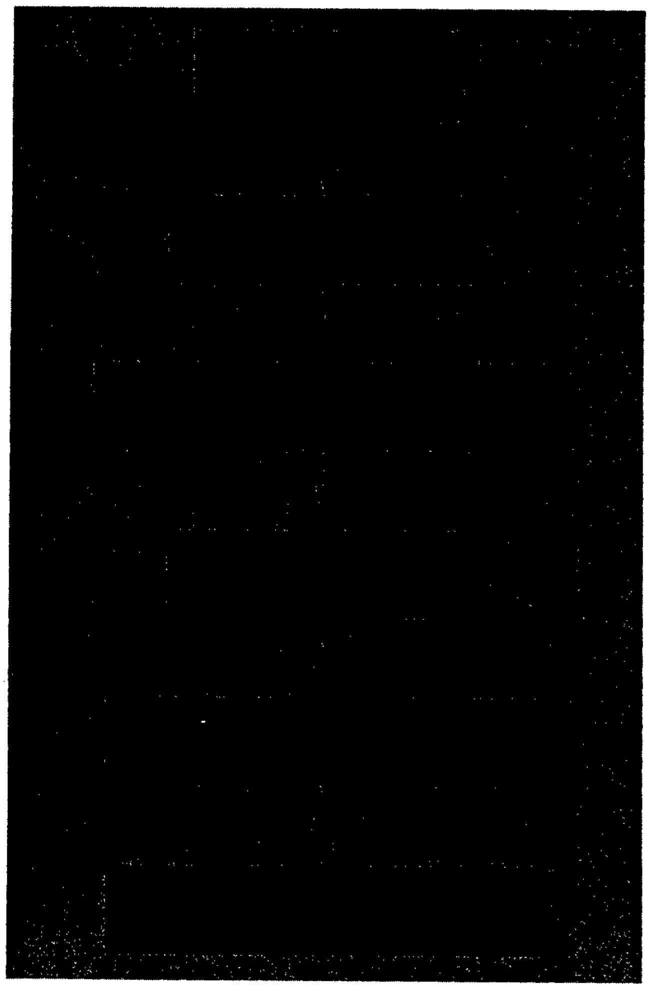


Figure 2

VIDEO SYSTEMS

Available video systems range in sophistication from simple CCTV equipment mounted on microscopes to image analyzers that can map dust particles on semiconductor chips. Video systems are employed at many stages of production to inspect raw materials, wafers, devices, circuit boards, and finished products. The technology has added accuracy and speed to both complex and simple inspection routines in many areas.

Several microscope manufacturers offer photomicrographic video equipment as options for their products. In the simplest arrangement, a TV camera is mounted on a trinocular microscope, and a video monitor is used to display the magnified image. The unit under test is thus magnified by the microscope lens and enlarged by the video system. Such systems are useful to reduce eyestrain or to allow more than one person to observe the unit under test. Multiple monitor hookups can also be arranged to carry the image to other locations. Instrumentation of this sort facilitates inspection in cases where low volumes do not demand automated techniques or where the object does not lend itself to inspection by any other method.

The TV systems' enlargement or magnification is a function of the camera's picture tube diameter and the diagonal dimension of the monitor. This factoris multiplied by the microscope magnification to obtain the total magnification. For example, a 1 inch camera tube, 13 inch monitor, and a 40X microscope objective yield a total screen magnification of 832X. A setup that provides such power can aid an inspector in making basic accept or reject decisions. For instance, shapes of incoming devices may be checked by comparing the video image of the sample with a Mylar overlay affixed to the monitor. Deviations from the standard drawn on the Mylar are readily apparent for noncomplex items, and the inspector can make a go or no-go judgment. If measurements are necessary, microscope manufacturers offer a variety of stage micrometers and reticles.

Video Comparators Strengthen Analysis

Just as video technology has enhanced microscope inspection techniques, optical comparators have been transformed into video comprators by the addition of two cameras and a monitor. While most optical comparators require special room illumination or an overhead canopy for a clear view of the projected image, video based systems are freed from these constraints. Alternate images of the sample and the standard may be flashed on the monitor and errors show up as differences in color or motion between the views. Based on these differences, the inspector can assess the sample as good or bad. For closer inspection, both images can be displayed on a split or overlaid screen. Such instruments are in use inspecting high density printed circuit boards used in computer and aerospace equipment.

In addition to the simplified closed loop video systems as described above, there are various methods of processing the video signal prior to display in order to enhance the image or evaluate its characteristics. Analog video signals from the camera tube can be converted to digital data that may be stored in computer memory or mass storage devices or manipulated and conditioned stored in a number of ways to enhance clarity, identify perturbations, and signal existence of deformities. Such image analysis instruments have generally been employed in fields outside the electronic industry, such as material sciences for counting asbestos fibers and examining petrochemicals and biomedical applications for ascertaining structure and character of cell tissue. There have been limited applications of image analyzers by semiconductor manufacturers for checking direct photolithography and particle contamination of wafers.

AUTOMATED INSPECTION SYSTEMS

Manufacturers of automated test equipment (ATE) were contacted to see if they currently had or were developing an automated system to perform the pre-cap visual inspection. To date, however, no one has such a system available on the market. Details about these systems are difficult to obtain because they are still in the development stage and much of the information is proprietary. However, the following was learned.

KLA Instrument Corporation of Santa Clara, California currently is working on an IC inspection system. This sytem apparently utilizes image comparison techniques between the test chip and a master reference chip. The difficulty with developing such an inspection system is that the requirements of Method 2010.4 push the state of the art in software capabilities. It is one thing to design a system that can automatically perform the inspection. It is another to design one that is cost effective. At present, KLA is using a general purpose computer which is not fast enough to show large decreases in inspection times, although it is still faster than human inspectors. KLA hopes to improve this by custom making the computer to better serve the system. The development process has not yet reached the point where there is any printed information ready for release.

In Japan, Hitachi is reportedly working on an automated visual inspection system for ICs. No details are available about the system other than that Hitachi estimates that it will be about two years before its system will be ready to market.

Contrex, Inc., of Burlington, Massachusetts, has been developing a fully automated chip inspection system (CIS) which utilizes a technique called image understanding. Image understanding can be thought of as the capability of a computer to extract, process, and interpret, in real time, visual information provided by an image acquisition device such as a CCTV camera. The CIS is made up of the following design elements:

- **System controller,** with custom software for chip inspection, error reporting, and tabulation.

- **Image analyzer,** which converts the viewed image into a digitized form, extracting the features needed in the decision making process.

- **Operator console,** which allows manual entry of data and manipulation of the various electromechanical components of the system. The console also includes a videomonitor for reviewing the progress of the tests and for operator prompting.

- **Optical microscope,** with computer controlled Z-axis movement for automatic focusing.

- **An X, Y, Theta positioning stage,** allowing reproducible positioning of the chip under test to 0.0001 inch. This positioner is also controlled by the system controller via the imaging feedback loop.

- **Computer controllable illumination system,** which allows the system controller to maintain a constant level of illumination over the span of the test. It also enables the system to reproduce the level of illumination from one test run to a new test run some period of time later without requiring manual intervention.

LASER OPTICS

Several companies are working on automated systems for the visual inspection of printed circuit boards. In these efforts, laser technology has proven to be a useful tool.

Chrysler Electronics Division in Huntsville, Alabama has developed the LIS-510 inspection system which utilizes a low power helium-neon laser, an X-Y moving iron galvanometer scanner, and several folding mirrors. By scanning over a preprogrammed path, the system produces unique shadow signatures which are picked up by silicon photodiodes. These signals are evaluated by a minicomputer which also controls the scan pattern.

The LIS-510 system is capable of automatically detecting missing components, incorrect lead clinch direction, and improper lead length (long and short). With the use of a reflective glint screen, solder bridges can also be detected. This system is better than 99 percent effective in detecting board faults on the Chrysler production line. It can inspect a 400-lead board for component presence and proper lead dress in less than 5 seconds. It can scan a bare board for improperly sized or placed component holes at a minimum rate of 50 holes per second.

Altman Associates, Stamford, Connecticut, has developed a board verifier system which also analyzes reflected laser beams from the test board to check hole sizes and positions. However, this system does not utilize a master patter stored in its memory. In its place, a second beam from the laser scans artwork that describes the nominal tolerances of the board. The minicomputer then decides if the features of the test board come within the allowed tolerances. This system allows the inspection of different board types without reprogramming. The predicted inspection rate is up to 50 square feet of bare board per minute with measurement accuracies to within 1 mil.

The Inspection System by the **Advanced Control Products Division of Cooper Industries** in Irvine, California is predicted to take about one minute to inspect a bare board for line widths and spacing, line breaks, excess copper, and voids. The system will also detect incomplete pads, poor pad-lead connections, and shorts in ground planes. The inspection utilizes reflected laser beams in analyzing these board features, but its only reference is a set of design rules programmed into its minicomputer. When a violation is detected, the system will either print out the coordinates of the defect or stop scanning so an operater can examine the defect. The use of general design principles instead of master pattern of artwork references eliminates the need for precise orientation of the test board. This system is still in the development stage.

Also in the development stage is a unique solder joint inspection system from **Vanzetti Infrared and Computer Systems** in Canto, Massachusetts. This system utilizes infrared rather than visible light detectors. The laser delivers low power pulses to each joint, heating it a few degrees above the temperature of the room. The minicomputer then compares the joint's thermal response and makes a pass or fail decision. For example, a joint with insufficient solder or a subsurface void will warm up faster and reach a higher peak temperature than will a good joint. Thus, this system can pinpoint faults that a human inspector would be unable to detect.

However, none of these systems in their present forms is capable of performing the pre-cap visual inspection described in Method 2010.4; the pre-cap inspection is too complex and the ICs are too small. However, lasers are capable of very high resolution and pinpoint accuracy. It may simply be a matter of thinking of the inspection problem in terms of lasers.

ACOUSTIC MICROSCOPY

Another useful tool is the acoustic microscope, which allows an inspector to see minute structural details of an object by displaying the object's response to ultrasonic waves. Unlike optical microscopes, they are capable of probing beneath the visible surface. The acoustic microscope displays the changes in the efficiency with which sound is generated in or propagated through the item being inspected. The physical properties of the object such as density, viscoelastic moduli, and thermoelastic coefficients determine the sonic speed, disperson, and refraction of the sound waves. Thus, when reflected or transmitted sound waves are enlarged and displayed, an accurate picture of the target is produced. This display will include those portions of the item which are optically opaque, allowing the inspector to see within or beyond these areas. The system consists of two basic parts. One exposes the object to the ultrasonic radiation and the other senses and displays the resulting acoustic fields. The acoustic microscopes investigated differ in the manner in which they expose the inspected object to the ultrasonic radiation. The image conversion and image display systems are very similar to each other and are widely used in many other imaging systems.

In each acoustic microscope examined, an image display system is required. This commonly is a television type picture on a CRT, but the faster pattern can be directly printed by a camera on film. Electronic image processing can be incorporated to enhance or enlarge the image or to extract specific information. Electronic pattern recognition or comparison could be employed to automate the accept or reject decision.

ELECTRO-OPTICAL PATTERN RECOGNITION

Perkin-Elmer Corporation has developed an automatic electro-optical pattern recognition system for the Bureau of Engraving and Printing. The developmental model of this equipment is currently being used to inspect sheets of

U.S. currency. Each new bill is compared electronically to a master reference bill whose image is stored in a computer. The images are compared on pixel by pixel basis. Flaw discrimination is accomplished by generating exceedance data for each pixel (the position or negative difference between the features of the examined pixel and those of the stored master pixel). Computer algorithms determine the reject criteria for the note as a whole. The scan head that examines the notes is a charged coupled device (CCD) detector. It has 1024 photosites, with two adjacent sites representing a single pixel. Thus, each pixel is 0.3 mm square. For each pixel a four bit digitized word is generated representative of that 0.3 x 0.3 mm pixel. There are eight scan heads in line allowing simultaneous inspection of eight bills. This facility inspects the front and back of 6000 sheets of bills, 32 to a sheet, in one hour. A significant part of the equipment hardware and software is involved in transporting, aligning, registering, flipping, sorting, and stacking the sheets of bills. Such a device could be adapted to the examination of magnified images of integrated circuit chips and making a pixel by pixel comparison with a perfect master image.

Evaluation of Internal Visual Inspection

The internal visual inspection of integrated circuits is a very involved procedure. As integrated circuits continue (as they will) to become smaller and more complex, the probability of a defect being detected by a visual inspection will decrease. The exception would be gross physical defects which would probably be detected in later screening tests anyway.

The fact that this is a human visual inspection gives rise to further problems. First of all, there is a limit to the speed with which an operator can perform the inspection. Second, in any human inspection a certain number of rejects are going to slip through. This number increases as the inspection rate goes up. Finally, there is the problem of subjectivity in the inspection. What one operator would reject, another might pass. Thus, the speed and effectiveness of the inspection is degraded by the fact that it is performed by humans, and this degradation can be expected to become more pronounced as the complexity of the integrated circuit increases.

Availability of Automated Inspection Systems

None of the IC manufacturers contacted by Columbia Research currently have available an automated system to perform the pre-cap visual inspection. Few of the instrument manufacturers are even working on it. The primary reason given for this is that the inspection itself is so complex. Three manufacturers (KLA, Hitachi, and Contrex) attempting to automate the inspection process were discussed in the section entitled Automated Inspection Systems. Detailed information is not available at this point because the systems are still in the development stage, and much of the information is proprietary. Thus, a best buy prediction, even among these systems, cannot be made at this time. Also, there may still be other systems under development that have not come to the attention of Columbia in the course of the survey.

Further Studies Required

It is recommended that the following actions be taken to resolve questions unanswered by the present survey and to provide important additional information required by ARRADCOM to make an informed technical decision as to the feasibility and cost effectiveness of automating the pre-cap visual inspection of integrated circuits:

(1) Evaluation of the necessity and effectiveness of the pre-cap visual inspection should be undertaken. As part of this evalaution, the IC manufacturers should be tasked to tag the chips failing the visual inspection and then allow them to continue through the screening process to see if they are detected in subsequent tests.

(2) To obtain the detailed information on cost and predicted availability required to make a best buy determination regarding an automated test system, a Request for Proposal should be issued for the establishment of such a system.

(3) To verify the superiority of the automated system over human visual inspection, a test program should be established in cooperation with the IC vendors in which a large sample of chips is inspected sequentially by both systems. A statistical analysis should be performed on the resulting data to compare the relative screening effectiveness of the automated and human systems.

(4) The progress of private industry (KLA Instrument Corporation and Contrex, Inc.) engaged in the research and development stages of this technology should be monitored. If techniques become available, a future MTT project to adapt them to specific components of interest to the Army should be pursued.

M1 Abrams Tank NDT Program

Efficient and Sophisticated Inspection

By
Don Pope
Project Engineer
U. S. Army Tank-Automotive Command

The overall objective of a recent Mantech program for the Army Tank—Automotive Research and Development Command was to formulate and implement a nondestructive program that would establish effective inspection procedures for the verification and acceptance of M1 tank hardware. To accomplish this objective, the contractor-chrysler Defense, Inc.—conducted fifteen specific tasks.

Ultrasonics Manual Developed

Chrysler has developed an efficient and sophisticated NDT inspection system for the M1 tank program—for castings, forgings, and armor welds, they established inspection methods and operating procedures for ultrasonics, radiography, liquid penetrant, magnetic particle, and eddy current for use directly on-line. Chrysler developed a nuclei of highly trained and efficient NDT engineers and technicians who, with their combined effort, will continually update and improve the quality of NDT inspection methods.

However, the most significant benefit derived from the program was the development of an ultrasonic inspection procedures and standards manual for armor welds. Application of ultrasonics as a weld inspection method will reduce inspection costs to about one third of those required for radiography.

Fifteen Tasks Conducted

Fifteen separate but interrelated tasks conducted to complete this program included:

- Review M1 quality control requirements
- Continuously survey state of the art
- Select appropriate NDT methods and define application techniques.
- Identify and procure inspection equipment.
- Establish standard inspection procedures for all selected methods.
- Prepare initial ultrasonic weld inspection procedures.
- Establish parameters for personnel qualification.
- Conduct an in-house training and certification proprogram for production inspection personnel.

NOTE: This manufacturing technology project that was conducted by Chrysler Defense, Inc. was funded by the U.S. Army Tank-Automotive Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The TACOM Point of Contact for more information is Don Pope, (313) 574-8328.

- Verify NDT inspection methods on qualification hardware.

- Document test methods and prepare position charts for radiographic and ultrasonic inspection.

- Evaluate and establish an automatic ultrasonic inspection system for armor assemblies.

- Establish sampling plan inspection rates for M1 hull and turret structures.

- Implement NDT inspection procedures for use in production.

- Verify inspection procedures on preproduction and initial production structures.

- Prepare a manual on ultrasonic inspection procedures and standards for armor welds.

Four NDT Methods Suitable

About 1,000 manufacturing process drawings, machine drawings, and quality assurance requirements (QAR) representing major critical components of the tank were reviewed for (1) selection of NDT methods and (2) determiniation of percent and frequency of inspection. Chrysler determined that 107 components were suited to four NDT inspection methods: ultrasonics, liquid penetrant, magnetic particle, and radiography. Also, about 700 NDT technical reports, papers, and publications were reviewed which consisted of the following NDT methods: ultrasonics, radiography, magnetic particle, liquid penetrant, eddy current, and acoustic emission. In addition, contractor personnel attended conferences, seminars, and equipment demonstrations concerning various NDT methods and application techniques.

Selecting Methods and Their Application

Selection of the majority of NDT methods and definition of their applications was accomplished simultaneously with review of the M1 quality control requirements. Automation feasibility studies for all NDT methods were conducted at various stages of production.

Radiography techniques involved use of 2-MEV linear accelerator X-ray unit for hull and turret weldments and suspect castings that are thicker than 2 inches. A 300-KV portable X-ray unit is used for hull and turret weldments and suspect castings that are up to 2 inches thick. Further, 420-KV X-ray unit is used for welder qualification plates, ballistic H plates, and small castings that are 3 inches or less in thickness. After a thorough review of the automated systems available for radiography, it was decided that none of the systems would be economically feasible or practical.

Liquid penetrants are used to inspect completed hull and turret weldments, suspect castings, forgings, and flame-cut edges for surface indications (i.e., cracking, porosity, and plate laminations). Liquid penetrant proved ineefective on areas where the temperature exceeds 150 F. Automation of liquid penetrant inspection is impractical for the M1 tank program.

Magnetic particle inspection is used on rework areas of the hull and turret weldments and casting and forging repairs where interpass temperatures of 150 F or greater have to be maintained until rework or repair is completed. The limited use of magnetic particle inspection in production does not necessitate the use of an automated system.

Through experimentation, it was determined that the **eddy current method** was too time consuming and uneconomical to be used as a production inspection method on hull and turret weldments. It is being used for alloy sorting, case hardness depth checks, and plating thickness measurements. Because the use of eddy currents is limited to special types of inspections, automation is unnecessary.

At this time, **ultrasonics** is being used to locate flaws found by X-ray of hull and turrent weldments for ease of rework. It also is being used on armor assemblies; however, the material and the inspection procedures are excluded from this report. Various automated ultrasonic inspection systems were studied to determine adaptability to inspect welds on the M1 tank. However, because of the numerous and varied weld joint configurations, it was decided that automation would be impractical and uneconomical.

Operating Procedures Established

Twenty three standard operating procedures in the form of quality control instructions were established for all selected NDT methods. The instructions are in the contractor's format and include both general and specific directions based on MIL-Q-9858A requirements. The instructions also denote the applicable level of NDT personnel certification requirements. Listed below, they were used to implement and control the NDT program and will be updated as the need arises.

- NDT Methods and Their Applications

- Ultrasonic Inspection of Partial and Full Penetration Welds

- Ultrasonic Inspection of Armor Assemblies (Manual Method)

- Ultrasonic Inspection of Armor Plate
- Ultrasonic Inspection of Forgings
- Ultrasonic Calibration (Angle Beam Transducers)
- Ultrasonic Thickness Measurements
- Ultrasonic Inspection of Steel and Armor Castings
- Radiographic Location of Flaws
- Magnetic Particle Inspection (General)
- Magnetic Particle Inspection (Torsion Bars)
- Liquid Penetrant Inspection
- Visual Inspection of Welds
- Eddy Current Inspection (General)
- Eddy Current Inspection (Plating Thickness)
- Eddy Current Sorting of Ferrous Metals
- Eddy Current Inspection (Case Hardness Depth)
- Eddy Current Inspection (Material Hardness)
- Radiation Safety Requirements for Industrial X-ray Equipment
- Ultrasonic Calibration (Horizontal and Vertical Linearity)
- Personnel Qualification and Certification
- Welder Certification

Ultrasonic Weld Inspection Procedures and Standards

The scope of work to prepare initial ultrasonic weld inspection procedures and standards comprised five parts:

(1) Review existing ultrasonic inspection procedures for full penetration welds to assist in establishing procedures for the M1 tank, which consists primarily of partial penetration welds.

(2) Establish ultrasonic inspection scan procedures for hull and turret weldments.

(3) Establish standard procedures for ultrasonic instrument calibration and documentation of inspection results.

(4) Verify ultrasonic scan procedures through radiographic correlations.

(5) Establish ultrasonic accept/reject criteria.

To establish a base for writing preliminary ultrasonic scanning procedures on welds, Chrysler reviewed specifications available from the American Society of Testing Materials, American Society of Materials Engineering, American Welding Society, and the U.S. Navy. With the help of such review, they wrote procedures that will ensure the integrity of weld joints consistent with M1 production goals. The procedures were based on developed NDT requirements, state of the art methods, and experimentation.

Ultrasonic inspection results were correlated with radiography to verify the type and severity level for determining quality levels for acceptance standards. Figure 1 shows a weld cross section and a portion of a radiograph of that weld. The actual full size radiograph shows a continuous discontinuity in the outer weld nugget in the root area.

Ultrasonic examination placed the disconinuity along the indicated weld to parent metal interface. The cathode ray tube (CRT) presentation depicted in Figure 1 shows a relatively clean spike with an amplitude of approximately 35 percent.

Personnel Training and Certification

The scope of work for training and certification of personnel comprised six parts:

(1) Prepare quality control instructions (QCI) covering training and personnel certification requirements necessary to perform the NDT functions established for the M1 tank production program.

(2) Establish training course outlines for each NDT method.

(3) Procure training material for all NDT methods to be used.

(4) Conduct Levels I and II in-house training for all methods.

(5) Provide on-the-job training experience for all methods and levels as required.

(6) Prepare and conduct certification examinations for all methods and levels.

A procedure for personnel training and certification was written. Included in it are the training outlines for all NDT methods being used in production. Also, training

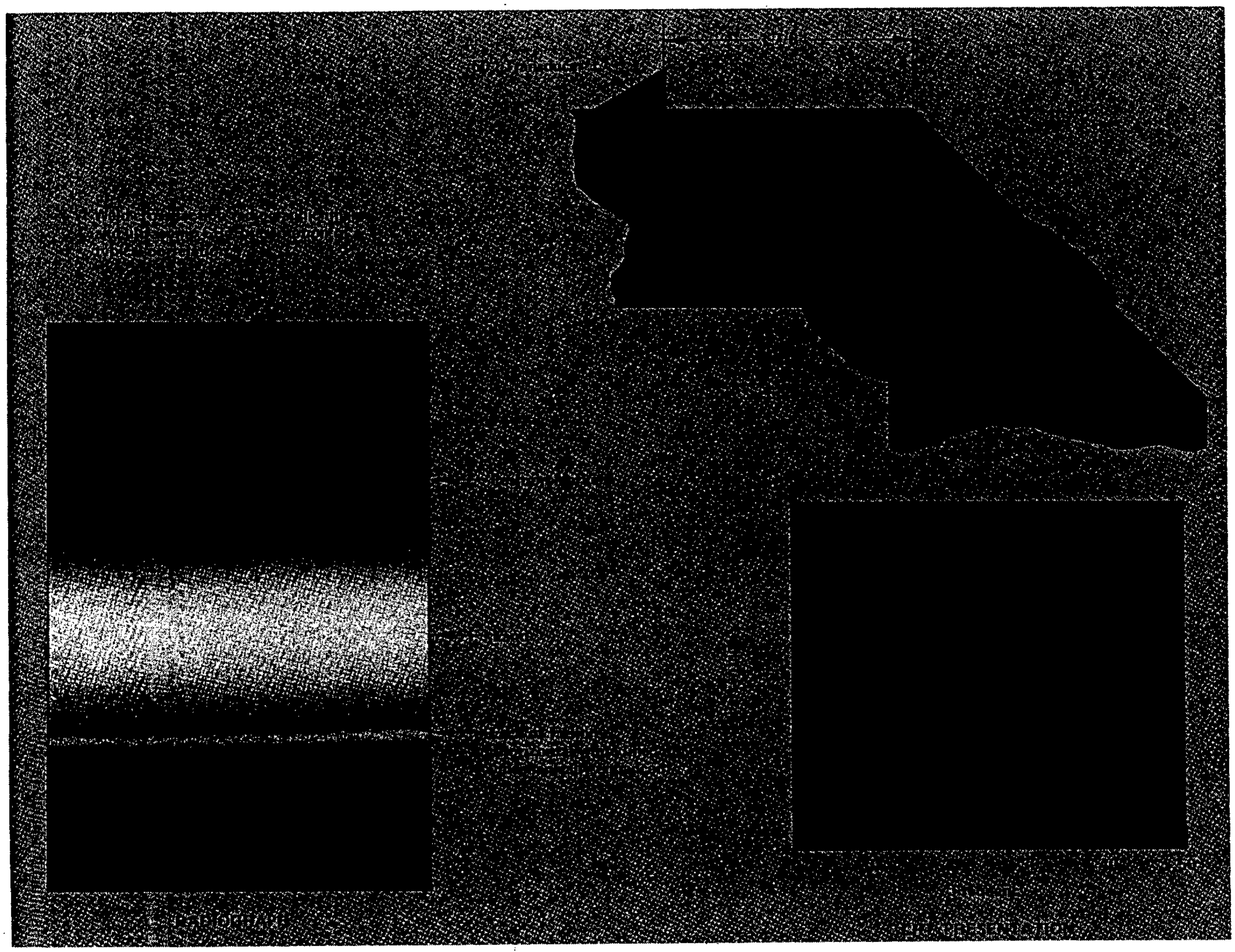


Figure 1

films and instruction manuals were procured for Levels I and II in-house training for each NDT method. Contractor personnel were trained at vendors' schools such as Krautkramer-Branson, Magnaflux, DuPont, and Automation Industries. These personnel then conducted in-house and on-the-job training courses for other personnel.

Ultrasonic Weld Inspection Manual Prepared

The purpose of this work was to compile data from associated tasks and to prepare an ultrasonic weld inspection manual which would include the following:

- Basic principles of ultrasonic inspection
- Personnel certification requirements
- Instrument calibration procedures
- Accept/reject criteria
- Standard scan procedures for M1 tank joint configurations
- Limitations of ultrasonic inspection
- Flaw classification using a computer assist system
- Standard procedures for documentation of results.

All the preliminary work for the manual for seven of the eight tasks listed above has been completed. Work on the eighth task, flaw classification, continues.

Fabrication of YAG Laser Rods

8-Fold Production Rate Increase

By
Jeff Paul
Project Engineer
U. S. Army Electronics Research
and Development Command

A manufacturing technology project completed by Litton Industries for the U.S. Army Electronics Research and Development Command has successfully developed efficient new fabrication methods for meeting the Army's laser production needs.

The Nd:YAG (neodymium doped yttrium aluminum garnet) solid state crystal laser is the most widely used and studied device for present and future military applications. Since its discovery, Nd:YAG has proved to be a nearly ideal laser material, so increased rod requirements are a certainty for all service branches. However, two persistent production problems have slowed the more extensive use of Nd:YAG in the form of low cost rods. The first of these was (1) the availability of high purity and optically perfect rough boules capable of good yields. In 1970, the U.S. Army addressed itself to this area and a successful program was completed. The second problem involved (2) the fabrication of laser rods using techniques of batch processing in place of unit operations.

Demand High, Production Low

During the period 1970-1975, Nd:YAG laser devices experienced a period of advanced engineering development. At this stage the normal rod usage attained a maximum of 1-5 rods/month. Laboratory procedures for fabrication were developed and all operations were done by hand on each rod. At the present time, the Army laser programs include items such as the AN-VVG-1 laser pro-range finder, the GLLD locator designator, laser tank range finders, and the AN/GVS-5 hand held range finder. Similar programs and expanded plans are forecast for the Navy and Air Force. Thus, the production requirements of Nd:YAG are rapidly increasing and are already in excess of 500 rods per month. It therefore has become imperative to develop procedures for laser rod fabrication which accomplish increased production yields per man-hour. This program was conducted by the Airtron Division for the Solid State and Injection Laser Team of the Night Vision and Electro-Optics Laboratory, Fort Belvoir, Virginia.

NOTE: This manufacturing technology project that was conducted by Litton Industries was funded by the U.S. Army Electronics Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ERADCOM Point of Contact for more information is Jeff Paul, (703) 664-4766.

It relied on the fact that high quality material is available and also that the preliminary machining operations necessary to produce rough rods of material are basically available as are the techniques required for the coating and testing of the finished rods. Therefore, this program was directed at developing techniques for the batch grinding and polishing of rough rods to produce finished laser rods.

AN/GUS-5 Chosen

The laser rod configuration chosen for the development of batch grinding and polishing techniques is that of the component used in the AN/GVS-5 hand held laser range finder. This system represents the first system to go into volume production and is thus appropriate for the development of manufacturing techniques. The rod itself is smaller in length and diameter than rods used in the majority of military systems. Other specifications, however, are typical.

The input material to the program was single crystal neodymium doped yttrium aluminum garnet (YAG). From the single crystal boule, areas are selected which are of high optical quality. These areas are then used to core drill rough rods, which subsequently are centerless ground and sized in preparation for the final polishing operation.

The laser rod to be produced was a 4.27 mil diameter by 43 mil long rod. The outside diameter was to be of rough ground finish. Starting with rods of material having rough ground end faces, finished laser rods having a latness within 0.2 wavelength of sodium light and a surface finish better than 20-5 per MIL-13830 were to be produced. The end faces were to be parallel to within 20 sec arc and perpendicular to the rod axis within 5 min of arc.

Fixture Design

At the start of this program the majority of the fixturing in application in laser rod fabrication (Figure 1) was designed to hold a single rod during the grinding and polishing operations. The laser rod to be polished is held at the center of the fixture surrounded by polishing feet.

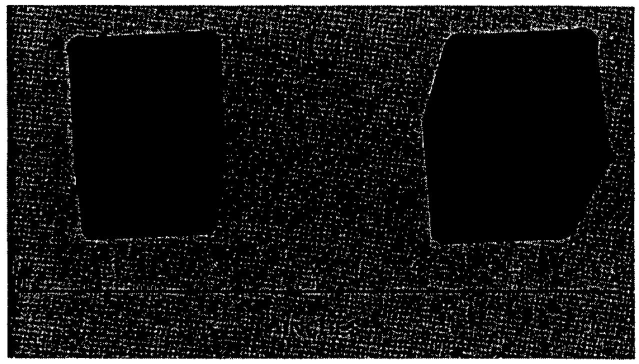


Figure 1

When one end of the rod is polished the rod is dismounted, turned and remounted. The second end is then ground and polished. This process yielded one rod per 5 man-hours.

Experiments previously performed on batch fabrication indicated the yields that could be expected from a fixture designed to hold twelve rods. Data showed that under laboratory conditions and for the rod sizes attempted yields of 65-85 percent could be achieved when the critical parameters were considered.

Three basic requirements existed for the design of an appropriate fixture for batch grinding and polishing:

- The fixture must hold a sufficient number of rods such that when yield characteristics are considered the design goal of the program will be achieved.
- The design must be such that rod specifications are met with a reasonable yield.
- The size and design of the fixture must provide for the fact that the grinding and polishing would be performed by hand.

For the fixture to perform well in a manufacturing process, all of the above criteria would have to be met.

The number of rods held by the fixture was derived from the yield data generated in earlier experiments. The design goal of the program was to achieve a rate of twelve fabricated rods per 8 man-hours.

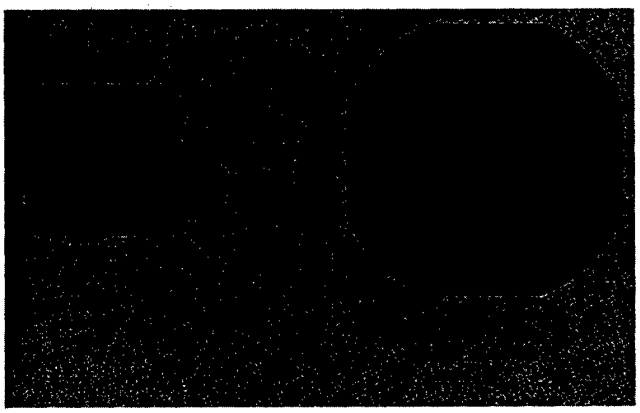


Figure 2

Fixture Design Adopted

The final design adopted for the fixture (Figure 2) is a block 3 inches in diameter and 1-9/16 inches thick. The block has flats ground on the sides to provide a convenient method of resting the block. It is made of a quality tool steel and has a thickness which will accommodate the 44 mm length rods, leaving both ends exposed.

To provide mounting for the laser rods, holes are bored through the block. There are eight holes located on each of two bolt circles—one 1.562 inch in diameter and the other 1.062 inch in diameter. The hole is 5/16 inch in diameter to accept a standard size bushing. These bushings are pressed into the block at each end and hold the rod (at each end) without constraining the center. This technique eliminates the stressing of the rod in the fixture.

Also, because during the finishing of the laser rod second ends it is possible for the first ends to become contaminated with the polishing grit and subsequently damaged, the finished ends were covered with an aluminum protective cap. This cap is 2.25 inches in diameter and is held in place using a 1/2-20 bolt with an "O" ring seal.

The holes in the block are perpendicular to the face within 0.0003" TIR, or to less than 1 minute. Assuming the smallest rod diameter and the largest bushing inside diameter allowed, the rod and bushing perpendicularity is within 2.5 minutes. Thus, a perpendicularity of less than 3.5 minutes should be maintained for all rods.

Polishing feet or dummies are located on each end of the block on a 2.625 inch diameter bold circle. Each rod is thus symmetrically surrounded and the surface will work evenly. In addition, the block will be stable.

Manufacturing Rate Exceeded

The design goal of this program was to achieve a laser rod manufacturing rate of 12 rods per 8 man-hours. During the engineering phase of the program the necessary tooling and process were developed to fabricate blocks of sixteen laser rods of the AN/GVS-5 configuration. The results of the program indicate that a rate in excess of fourteen rods per 8 man-hours was achieved, thus exceeding the rate required by the program and saving about $30 per rod ($180,000/year at current needs).

No major difficulties were encountered in achieving the desired rate at the rod specification required. A minor difficulty was encountered originally in controlling changes in parallelism between mounted and dismounted rods. This was overcome by exercising more care in mounting.

Rate variations between blocks were significant (3 to 13 hours per block). These variations were found to be independent of the operator and were minimized during the later stages of the program when more experience with the process was gained.

The program was successful in achieving a dramatic reduction in the number of man-hours required to fabricate a finished laser rod. The process has been applied to the AN/GVS-5 hand held laser rangefinder. As part of this program, a process demonstration also was held.

More Automation Coming

The process developed was successful for 4.27 mm by 43 mm laser rods. In future work, the results of this effort should be extended to other sized laser rods. In addition, this work was directed at a parallelism tolerance of 20 sec of arc. For many applications a tolerance of 10 secons is required. At the latter tolerance, a significantly reduced yield is obtained. Efforts at improving the yield at this specification should be made.

This process relies heavily on the operator to control parameters. If even higher process rates are required, it will be necessary to develop processes where this reliance on the operator is reduced.

Commercial Welding Techniques Used

Joining Dissimilar Metals

By
Buck Schevo
Project Engineer
U. S. Army Tank-Automotive Command

Reduction in weight and improvement of performance are matters of significance in the design and manufacture of armored military vehicles. These objectives must be reached without materially sacrificing ballistic protection. Manufacturing methods to produce more efficient designs must be economically feasible, but also should rely on tools, materials, and skills readily available in the supplier community. Further, these methods must have proven service reliability.

Therefore, a test program was initiated by the U.S. Army Tank-Automotive Command to evaluate the use of roll bonded and explosive bonded bimetal transition materials in joining steel and aluminum armor for military vehicles. The goal was to verify that commercially available steel/aluminum transition strips can be used successfully with production welding techniques to fabricate vehicles. Ballistic tests were performed to determine the integrity of butt and corner joints obtained on samples of one inch steel and aluminum armor plate.

Successful application of this technology to armor in production would make it possible to optimize ballistic protection as well as vehicle weight and performance.

Transition Strips the Key

Replacement of steel armor with aluminum in certain areas, such as floor panels, or the addition of steel armor in aluminum vehicles has been suggested as one way to arrive at optimum weight/protection designs. Aluminum and steel cannot be joined directly, however, by conventional welding techniques. The use of mechanical fasteners not only introduces undesirable stress concentrations, but also limits design flexibility and provides the opportunity for secondary missiles in combat service.

For a number of years, transition strips fabricated by explosion bonding or roll bonding of dissimilar metals—which cannot be joined by conventional welding—have been available to industry. These materials have been in use for several years for welding applications in electrical and fabrication industries, including the joining of steel and aluminum. They had not, however, been verified for heavy steel and aluminum armor manufacturing applications.

NOTE: This manufacturing technology project that was conducted by the Combat Systems Division was funded by the U.S. Army Tank-Automotive Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The TACOM Point of Contact for more information is Buck Schevo, (313) 574-5814.

Roll vs. Explosion Bonding

To verify the welding of steel and aluminum armor and subsequent ballistic testing, samples of commercially available explosion bonded and roll bonded layered aluminum/steel transition strips were selected. The explosion bonded sample was DuPont Spec 604M ("Delta Couple"), 1-3/8" thickness, consisting of 3/4" steel ASTM 516Gr55 and 5/8" aluminum 5086 or 5456 with an 1100 aluminum interlayer. The roll bonded specimen was Kaiser Spec KA-09006A, 7/8" thickness, consisting of 1/2" aluminum 3003 and 3/8" steel 304 stainless with an 1100 aluminum interlayer. No Federal specifications for either of these transition materials exist at this time.

Butt and Corner Joints Selected

Butt and 90 degree corner joints were chosen for tests to simulate potential design requirements. One inch rolled steel armor MIL-A-12560 and one inch aluminum MIL-A-46027 in the form of flat plates nominally 18" x 36" were joined using the joint geometry indicated in Figure 1. These configurations were selected on the basis of recommendations from suppliers of the transition strips.

Welding techniques were critical, since overheating of the transition material would degrade the bimetal interface. DuPont in the guidelines furnished with its material specified that the interface temperature remain below 600 F to prevent the formation of brittle intermetallic compounds. Kaiser Aluminum specified a maximum interface temperature of 800 F. Interface temperatures were minimized by providing the maximum practical heat sink and by reducing the heat input to the weld.

Width of the transition strips was chosen to be 4", or four times the plate thickness, to allow for heat distribution and compensate for possible small bonding defects. Such a guideline on width also permitted fillet welding which reduced the possibility of penetration and consequent destruction of the steel/aluminum interface.

Aluminum Side Welded First

The aluminum side of the joint always was welded first to provide a larger heat sink while welding the steel side; no weld preheat was provided. In all cases, stringer beads were used to maintain low interface temperature. Interpass temperatures were measured using surface pyrometers and were not allowed to exceed 600 F for any specimen at the steel/aluminum interface.

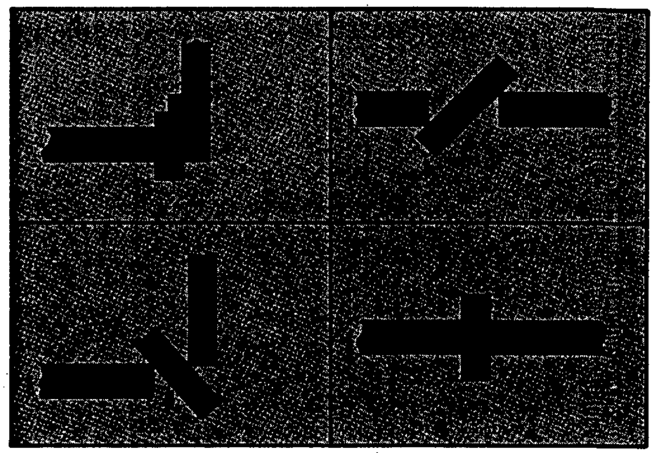


Figure 1

Edge preparation for all specimens consisted of 90 degree square cuts; when required, they were machined. Steel armor was flame cut to size. Both corner and butt joints were tilted after setup to allow flat horizontal welding. On Type "A" specimens, steel was machined off the transition strips approximately 1/2 inch from the aluminum fillet weld to protect the interface (Figure 2).

Welding was accomplished using a gas metal arc, semi-automatic technique, with a 500 Ampere dc rectifier. Shielding gas for aluminum was 100 percent argon at 40 cFH, and for steel it was 97 percent argon with 3 percent oxygen at 50 cFH. Welding electrodes were 1/16 inch diameter aluminum Type 5356 MIL-E-16053 and steel Type B88 MIL-E-19822. In all cases, beads were laid alternately on both sides of the armor plate to minimize residual stress and interface temperature.

Figure 2

Overall, twenty-four specimens were fabricated, which represented eight different combinations of joint geometry and transition materials (Table 1). When radiographic examination was performed on the first ten weldments, it was found that steel welds frequently exhibited linear porosity, while aluminum welds showed scattered porosity. In two cases, steel fillet welds exhibited cracks in corner joints. In general, however, specimens examined were radiographically acceptable and further radiographic tests were excluded.

Impact Velocities Monitored

The twenty-four fabricated specimens described were transported to the U.S. Army Aberdeen Proving Ground for ballistic testing. In each case, the aluminum side of the weldment was impacted first using 75 mm M1002A aluminum plate proofing projectiles from a 75 mm howitzer. The steel side (of the same specimen) was then tested using 57 mm M1001 steel plate proofing projectiles from a 57 mm gun. Striking velocities were measured using Weibel sky screens and circuit break screens. Striking velocity was adjusted after testing the first weldment of each joint type to attain the highest velocity without catastrophic cracking.

Tests were performed at ambient temperature (39 F); no low temperature tests were performed. During firing, specimens were held in a heavy steel frame consisting of two vertical components and a base plate. Impacted surfaces were perpendicular to the line of fire. Corner specimens were impacted on the outside angle.

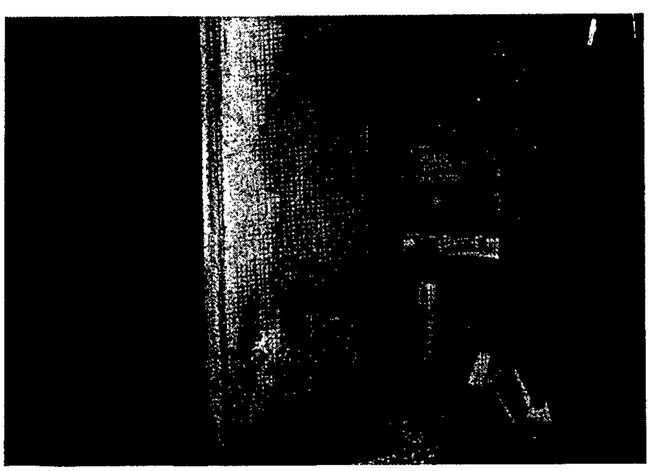


Figure 3

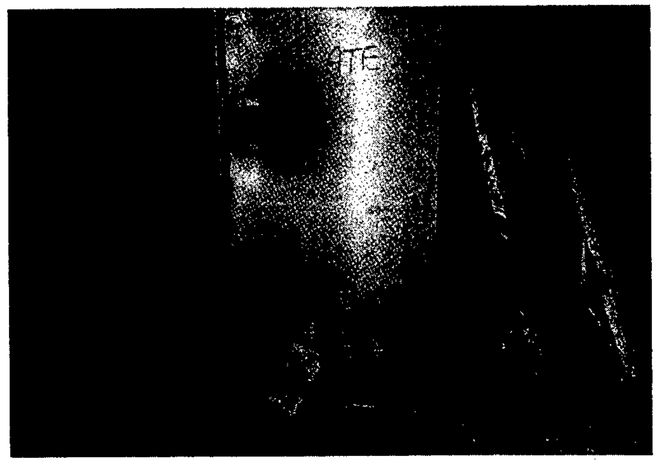


Figure 4

Results Striking

Ballistic tests of the samples demonstrated that the transition strips performed at least as well as the armor plate itself or the welds (see Figures 3 and 4). For example, of 48 impacts there were five transition strip failures out of a total of approximately 80 failures noted. For purposes of this discussion, a failure occurred when a crack was visually detected in the assembly.

Although differences in performance of the joints were small, results on the aluminum side suggested that Design A (Figure 1) withstood ballistic impact better than Design C. In these assemblies, there was less cracking and displacement of components after impact. This effect was due, in most part, to the stiffer mechanical configuration of Joint A which tended to support the aluminum plate at the weld. The greater strength of groove welds in Design C was insufficient to overcome this effect. A similar effect was seen in a comparison of Joints B and D, where Joint B provided greater mechanical rigidity and slightly better performance.

Unlike the specimens tested, plates in actual vehicles probably would be supported on three or four sides by welds. Because of added support of such an arrangement, these welds should perform better than the specimens tested.

Aluminum/Steel A Strong Contender

Designers of armored combat vehicles should consider aluminum/steel structures to meet current requirements of performance, based on the results of these tests.

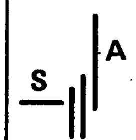
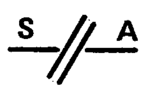
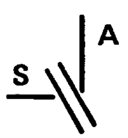
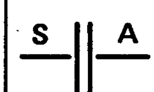
Spec. No.	Joint Type	Transition Material	Aluminum			Steel		
			Passes	Volts	Amps	Passes	Volts	Amps
1A		Roll Bonded	8	28	230	6	28	300
2A		Roll Bonded	8	28	230	5	25	250
3A		Roll Bonded	9	29	240	5	26	290
4A		Explosion Bonded	9	28	260	6	26	285
5A		Explosion Bonded	9	28	260	6	26	285
6A		Explosion Bonded	6	26	250	8	27	285
1B		Roll Bonded	10	25	280	10	25	270
2B		Roll Bonded	8	25	280	12	27	270
3B		Roll Bonded	10	25	260	16	25	260
4B		Explosion Bonded	9	26	280	11	25	260
5B		Explosion Bonded	10	27	270	14	28	280
6B		Explosion Bonded	10	27	270	16	27	290
1C		Roll Bonded	12	27	320	17	24	240
2C		Roll Bonded	12	27	320	17	24	240
3C		Roll Bonded	12	27	320	17	24	240
4C		Explosion Bonded	12	26	310	17	25	310
5C		Explosion Bonded	12	26	310	17	25	310
6C		Explosion Bonded	12	26	310	17	25	310
1D		Roll Bonded	8	27	270	8	26	280
2D		Roll Bonded	8	27	270	8	26	280
3D		Roll Bonded	8	27	270	8	26	280
4D		Explosion Bonded	10	27	270	6	26	280
5D		Explosion Bonded	10	27	270	6	26	280
6D		Explosion Bonded	10	27	270	6	26	280

Table 1

However, design of steel/aluminum armored vehicles should be approached with due attention to joint design and welding procedure, not only to minimize the danger of damage to the transition strip but also to account for thermoelastic effects. Because of the difference in thermal expansion coefficients between steel and aluminum, the in-homogeneous nature of heating during welding, and the rigid nature of thick gage armored structures, conditions exist which could result in high residual stress as well as structural forces. Given the typical service requirement of impact loading, these conditions could contribute to brittle behavior if not carefully controlled. And, because of the interaction between structural rigidity, the state of stress, and low temperature behavior of steel, designs intended for service in cold regions should be subjected to low temperature impact testing.

Proposed designs also should consider the effects of corrosion of dissimilar metals, particularly in applications where vehicles will be subjected to salt or saltwater exposure. Both galvanic corrosion and stress corrosion (of high strength aluminum) should be controlled.

Cleanliness Essential

Projectile Banding Via Inertia Welding

WILLIAM R. SHARPE is a project engineer for the U.S. Army Armament Research and Development Command at Dover, N.J., where he works on metallurgy related projects in the Munitions Systems Division of the Large Caliber Weapon Systems Laboratory. He attended the University of Notre Dame, receiving a B.S. in Physics and an M.S. in Metallurgy. From there he began his government service at Frankford Arsenal, Philadelphia, where he acquired a strong background in the munitions metal parts field. He has been in his present position for 5-1/2 years.

Disbond free welds can be obtained by inertial welding of banding onto 155-mm projectiles if the band seat and rotating band are clean. Disbond free welds also can be achieved when certain lubricants are used. Such were the findings from a recently completed manufacturing technology project sponsored by the U.S. Army Armament Research and Development Command.

Early in 1981, the Chamberlain Manufacturing Corp. undertook a project for the Munitions Systems Division to define the process parameters for inertia welding of rotating bands to the 155-mm M483A1 projectile on the high-capacity inertia welder at the company's New Bedford Division (Figure 1).

To help prevent areas of disbond at the weld interface, program researchers initially studied cleaning and storage procedures to minimize oxidation and impurity levels on the rotating band and projectile band seat prior to welding. Also, while optimum inertia weld parameters were being determined, nondestructive ultrasonic testing of the inertia welds was verified by correlating data from two sources: (1) ultrasonic scanning on the linear transducer array at the Army Materials and Mechanics Research Comman (AMMRC); and (2) ultrasonic scanning on the single transducer scanner at Chamberlain R&D, Waterloo, Iowa. These data were compared to data from destructive shear and bend tests to verify ultrasonic scanning as an accurate and reliable inspection method for inertia welds.

Traditional or Axial Thrust vs. Radial

In traditional inertia welding in which the parts to be welded are brought together by an axial thrust, surface contaminants are driven out of the weld area by the "washing action" of the upset of material at the weld interface. Because of this cleaning action during welding, little needs to be done to prepare the surfaces being welded. On the other hand, in inertia welding of rotating bands to projectiles, the axial thrust of the welder is converted to a radial motion and the nature of the weld, with minimal upset, is such that there is little self-cleaning action. Most of the contaminants on the surfaces being welded are expected to be trapped in the weld. These contaminants can include materials used in machining operations, coatings applied after machining, inert material deposited during storage (dust, oil, film, etc.), or reactants formed during storage (e.g., metal oxides).

NOTE: This manufacturing technology conference that was conducted by Chamberlain Manufacturing Corp. was funded by the U.S. Army Armament Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The ARRADCOM Point of Contact for more information is Bill Sharpe, (201) 724-2522.

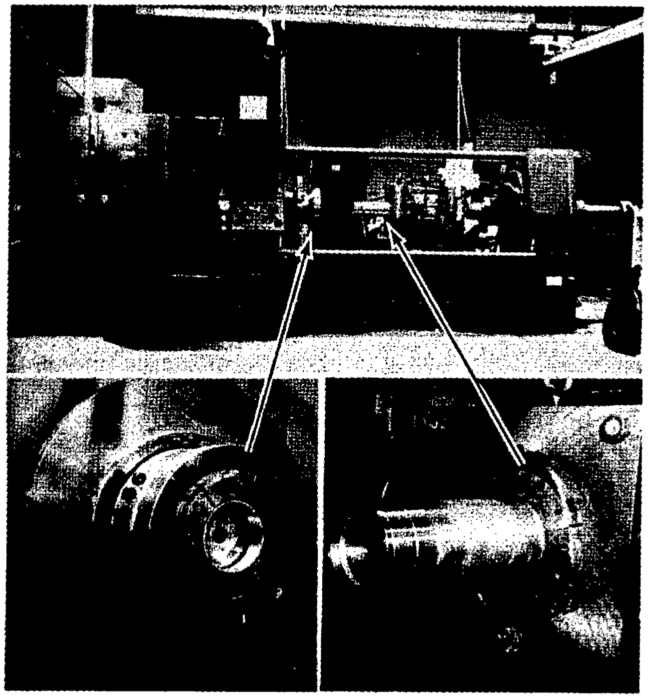


Figure 1

In order to minimize their detrimental effect it was found that either acid etching the bands or machining them without using a lubricant were acceptable band cleaning methods. A detergent wash and hot water rinse, followed by immersion in chemical degreaser, were the accepted steps in cleaning bodies. Various exposure conditions and times were examined; long storage times were found to be deleterious to weld quality. In particular, when acid etching was used on bands, the active surface began to tarnish in 10 to 15 minutes, so it was essential that the welding be done immediately after cleaning. If the band was machined, it could be stored for at least 1 day before welding. Bodies could be stored for longer times (up to 2 months) after machining, but they had to be stored in a sufficiently dry environment so that rusting did not occur (see Table 1).

Inspection—An Essential Factor

A rapid and reliable method for inspecting inertia welded rotating bands was necessary to make inertia welding a viable production process. Inspection by ultrasonic scanning had been used in earlier contract work and was the primary inspection method used in work associated with this contract. In addition, a number of auxiliary destructive tests were performed on sections of welded bands in an attempt to verify ultrasonic scan information and to better understand the welding process.

Nondestructive ultrasonic testing of inertia welds was verified by correlating data from ultrasonic scans on the linear transducer array at AMMRC and the single transducer scanner at Chamberlain. Comparing these data with data from destructive shear and bend tests showed that, indeed, ultrasonic scanning is an accurate and reliable inspection method for inertia welds, with welding done before heat treatment and scanning after.

Heat Treatment/Weld—In What Order?

When inertia welded rotating bands are to be used on projectiles requiring heat treatment, the heat treatment could be performed either before or after band welding. In either case, the inertia welding would heat a shallow region of the band seat above the critical temperature for the steel. The adjacent ambient temperature steel will extract the heat rapidly enough to give an effective quench and to convert the heated material to brittle martensite (Figure 2).

If bands are welded before heat treatment, the martensite layer is, of course, erased during heat treatment. If bands are welded after the projectile bodies have been heat treated, the resulting martensite layer could possibly be left as is, or it could be tempered by heating the steel to the temperature that had been used in tempering the projectile during heat treatment. Inertial welding of bands prior to projectile heat treatment follows the current practice used for projectiles having overlay welded bands.

In work preliminary to making this determination, sixty-one M483A1 projectiles had rotating bands applied

Weld Number	% Bonded Area	Average	Band Preparation and Cleaning[1]
1.1.A	93.35	94.27	Machine dry. Acetone wipe.[2]
1.1.B	95.18		
1.2.A	92.24	91.46	Machine dry. Acid etch.[3] Acetone wipe.[2]
1.2.B	90.67		
1.3.A	92.17	93.99	Machine with lube.[4] Acetone wipe.[2]
1.3.B	95.80		
1.4.A	88.45	88.16	Machine with lube.[4] Acid etch.[3] Acetone wipe.[2]
1.4.B	89.87		

[1] All bands stored in polyethylene bags after washing. Removed shortly before welding.

[2] Band wiped with reagent grade acetone (using clean cheesecloth) immediately before welding.

[3] Acid solution: 40% HND_3 (reagent grade), 60% H_2O (deionized).

[4] Johnson's J-Wax used as lubricant.

Table 1

by inertia welding and were heat treated using a relatively fast oil quench. Ultrasonic scanning was performed both before and after heat treatment. This indicated that projectiles with poorly bonded rotating bands show a greater degree of disbond after heat treatment; projectiles with well bonded bands are not adversely affected by heat treatment. One hypothesis to account for this is that intimate contact between the steel and copper band would indicate a good bond before heat treatment, with the expansions and contractions of heat treatment revealing the true nature of the weld. However, experimental work performed at AMMRC and at Chamberlain could not adequately demonstrate this effect. Since this could not be resolved, the current practice of welding before heat treatment was continued, with scanning done afterwards.

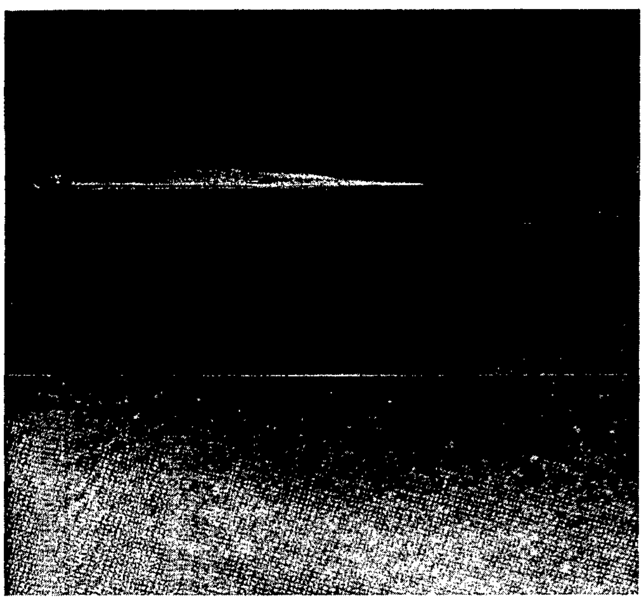


Figure 2

Martensite Layer Formed

An intensive metallurgical examination of the rotating band-projectile body interface was conducted by analyzing microstructure, microhardness, and electron microprobe data: These data show that the heat generated by inertia welding forms a martensite layer under the band-band seat interface and recrystallizes the band material. Analysis shows that the body martensite layer can be as deep as 0.024 inch into the steel. The band recrystallized layer varied up to 0.050 inch in thickness.

Variation of Band and Band Seat Geometry

In work performed under a prior ARRADCOM contract with a marginally acceptable welder (capacity wise) Chamberlain R&D consistently achieved high quality inertia welding of rotating bands to M483A1 projectiles. However, in work performed during this contract with a new, higher capacity welder it was more difficult to obtain consistently good welding along the forward edge of the rotating band. The geometry of the rotating collet that held the rotating band on the marginally acceptable welder was such that when the collet pads were opened to accept the band prior to welding, the pads were not parallel (in the axial direction) to the axis of the projectile body. The collet pad diameter was less at the aft end of the rotating band than at the forward end. As the collet pads closed during the welding operation, the angle between the pads and the projectile axis decreased, and at some specific value of the collet diameter the pads and projectile axis were parallel. On this equipment it was theorized that if the weld was made at the diameter where parallelism occurred, the pressure from forward to aft on the rotating band should be uniform and a good weld should be observed (see Figure 3). If not, there would be some degree of disbond.

On the higher capacity inertia welder used for this effort, the above theory was applied and the collet design was such that the pads were always parallel (see Figure 4). However, as stated, there was a problem with welds on the forward end. An attempt was made to vary geometry to bias pressure toward the forward end in welding. Results were inconclusive and band seat contour was left as in normal production for further efforts.

Lubricants Don't Affect Weld Strength

Inertia welding of rotating bands using various lubricants and coatings on the band blank was studied to determine the effects on tooling and weld quality. In the limited testing performed, certain lubricants extended machine deceleration time, reduced the tooling load (hypothetically extending tooling life), and did not adversely affect weld strength. However, since testing was minimal and results were comparable to previous tests without lubricant, further parameter refinement was done dry.

Process Refinement

In inertia welding, one part is held stationary and the other with a predetermined mass is rotated to a predetermined set RPM. When that RPM is reached, the rotating part becomes free wheeling and the stationary part is thrust into it with a predetermined force. Then the energy associated with the rotating part is converted into frictional heat between the parts to be mated. Just before rotation stops, the two parts bond and the remaining energy hot works the metal interface. Thus, the three parameters associated with inertia welding area: (1) the

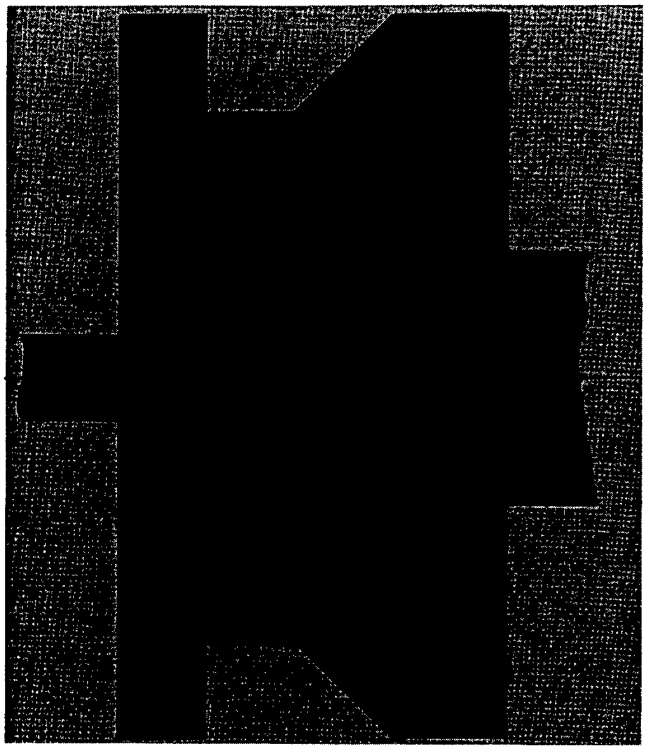


Figure 3

mass associated with the rotating part, (2) the final RPM of that part, and (3) the thrust of the stationary part.

In the case of this application, the stationary part was the projectile body and the rotating one was the band blank. Process refinement efforts involved the varying of all three of the above parameters in order to define the optimum set of parameters to produce a consistent quality weld. Unfortunately, while feasibility was firmly established, inexplicable inconsistencies from weld to weld and machine tooling problems make further study into radial inertial welding necessary.

Test Firings

When a preliminary set of parameters had been determined and the above testing had been completed, twenty abrasion cleaned and heat treated M483A1 projectiles with inertia welded rotating bands were fired in a series of acceptance tests in an attempt to correlate ultrasonics with actual performance and set standards for further work. These projectiles represented a wide range of weld quality. Disbond was much more severe at the leading and trailing edges than at the center of the band. Results indicated that in some areas where the ultrasonic scan indicated disbond at the edge of the rotating band, there was a loss of band material. This loss is believed to be due in some cases to firing and in others to impact. Correlation with ultrasonics was established to a degree, but a larger sample would be required to set ultrasonic standards.

Economic Analysis Needed

Although a great deal of information was gleaned from this work, weld inconsistency remains as a problem to be eliminated, and some secondary questions are left to be answered. For example, an in-depth analysis of available data would be needed to determine whether a positive correlation exists between inertia welding machine parameters and weld quality. If a positive correlation between machine parameters and weld quality was found, then a minicomputer system should be installed on the inertia welder to monitor and display those parameters. This would give the inertia welding machine operator a visual display depicting weld quality.

Additional inertia weld testing also would be needed to determine whether using the proper lubricant materials will provide extended tooling life and more consistent weld quality during production operations. And, finally, an economic analysis should be conducted of the inertia welding process. This analysis should consider all the necessary process/procedures in the inertia welding of a rotating band to determine the cost effectiveness of using the inertia welding process for banding projectiles.

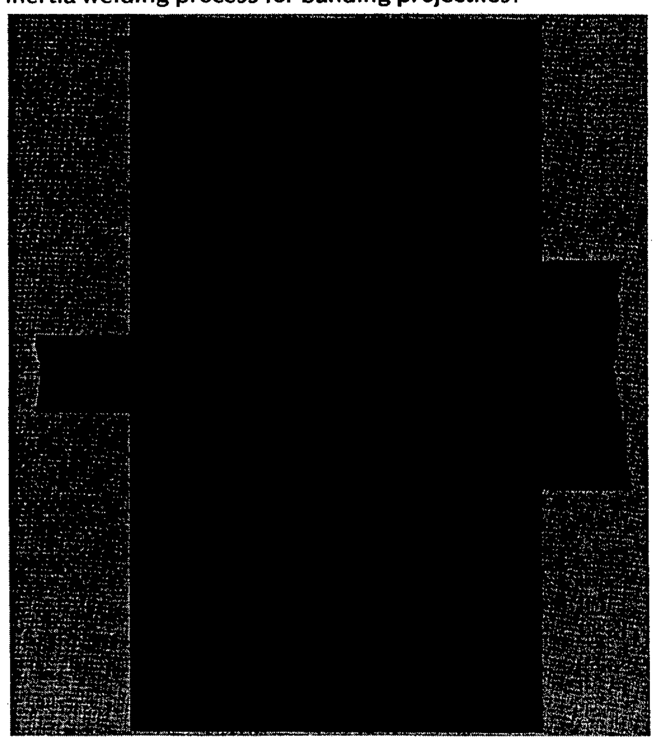


Figure 4

Peering Into the Future

Lightweight Armored Vehicle Vision Blocks

C. DOUGLAS HOUSTON, Jr. is a project engineer with the U.S. Army Tank-Automotive Command, and has been associated with work in vision devices since 1961. He holds a BS in Electrical Engineering from Michigan Technological University. He was also associated with Crysler Corporation on early projects in guided missiles.

A remarkable potential now is available to the U.S. Army Tank-Automotive Command for new transparent viewing systems that offer a level of protection that was considered impossible only three years ago. Where light weight and a high level of protection previously were tradeoffs, now they are welcome companions in the Army's new vision block technology. The new ultimate transparent armor is made up of an outside layer of extremely hard aluminum oxide plate backed by plies of a new high hardness glass and lined by a layer of tough new polycarbonate plastic to act as a spall guard. The new vision blocks are only part of the results from a project sponsored by the U.S. Army Materials and Mechanics Research Center for the Tank-Automotive Command.

Work recently completed by Goodyear Aerospace for the Army Materials and Mechanics Research Center has resulted in this improved capability, and when these vision blocks are incorporated in lightweight armored vehicles, they should increase the operational and survivability aspects of their operation.

The Need for Improved Visibility

Good visibility is of paramount importance to the operational and survivability aspects of armored vehicle performance. Unfortunately, vision blocks currently in use having even modest resistance to armor piercing kinetic energy projectiles have very marginal visibility characteristics. The principal problem is one of low luminous transmittance through the appreciable thickness of laminated soda-lime glass. The problem is increased by poor lighting such as can be experienced with overcast sky or near dusk conditions. The advent of high performance, lightweight armored vehicles such as the XM-2 Infantry Fighting Vehicle, XM-3 Calvalry Fighting Vehicle, Commando Scout Vehicle, Commando V-150 Armored Vehicle, and the MPG-NT Mobile Protective Gun Combat Vehicle has compounded the visibility handicap. Such vehicles, by the very nature of their increased road speed and advanced reconnaissance and fighting mission requirements, make greater demands on operating personnel vision.

During the last several years, great strides have been made in advancing the state of the art in the transparent armor field. The glass/plastic transparent armor concept has resulted in significantly reduced armor weights, improved optical quality, and elimination of backside spalling characteristics. The incorporation of specialty

NOTE: This manufacturing technology project that was conducted by Goodyear Aerospace thru the U.S. Army Materials and Mechanics Research Center was funded by the U.S. Army Tank-Automotive Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The TACOM Point of Contact for more information is C. Douglas Houston, (313) 574-6478.

glass also offers the possibility of achieving much higher luminous transmittance and a "water-white" appearance. New and extremly hard materials such as transparent ceramic (aluminum oxide) are now available for use in transparent armor composites. The transparent ceramic material also has high luminous transmittance and "water-white" characteristics. The material components and technology therefore exist which offer a high confidence level of success in achieving significant improvements.

The transparent armor program at the U.S. Army Materials and Mechanics Research Center funded the development of a new high hardness glass by PPG Industries. The performance of this material is such that when used in a vision block, equal protection from impact is provided with far less glass. The resulting thinner block enables a reduction in the surrounding armor "pocket" depth and a weight savings.

Further developments contributed to yet another plateau of vision block technology. These are the tough polycarbonate plastics and the cast interlayer adhesives that bond them to glass and other plastics. These cast interlayers replace polyvinyl butyral interlayers in some instances.

An important new material in transparent armors is single crystal aluminum oxide. This is a product of synthetic crystal technology, which permits a clear, cylindrical aluminum oxide crystal to be produced up to 12 inches in diameter. From this, plates may be cut and polished to a transparent plate, like plate glass, but many times harder.

Applying this aluminum plate as the outboard face of the composite transparency as described above, we have a high ballistic transparency of greatly reduced thickness and, of course, weight. This project of applying a new material to known materials has provided significantly lighter but ballistically superior vision blocks for armored vehicles.

Objective: Maximize Visibility

The program was divided into two phases, and was structured in a logical design, test, optimization and comparative evaluation format. Both glass/plastic (Type 1) and transparent ceramic/glass/plastic (Type II) armor vision block constructions were carried in competition throughout the program at a common threat level (Figure 1). The most important objectives consisted of maximizing vision block visibility and armor piercing ballistic defeat capability, in that order. Additional objectives consisted of ensuring the produceability and in-service durability of the improved vision blocks.

The best designs of each of the competing armor constructions subsequently were fabricated into prototype military configuration vision blocks (Figure 2). A series of rigorous optical, ballistic, and environmental tests were conducted on these configured test articles. An important

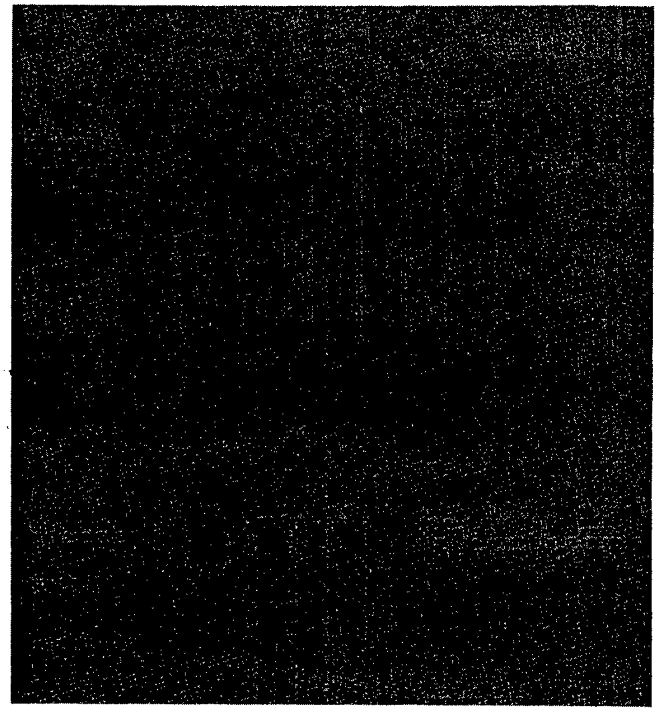


Figure 1

objective was to obtain sufficient data by the conclusion ot work to permit a critical comparative review of optical properties, projected cost, areal density, and thickness factors. This review would identify the armor construction of highest merit offering protection at the design threat level.

The Phase I work effort consisted of the following sequential tasks:

- Analysis of threat level specified by the Army Materials and Mechanics Research Center (AMMRC) and existing transparent armor data base
- Preliminary design consisting of the selection, gauging, and geometric arrangement of materials
- Preparation and forwarding of preliminary design test laminates to AMMRC for ballistic testing
- Vision block design optimization
- Preparation and forwarding of optimized design test laminates to AMMRC for verification ballistic testing
- Program review meeting.

Threat Level and Ballistic Data Review

A review of the threat level specified by AMMRC for the program was conducted. A search of available sources of glass/plastic and transparent ceramic/glass/plastic armor ballistic data failed to disclose useful information for the specified threat. This lack of data necessitated the utilization of both opaque armor data at the design threat level and the extrapolation of lesser armor piercing threat data.

Preliminary Test Laminate Design

Using the best available information from the threat level review and data search, preliminary designs of glass/plastic and transparent ceramic/glass/plastic were established by mutual agreement between Goodyear Aerospace Corporation and the AMMRC technical supervisor. These designs were identified as Type I (glass/plastic) and Type II (transparent ceramic/glass/plastic) for categorical identification throughout the program.

The preliminary laminate designs established consisted of one Type I and three Type II configurations. Borosilicate glass was selected for both the Type I and II designs. It possesses the following advantages:

- High luminous transmittance
- Water-white appearance
- Higher hardness than soda-lime glass
- Lower density than soda-lime glass
- Commercial availability in very thick section.

A SL3000-111N-grade General Electric Company, polycarbonate sheet Lexan, was selected for the following reasons:

- High luminous transmittance
- Light straw color
- Best optical quality.

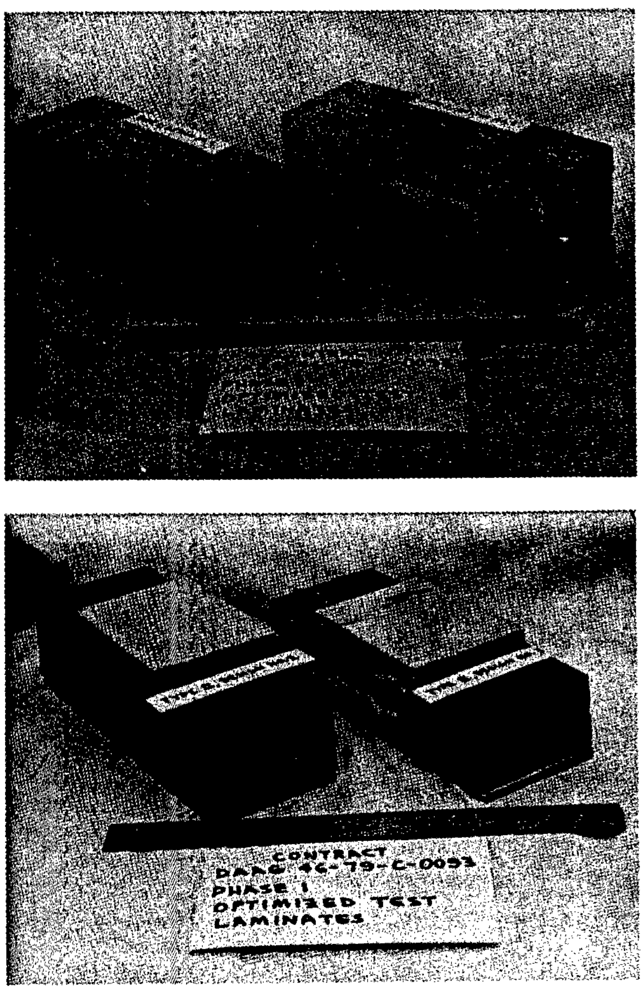


Figure 2

Preliminary Test Laminate Fabrication

All ceramic plates required were Government furnished equipment (GFE) provided to the program by AMMRC. Opague Coors AD94 aluminum oxide was used as the facing plies on all Phase I, Type II test articles for reasons of cost. The opaque AD94 ceramic has approximately the same hardness and ballistic capability as the transparent ceramic used in the Phase II configured vision block test articles.

Preliminary Test Ballistic Testing

The Type I and II preliminary test laminate specimens were ballistically tested at AMMRC on 16 January and 24 January 1980. At the conclusion of testing, the test specimens and the ballistic data were carefully studied by the AMMRC technical supervisor and the Goodyear Aerospace Corporation project engineer during a design review meeting. Assessments by those participating in the meeting were based on optical properties, ballistic performance, material costs, manufacturing economy and weight factors. The meeting resulted in the establishment of two each of the Type I and II optimized vision block laminate designs by mutual agreement.

Optimized Test Laminate Fabrication

Eight each of the two Type I and six each of the two Type II optimized laminate designs were fabricated. The Type I and II optimized test laminates were ballistically tested at AMMRC in late April, 1980. A program review was conducted with joint AMMRC/Goodyear Aerospace

Corporation participation on 23 April 1980. The ballistic data was used in conjunction with optical quality and fabrication assessments to define the final Type I and II laminate designs for Phase II work effort.

The Phase II work effort consisted of the following sequential tasks:

- Fabrication of 12 each Type I (glass/plastic) and II (transparent ceramic/glass/plastic) military configuration vision blocks
- Optical test evaluation of the vision blocks
- Environmental testing of the vision blocks
- Ballistic testing of the vision blocks (Figure 3)
- Preparation of engineering drawings for the Type I and II vision blocks.

The Phase II work effort consisted of the following sequential tasks:

- Fabrication of 12 each Type I and II military configuration vision blocks
- Optical test evaluation of the vision blocks
- Environmental testing of the vision blocks
- Ballistic testing of the vision blocks
- Preparation of engineering drawings for the Type I and II vision blocks.

Prototype Vision Block Design

The prototype transparent vision blocks fabricated in Phase II were designed to incorporate the geometric ply arrangements and component scaling in accordance with the final Type I and II designs selected at the conclusion of Phase I. The overall length of ten of the Type II vision blocks was reduced to accommodate the present state of the art of aluminum oxide producibility.

Goodyear Aerospace Code 706 abrasion resistant coating was specified to protect the inner surface of the polycarbonate ply on both Type I and II designs. This coating is used on all production transparent armor made by Goodyear Aerospace. It significantly increases the abrasion and chemical resistance of the material.

Goodyear Aerospace Code 806 sealant was specified for the filler which bonds the laminated vision block in the metal case. This sealant has a low modulus of elasticity and an extremely low rate of moisture permeability.

Engineering reproducible drawings were prepared for vision blocks of both Type I and Type II designs in accordance with MIL-D-1000A, Level 3 (Production). A total of 12 each Type I and II prototype vision block assemblies were fabricated in accordance with the production drawings.

One material substitution was made during the fabrication of these parts. Goodyear Aerospace Code F6X-2 sheet interlayer replaced the SR-41 PVB in bonding the transparent ceramic face ply to the glass, and the F4X-2B cast in place interlayer to bond the polycarbonate back ply to the glass.

Typical laminated transparent vision block and metal case components prior to assembly are shown in Figures 4 and 5. The completed assemblies together with a standard vision block are shown in Figure 6.

Ballistic Testing

Eight each of Type I and II prototype vision blocks were shipped to AMMRC for ballistic testing at the design threat level. Goodyear Aerospace designed and fabricated holding fixtures to support this effort. The fixture made from 1/2 inch thick MIL-A-12560D (MR) armor steel plate featured a bolted replaceable top plate and adapting shims for mounting the shorter Type II test articles. The holding fixture simulated the hull of an armored vehicle to secure the vision block assembly upon projectile impact (Figure 3).

Environmental Testing

Four each of Type I and II prototype vision blocks were subjected to a series of environmental tests intended to impose rigorous demands on the designs in recognition of the intended military usage. All eight test articles were conditioned during each test, and the same parts underwent all of the test exposures. Visual examination of each test article was made at appropriate times throughout the various conditioning modes. Each part also was examined carefully at the completion of each specific test. Control optical tests were made prior to the start of the environmental test conditioning.

Following the completion of the environmental testing, all prototype vision blocks were retested for optical properties. A comparison of original and post-test values was used to determine the changes, if any, created by the conditions imposed.

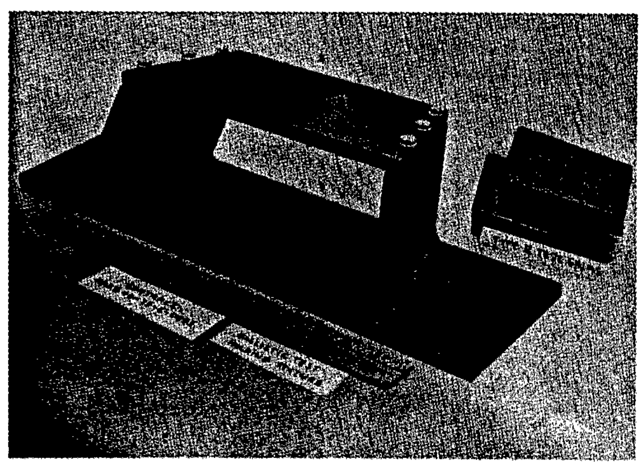


Figure 3

Test Descriptions

The optical and environmental tests utilized to evaluate the durability of the prototype vision block designs are described in the following paragraphs. Comments regarding the manner in which the test articles withstood these conditions are included.

(1) Unexposed Control Optical Tests

Luminous Transmittance values were determined in accordance with Federal Test Method No. 406, Method 3022. A Gardner Laboratory Model XL-230 Colorimeter was used for this test.

Haze values were determined using the same procedure and apparatus described for luminous transmittance.

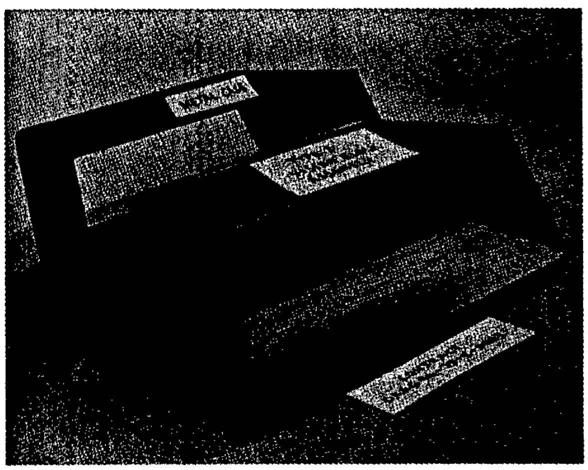


Figure 4

Optical Distortion through each test article was determined by direct measurement of grid line slope from photographs. The procedure, in accordance with MIL-G-5485C, consists of photographing an optical test grid board through the vision block. The test grid is made of accurately positioned fine white lines crossing to form a pattern of 1 inch squares on a black background. The first test articles of each type were evaluated using the double exposure photographic technique. This superimposes the reference grid over the grid as seen through the vision block.

An examination of the first double exposure photographic records showed virtually no optical distortion. Some optical deviation (apparent parallel displacement of grid lines) was evident, due to the

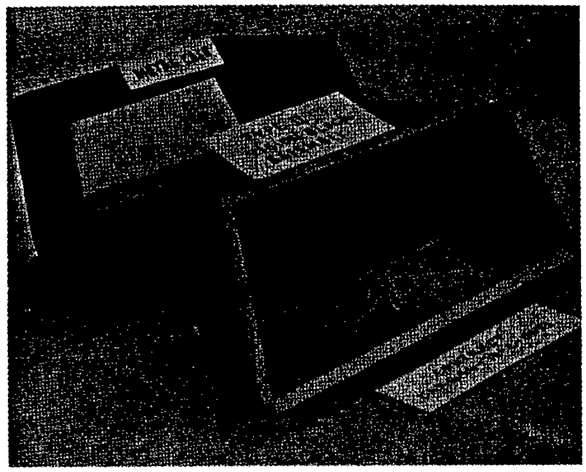


Figure 5

camera lens viewing through the appreciable thickness of the vision block. The displaced grid lines created a very busy record. After visually examining the remaining test articles and finding negligible distortion, it was decided to use single exposure photographs to provide a cleaner record.

(2) Environmental Test Evaluation

High Temperature testing was done in accordance with MIL-STD-810C, Method 501.1, Procedure 1. The high temperature test is intended to determine the resistance of equipment to evaluated

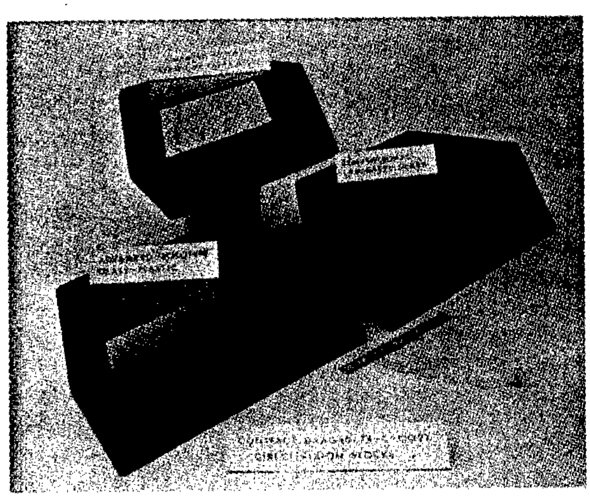


Figure 6

temperatures that may be encountered during service life either in storage or under service conditions.

The post-test inspection disclosed the following changes in the test articles:

- Small areas of delamination of the GACA Code 806 adhesive sealant to the glass and polycarbonate vision block surfaces were visible on all four Type I test articles. These delamination were estimated to include from less than one percent to a maximum of five percent of the total bonded area for the various test articles. The integrity of the laminated vision block transparency remained intact.
- Similar small areas of Code 806 adhesive sealant delamination to the glass and polycarbonate surfaces were noted for the Type II test articles. In addition, nearly all of the Code 806 bond to the edge of the transparent ceramic face ply had delaminated on all four parts.

Very slight edge and corner delaminations of the GACA Code F6X-2 interlayer bond to the transparent ceramic face ply were also visible. These delaminations, located primarily in the lower corners of all four parts, did not exceed approximately 0.05 inch encroachment into the laminate.

Low Temperature testing was conducted in accordance with MIL-STD-810C, Method 502.1, Procedure 1. The low temperature test is intended to deterine the effects of low temperature on equipment during storage or in service. The post-test inspection disclosed no changes in the condition of the test articles except for the following:

- One additional very small area of GACA Code 806 adhesive sealant delamination to glass on three of the four Type I test articles. These delaminations did not exceed 0.1 square inch each.
- One similar size GACA Code 806 bond delamination to glass on two of the four Type II test articles.

Temperature Shock testing was conducted in accordance with MIL-STD-810C, Method 503.1, Procedure 1. The temperature shock test is intended to determine the effects on equipment of sudden changes in temperature of the surrounding atmosphere. One of the most common causes of such rapid changes in the military environment is associated with rapid altitude changes during air transport of equipment.

Post-test inspection of the test articles revealed no change in condition for any part except the Type II, S/N 8 item. The outer ply of borosilicate glass (directly behind the transparent ceramic face plate) developed a fracture in the lower corner. The fracture probably resulted from a small, undetected defect on the edge of the glass.

Humidity testing consisted of exposing the test articles for 10 days at 160 deg F and 37 percent relative humidity under steady state conditions. The test specimens were examined daily throughout the exposure period. After four days of exposure, small delaminations of the F6X-2 interlayer bond to the polycarbonate back ply were visible on the Type I, S/N 2, and S/N 4 articles. By the fifth day of exposure, the S/N 2 vision block delamination had increased. The S/N 4 article delamination appeared to be unchanged in size. No delamination or other degradation was observed on the remaining two Type I or the four Type II test articles. At the conclusion of the 10 day exposure period, the test articles were returned to standard ambient conditions and stabilized. All of the test articles were cleaned and visually examined.

The S/N 2 vision block delaminations had increased, as had the single delamination on the S/N 4 vision block, but no additional delaminations were visible on these two vision blocks and there was no evidence of degradation resulting from the humidity exposure on the other two Type I and all four Type II test articles.

The F6X-2 interlayer delaminations experienced on the two Type I vision blocks were not typical. The quality of the interlayer bond achieved on these articles is questionable. The dissimilarity of behavior between the two delaminating vision blocks and the other six test articles creates the suspicion that a contaminant was present during fabrication of the two parts. The contaminant could have been on either the polycarbonate surface or on the F6X-2 sheet interlayer. After concluding the post-test examination, all of the test articles were thoroughly recleaned and readied for the post-environmental test optical retesting.

(3) Post-Environmental Test Optical Retests

Following the completion of the environmental test series all eight test articles were retested for luminous transmittance and haze in accordance with the original test procedures. All eight test articles were reexamined at the optical test grid board for distortion. No visual change was evident in any of the parts. The rephotographing of the test assemblies was waived due to the lack of observed distortion worthy of documentation.

(4) Disposition of Environmental Test Articles

After concluding the post-test evaluation of the environmental test articles, all eight parts were delivered to AMMRC for ballistic testing.

Significant Potential for New Designs

The feasibility of designing and producing direct vision type vision blocks which offer very significant improvements in operating personnel visibility and ballistic protection has been demonstrated and the improvements can influence the operational and survivability aspects of armored vehicle performance. Further, the utilization of the improved vision blocks will be most applicable to lightweight, high performance armored vehicles such as the XM-2, XM-3, Commando Scout, Commando V-150 and MPG-NT Mobile Protective Gum.

These improvements also are beneficial to the entire inventory of more conventional armored vehicles, such as tanks, personnel carriers, and rocket system vehicles, particularly as they are upgraded in performance characteristics.

However, the most significant visibility gain potential lies in the application of the advanced transparent armor constructions to new vehicle designs. The higher level of ballistic capability offered by the improved designs will allow an increase in the vision block viewing area. Current vision blocks are very small to minimize ballistic vulnerability, since the transparent block sometimes has less ballistic defeat capability than the vehicle hull.

Within the current state of the art, the Type I glass/plastic design offers the best performance/cost tradeoff.

Contamination and Bonding Still Problems

Several aspects of the materials and manufacturing technology used to produce the prototype vision block assemblies must be improved. This effort is required to correct the deficiencies uncovered during the environmental testing. Specifically, improvements are needed in the following areas:

- Increased adhesion of the Code 806 sealant to glass and polycarbonate materials. The integrity of the sealant bond which joins the vision block and case must be maintained during environmental conditioning.
- Increased awareness of contamination potential and its effect on the resultant interlayer bond. The bonding substrates must be adequately cleaned, and this state must be maintained until the composite is assembled and the bond achieved. The sheet interlayer must be produced free of contaminants and must be stored in packaging and environments which do not add contaminants prior to its use.

Scratch Resistant Coating Needed

A need exists for an improved hard coating to protect the exposed inner surface of the armor composite polycarbonate component. The present state of the art in abrasion resistant coating adds chemical resistance, and also prevents damage to the inner vision block surface during routine cleaning operations. The success of the present coating relies on careful attention to the cleaning procedure, which requires air blast and water flooding techniques to remove abrasive particles. The coating can be marred by gross abrasion or sharp objects. The durability of the coating in the severe operational and maintenance environment of military vehicles has not been proven. A truly scratch resistant coating for polycarbonate should be developed and incorporated into high performance glass/plastic vision blocks to add to their service life.

Field Trials and New Designs Beneficial

Two types of armored Army vehicles which have direct vision type vision blocks should be selected for use in field trials of the improved design articles. One vehicle should be either an armored personnel carrier or tank of the latest design, while the second selection should be a high performance, lightweight, armored reconnaissance vehicle.

The complexity of this field trial program should be minimized by designing direct replacement configuration improved vision block articles for both vehicles. This action will preclude the need for vehicle modifications and permit comparisons to be made of the merits of standard versus new vision blocks unaffected by size or configuration factors. A comprehensive field test plan should be preparred to define the scope, conduct, and assessment criteria for this effort.

Also, a design review should be made of all currently operational direct vision type vision block installations in Army armored vehicles. Present designs should be analyzed and categorized by form and function. New designs incorporating the improved vision block construction should be prepared for retrofitting current vehicles. This would be a more formal engineering effort than the activity supporting the fabrication of the prototype vision blocks for the two vehicle field test. Improvements in the design of the vision block installation and casing techniques should be sought for functional and cost reduction reasons. The scope of this new design and retrofit activity would be dictated by the findings of the design review and Army requirements.

Affording A Low Cost Alternative

Composite Dies for High Energy Rate Forming

Development of medium life composite dies for forming stainless steel and titanium alloys has slashed costs in half and shortened lead time by at least as much compared to conventional dies. This milestone was marked by the successful completion of a manufacturing technology program for the U.S. Army. A 10 month development program for the Army Materials and Mechanics Research Center was conducted by Hughes Helicopters to design, fabricate, and test/evaluate a low cost composite die system for high energy rate forming (HERF) of titanium and high temperature alloy parts commonly used on helicopters.

HERF Best Candidate

During several earlier years the manufacturing engineers at Hughes Helicopters had analyzed a number of methods for precision compound contour forming of fatigue resistant sheet metal. Four of the most promising methods investigated were as follows:

- Explosive forming (high energy rate forming—HERF)
- Stretch forming (shallow, open contours only)
- High pressure bladder (Verson-Wheelon typical)

ERNEST N. KINAS is a Mechanical Engineer, Prototype Devèlopment Division, Metals and Ceramics Laboratory, U.S. Army Materials and Mechanics Research Center. He has been active for over twenty-five years in metals research and development, specializing in process development and prototype processing. He is also extensively engaged in engineering investigation programs in high density kinetic energy armor piercing penetrator materials, atomic shell munitions, prototype ceramic forging dies, and prototype high strength metal-plastic laminates. He serves as a forging consultant to other Army organizations and represents the Army in Government committees and conferences on forging. He is a registered Professional Engineer and a member of American Society for Metals, the Project Management Institute, and the American Association for the Advancement of Science. He received his B.S. in Engineering from Northeastern University.

NOTE: This manufacturing technology project that was conducted by Hughes Helicopter thru the U.S. Army Materials and Mechanics Research Center was funded by the Aviation Research and Development Command under the overall direction of the U.S. Army Directorate for Manufacturing Technology, DARCOM. The AMMRC Point of Contact for more information is Ernest Kinas, (617) 923-5270.

- Precision roll forming (constant section shapes)

Of the four methods listed, only explosive forming (HERF) appears to meet the requirement of consistent dimensional precision on a part to part basis at reasonable recurring manufacturing cost. In the past, explosive forming had two major disadvantages. One was the cost and long lead time required to obtain high strength steel dies. The other was the limitations imposed by the various State and Federal agencies on the use of explosives in a factory environment.

New Material for Die Construction

Prior to this developmental effort, Hughes reviewed and evaluated all known low-cost short lead time die forming fabrication concepts used in both the aircraft and other commercial industries. These concepts used the following materials for die construction: ice mixed with nonmetallic fibers and sawdust, Cerrobend (trade name), Kirksite (trade name), plastic—cast epoxy (trade name of Devon) and urethanes, plastic (face) with conventional concrete backup in a steel container, and aluminum—cast and finished machined.

None of these fabrication materials were considered structurally adequate to meet the low cost, short lead time. medium life design objectives for the composite die. The Hughes HERF die approach uses a hard (electrodeposited) nickel liner about 0.120 in. thick to provide a high strength, smooth die surface. The liner is backed up with chopped steel wire fiber reinforced concrete having the trade name Wirand. The concrete backup material is contained by a steel outer shell.

Soniform One Answer

As previously mentioned, two drawbacks to the use of HERF were cost/long lead time and the use of explosives in a factory environment. Hughes Helicopters uses a machine called the "Soniform" to perform electrohydraulic forming. This type of cold forming involves the very rapid release (approximately 20 microseconds) of electrical energy from a capacitor bank into a working fluid, usually water.

The Soniform (Figure 1 & 2) has a capacity of 150,000 joules at 20,000 volts and consists of the following main subsystems when HERF cold forming is done:

- A power supply that converts 440 volts to the preset charging voltage for the capacitor bank.
- A capacitor bank to store the electrical energy.
- A movable console that contains the following low voltage controls:

  —Hydraulic press control (open-close)

  —Die cavity vacuum pump switch
  —Water cavity fill and drain switches

  —Capacitor voltage level control

  —Capacitor charge switch.

- A transducer (containing two electrodes) to discharge electrical energy in the working fluid
- A power switch to connect the capacitor bank to the transducer
- A 200 ton hydraulic press
- A die system for shaping a specific part.

Operation of the machine is fully automatic once the capacitor charge switch is closed. First, electrical energy (in kilojoules) is stored in the capacitor bank at predetermined voltage. Then the capacitor charge switch is closed. When the capacitor voltage reaches the preset level, the power switch automatically closes, causing a high energy spark to occur at the gap between the transducer electrodes in the water cavity. This release of electrical energy causes the water in the vicinity of the electrodes to become ionized, thereby creating a very high pressure (50,000 psi) in this area. A high velocity hydraulic pressure wave is formed inside the water cavity and acts on the part to be formed. Since the die cavity has been evacuated of air by a vacuum pump, the part is forced at a high rate of speed (500-800 ft/sec) to conform to the shape of the die cavity. Because the part is permanently deformed beyond the elastic limit, it takes the shape of the die cavity.

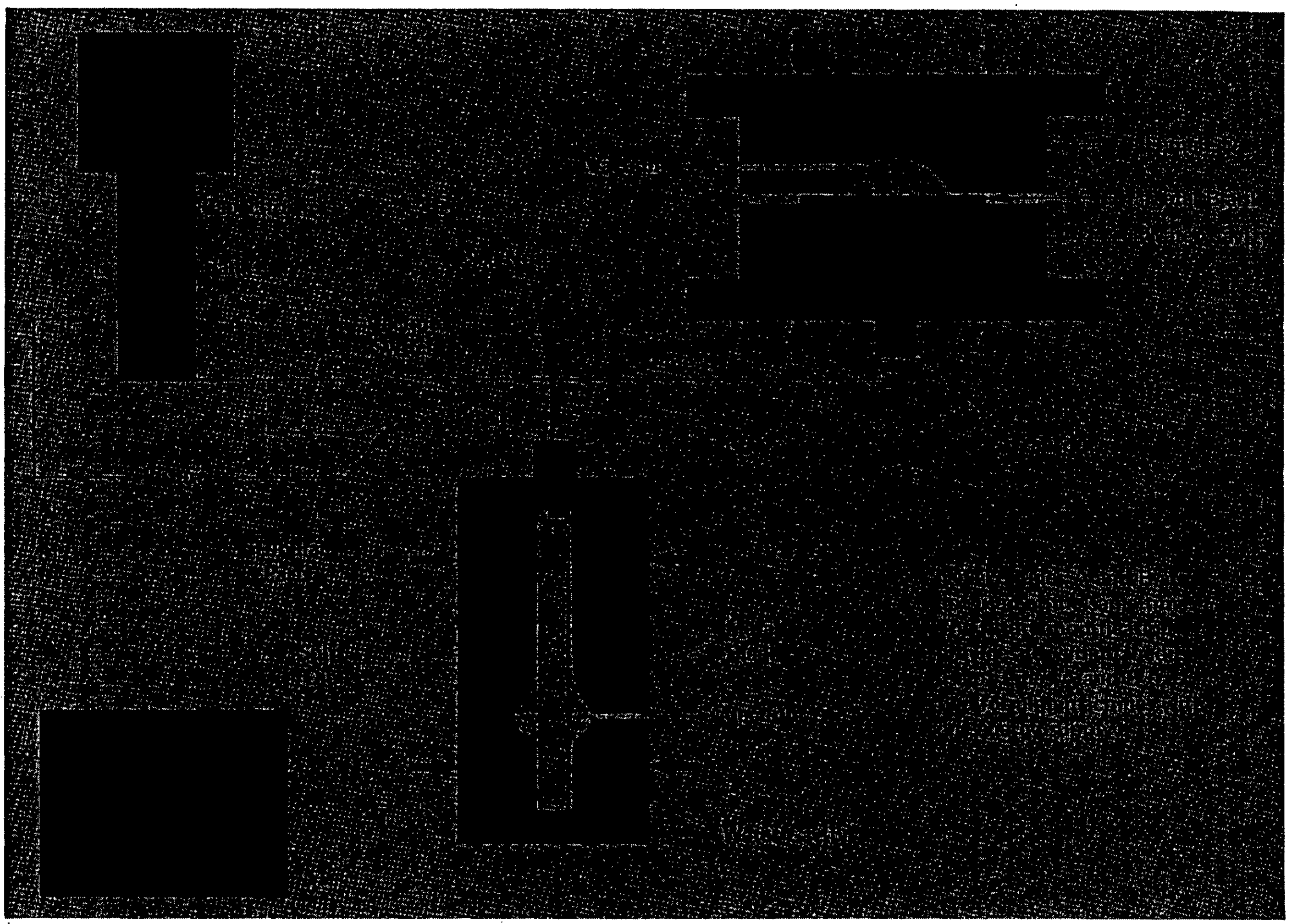


Figure 1

Forming Development

The two materials originally selected to evaluate the low cost composite die were N-155 and 6Al-4V titanium alloy. As permitted in the contract, 321 stainless steel was substituted for N-155 since it was cheaper and more readily available. (The two metals have equivalent forming characteristics.) The contract requirement for forming of five parts of each of the two selected materials was satisfied by using seven pieces of 321 stainless steel and eight pieces of 6Al-4V titanium alloy.

HERF operations, whether explosive or electrical discharge forming, usually require a few trial operations to develop the most efficient energy level per shot for maximum die life. In addition, a certain amount of time is also required to "shake down" a new forming development with regard to loading and vacuum sealing a part in the die. Also, a die handling sequence must be developed for dies as heavy as the 2200-lb die used in this project.

In the first trial forming effort using a 321 stainless steel part, a slight bulge formed in the ribbed area of the die for an overall elongation of approximately 4 percent. A series of concentric wrinkles was formed in the weld area (approximately 8 in. circumference) of the part. Successive trials under varying conditions did not solve the problem. Upon review of the above forming results, it was decided to try another part with a series of shots at a much lower energy level. This approach proved to be completely successful. The four parts all formed net to the die with excellent shape detail. The parts are shown in the photograph presented previously as Figure 2. The parts actually formed so tight in the die that a wheel puller type of part extractor had to be developed to remove the parts.

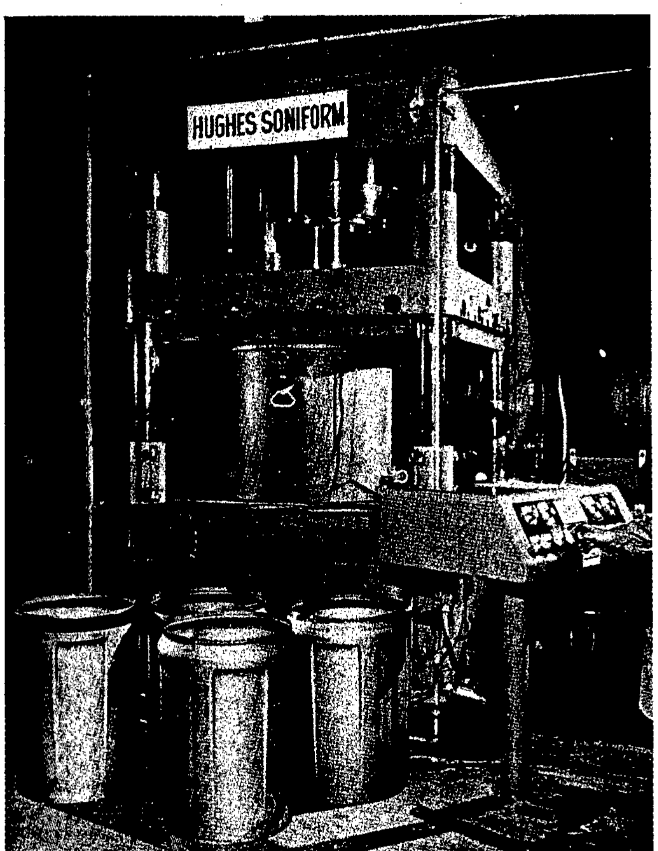


Figure 2

6A1-4V Titanium Alloy Forming

The contract required that five pieces of 6Al-4V titanium alloy be cold formed (using the HERF technique) on a best effort basis in the low cost die developed. Since cold forming of titanium to precise dimensions (±0.010 in. tolerance) is known to be pressing the state of the art, eight parts identical to the stainless steel parts were obtained for development of the forming parameters. Cold forming of the titanium alloy was approached very carefully in that the energy level was kept conservatively low for the first stage forming by holding the energy level below 20.0 kilojoules (14,752 ft-lb). However, this energy level proved too high, as one part failed (ruptured) on the fifth shot at 19.6 kilojoules (14,457 ft-lb). In order to develop an upper energy level limit versus the number of shots, a second part which had already been shot five times at 19.6 kilojoules was put in the die and shot once at 30 kilojoules (approximately a 50 percent increase). The increased energy level caused the part to rupture. After a careful analysis and review of the above die forming, a three stage forming schedule was selected.

An analysis was made to determine the cause of ruptures. It established that the failures were caused by the relatively sharp 0.172 in. radius of the ribbed section of the die cavity. This sharp radius created a notch effect which placed the material at such a high local stress level that the ultimate strength of the material was exceeded. The stress level of the unsupported (and incompletely formed) portion of the part must be kept in the yield region to permit the part to have complete forming (Figure 3). Figure 4 is a photograph of this part along with a formed 321 stainless steel part. This type of failure appears to be unique to high strength titanium alloys when they are subjected to cold forming (even though three stage forming is used).

HERF 49-55 Percent Cheaper

The development work performed under this project established that high energy rate forming of 321 stainless steel can be readily accomplished using low cost, short lead time, medium life composite dies. Cost was 49 percent cheaper for parts fabricated and an estimated 55 percent cheaper for twice size parts. Lead time was estimated at half of conventional tool steel systems. As far as die life is concerned, 275 cycles were performed with no die deterioration. Estimated die life in excess of 500 cycles. Sizable cost savings can be realized when parts used in this project are cold formed by HERF in a composite die. Die life of 2,000 cycles (medium run) should present no problem. Also, as more experience is gained with composite dies, the desired short lead time of one third of conventional die systems should be readily obtainable.

In the design of composite dies, careful consideration should be given to the die vacuum provisions to ensure trouble free, low cost production. For example, the O-rings and gasket material used to seal the die cavity should be readily replaceable in the event that they are damaged during a part insertion or extraction.

Cold forming of 6Al-4V titanium alloy by any method (HERF or conventional) will be compromised with regard to repeatable dimensional accuracy of the formed part due to the metal spring back variation on a part to part basis. Still other limitations are the low elongation possible with titanium as compared to stainless steel and the rapid work hardening of titanium when formed, which can lead to premature rupture of the part.

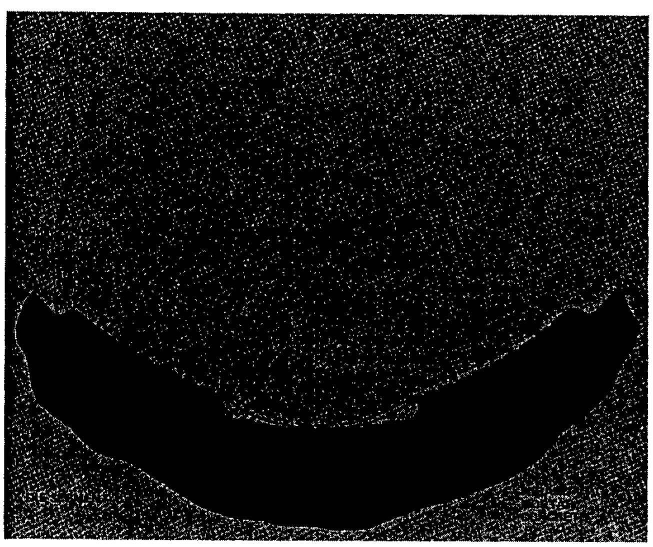


Figure 3

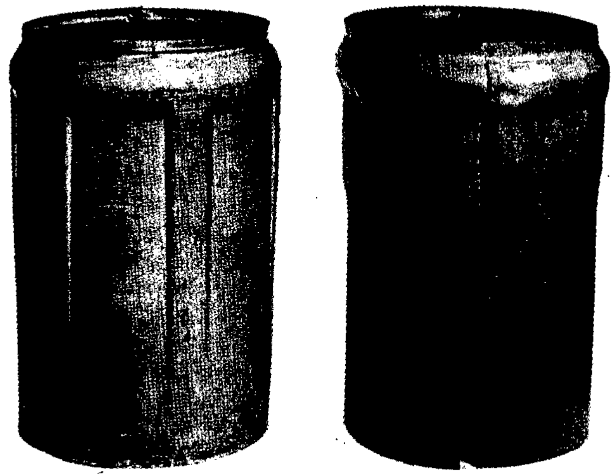


Figure 4

Twofold Work Needed

The successful developmental work completed under this project should be continued in a new twofold project:

- First, a low cost composite die should be fabricated to permit HERF cold forming of a relatively large, current production part such as the OH-6A engine access door (left and right hand parts fabricated simultaneously). The recorded costs, lead time, and die life using the new fabrication technique then could be compared to actual costs, lead time, and die life established for the conventional stretch-form method. In other words, the HERF low cost die system would be subjected to a "real world" comparison.

- Second, a detailed feasibility study should be made to determine the practicality and cost of cold forming a very large part using the out of press incremental forming concept. A proposed facility using this concept has been considered.

Brief Status Reports

Project 7412, AVRADCOM. Infrared Detector for Laser Warning Receiver. Perkin-Elmer Corp. Electro Optics Division is conducting production engineering on methods for making, assembling, and testing interdigitated IR detectors. Indium arsenide material suppliers were qualifid. Will be for AN/AVR-2 IR detector for use aboard aircraft. Masking, photolithographic, etching and bonding were used. Final status report received. For additional information, contact F. Reed, AVRADCOM, (314) 263-1625.

Project 1021, MICOM. CPPP Machined Cylindrical Parts (CAM). This project is complete. A computer managed process planning system has been developed and is currently being used at three companies. The system has been applied on two military aircraft engines. Final status report received. For additional information, contact R. Kotler, MICOM, (205) 8876-2065.

Project 1023, MICOM. Digital Fault Isolation F/Hybrid Microelectronic Modules. Hughes developed an automatic back trace and probing method to detect digital failure in hybrid circuits. DTS-70 test aid and fast race software acheived .94 comprehension. GD/ND-GD test is performed in 5 sec. system to be implemented at Hughes Tucson GDCD. Final status report received. For additional information, contact G. Little, MICOM, (205) 876-3604.

Project 1024, MICOM. MMT Radio Frequency Stripline Hybrid Components. Hughes developed a model of beam lead varactor diodes used in a frequency doubler. Thin dielectric sheet suspender substrate was used to match inpedance of diodes and wave guides. Dielectric thickness kept at .005 in. min. Diodes are reflow soldered. Final status report received. For additional information, contact L. Woodham, MICOM, (205) 876-4948.

Project 1050, MICOM. Low Cost Braided Rocket Motor Components. This project has been completed successfully. The Interim Tech Report, RK-CR-82-6, has been distributed. Final status report received. For additional information, contact W. Crownover, MICOM, (205) 876-5821.

Project 1086, MICOM. Cobalt Replacement in Maraging Steel-Rocket Motor Components. This Phase I technical effort is complete. Technical Report RK-CR-83-1 is disttributed. Phase II continuing. Final status report received. For additional information, contact W. Crownover, MICOM, (205) 876-5821.

Project 3516, ERADCOM. Cryogenic Cooler Hybrid Motor Circuit. Aeroflex completed its hybrid circuit work and documented it in a TV tape shown at the electronics minisymposium at MTAG 82. Final technical report received from Aeroflex. Circuit may be used in Stirling cooler for AN/TAS=4. For additional information, contact S. Horn, ERADCOM, (201) 544-4258.

Project 9813, ERADCOM. Ruggedized Low Cost Quadrant Detector for CLGP. Negotiated termination of TI contract has been completed. Martin-Marietta can meet all future Copperhead quadrant detector requirements. TI could not overcome sodium poisoning of silicon detector. Final status report received. For additional information, contact M. Skeldon, ERADCOM, (201) 544-4259.

Project 1026, MICOM. Production of Low Cost Missile Vanes. This project is complete. It was demonstrated that a composite missile vane can be manufactured and that automated production is feasible. The project was recognized throughout industry as a significant accomplishment. Final status report received. For additional information, contact E. Croomes, MICOM, (205) 876-7317.

Project 9835, CECOM. Integrated Thin Film Transistor Display. Aerojet found that present technology will not permit laying down multiple layers of display and driver films. Hybrid construction was used to build demo units. Rough surface is not suited for subsequent films. Final status report received. For additional information, contact M. Miller, CECOM, (201) 544-5205.

Project 3294, MICOM. Production Processes for Rotary Roll Forming. The interim technical report for this first phase is complete. Phase two is proceeding. Final status report received. For additional information, contact W. Crownover, MICOM, (205) 876-5821.

Project 3396, MICOM. Injection Molding of Low Cost One Piece Nozzles. Eighty MLRS nozzles were molded from six materials. Acceptable parts were made from four of those materials. Processing specs and QA requirements were prepared. Facility implementation costs were estimated. This facility could produce 120 per day. Final status report received. For additional information, contact W. Crownover, MICOM, (205) 876-5821.

Project 7338, AVRADCOM. Composite Tail Section. this project continuation was cancelled. Funds were reprogrammed. A final technical report has been received which summarizes the effort (FY 79, 80, and 81 projects). For additional information, contact G. Gorline, AVRADCOM, (314) 263-1625.

Project 7183, AVRADCOM. Semi-Auto Comp Manufacturing Systems for Helicopter Fuselage Secondary Structures. The contract was terminated. A final report has been received. For additional information, contact G. Gorline, AVRADCOM, (314) 263-1625.

Project 7338, AVRADCOM. Composite Tail Section. This program has been terminated. A final report has been submitted. For additional information, contact G. Gorline, AVRADCOM, (314) 263-1625.

Project 7371, AVRADCOM. Integrated Blade Inspection System (IBIS). Final software debugging is presently being accomplished in preparation for a scheduled end of contract briefing. Final status report received. For additional information, contact G. Gorline, AVRADCOM, (314) 263-1625.

Project 1121, MICOM. Missile Manufacturing Productivity Improvement Program. Rockwell and Martin Marietta reviewed their HELLFIRE facilities and prepared Phase I final reports. Proposals for Phase II were received at MICOM and are being evaluated. Follow-on activities were postponed by HELLFIRE project office. Final status report received. For additional information, contact Bobby Austin, MICOM, (205) 876-2147.

Project 3165, MICOM. Production Process and Techniques for Sealing Hybrid Microcircuit Pack. M&K Associates, Solid State Equipment, and Huntsville Microcircuits provided a system for baking, parallel seam welding, and gross leak testing of hybrid packages. System is capable of sealing and leak testing hybrid packages at rate of 100 per hour with 95 percent yield. Final status report received. For additional information, contact Bobby Austin, MICOM, (205) 876-2147.

Project 3396, MICOM. Injection Molding of Low Cost One Piece Nozzles. Eighty MLRS nozzles were molded from six materials. Acceptable parts were made from four of those materials. Processing specs and QA requirements were prepared. Facility implementation costs were estimated. This facility could produce 120 per day. Final status report received. For additional information, contact W. Crownover, MICROM, (205) 876-5821.

Project 3435, MICROM. Simplification of High Power Thick Film Hybrids. Westinghouse reduced materials costs for logic substrates by 50% with reworkable backing lay/solder system for substrate to header attachment. Capability for bonding aluminum wires up to .020 inch diameter was established. Final status report received. For additional information, contact L. Woodham, MICOM, (205) 876-4948.

Project 3453, MICOM. Ground Laser Locator Designator Production Improvements. Crystal technology has completed all contractural work resulting in production processes capable of 250 lithim niobate Q-switches per month. The Q-swithces have qualified for use by most U.S. manufacturers of military ranging and designator systems. Final status report recieved. For additional information, contact R. Kotler, MICOM, (205) 876-2065.

Project 5019, TACOM. Storage Battery Low Maintenance. Battery requirement and basic design of storage battery established. Contrac for prototype batterie sinplastic.on-

Project 5019, TACOM. Storage Battery Low Maintenance. Battery requirement and basic design of storage battery established. Contract for prototype batteries in plastic containers completed and batteries delivered to TACOM. Effort continuing. Final status report received. For additional information, contact J. Reinman, TACOM, (313) 574-6492.

Project 4064, ARRADCOM. Auto Lap Operations for 105 MM Tank Cartridges. A production system for the automated load and assembly of a family of 105 MM tank cartirdges has been designed. Technical data for the liner to case assembly is available. A technical report will be available. Final status report received. For additional information, contact K. Lischick, ARRADCOM, (201) 724-4162.

Project 4444, ARRADCOM. Body for M42/M46 Grenade. Worl completed awaiting final technical report. Final status report received. For additional information, contact W. Field, ARRADCOM, (201) 724-4422.

Project 4466, ARRADCOM. Evaluate TNT, Cyclotol, Dotol inMelt-Pour Facility. Project complete. Final technical report will be distributed upon publication. Final status report received. For additional information, contact L. Manassy, ARRADCOM, (201) 724-2545.

Project 7807, ARRADCOM. Programmed Optical Surfacing Equipment and Methodology (CAM). A Bostomatic CNC milling machine has been adapted for grinding and polishing of optical surfaces (all on one machine). In addition, a milling machine interpretive language, which permits complex movements or whole operations was developed. Final status report received. For additional information, contact N. Scott, ARRADCOM, (201) 724-6945.

Project 4480, ARRADCOM. High Speed Head Turn Too. Mod F/SC AMMO Products. A complete set of improved headturn modules were purchased and installed. They are performing satisfactorily and have increased the tool module performance to over 41,000 pieces between adjustments. Final status report received. For additional information, contact M. Leng, ARRADCOM, (201) 724-5688.

Project 6774, ARRADCOM. Manufacturing Methods for APDS Projectile. Process studies were completed and the equipment designed. A molding system, utilizing a four cavity mold, and a trim station were fabricated. Demonstrations were completed at the vendors facility and the equipment was shipped to Ford Aerospace. For additional information, contact J. McCormick, ARRADCOM, (201) 724-4581.

Project 6774, ARRADCOM. Manufacturing Methods for APDS Projectile. The equipment was assembled and sample projectiles were submitted for ballistic testing. Testing was performed over the full temperature range with satisfactory performance. This project resulted in immediate saving of $235K. More with late buys. Final status report received. For additional information, contact J. McCormick, ARRADCOM, (201) 724-4581.

Project 4462, ARRADCOM. Forced Air Dry for Multi-Based Propellants. All work has been completed and the final technical report published. For additional information, contact A. Graff, ARRADCOM, (201) 724-3637.

Project 4411, ARRADCOM. Small Caliber Ammunition Process Improvement Program. Four separate circuit boards were consolidated into one on the primer insert SM. Bullet and case feeder efficiency increased from 85 to over 98%. Prototype bearing and tool condition analysis system feasibility was demonstrated. Final status report received. For additional information, contact E. Rempfer, ARRADCOM, (201) 724-3737.

Project 0915, ARRADCOM. Group Technical Requirements Definition Electronics. This project is complete. The fundamental characteristics of a group technology electronics classi fication/coding system have been developed. Final status report received. For additional information, contact N. Scott, ARRADCOM, (201) 724-6945.

Project 7963, ARRADCOM. Group Technology for Fire Control Parts and Assemblies. A pilot group technology system for fire control machined parts was completed. A microcomputer group scheduling program was developed. A final technical report is available. For additional information, contact N. Scott, ARRADCOM, (201) 724-6945.

Project 8001, ARRADCOM. Rapid Flow Plating of Small Caliber Gun Tubes. This project is complete. Smooth, adherent chromium can be electroplated inside the bore of 50 caliber gun barrels by the rapid flow plating process. The rate of deposition was about 15 times that for conventional plating. Final status report received. For additional information, contact V. Lakshminarayana, ARRADCOM, (201) 724-5746.

Project 7339, AVRADCOM. Filament Wound Composite Flexbeam Tail Rotor. All funds were withdrawn and reprogrammed. The project was terminated after the AAH-PM decided not to fund the design alterations and testing necessary for flight qualification because of the high costs involved. Final status report received. For additional information, contact Gerald, Gorline, AVRADCOM, (314) 263-1625.

Project 5024, TACOM. Gear Design, Manufacturing, Utilizing Computer Technology (CAM) Phase 2. This project is complete. The final report was distributed in February, 1983. Final status report received. For additional information, contact Dave, Pyrce, TACOM, (313) 574-6467.

Project 5064, TACOM. Lightweight Saddle Tank (Phase II). Fuel tanks for 5 ton vehicle underwent feasibility testing at Yuma Proving Grounds, cold region and tropic test sites, without failures. Deficiencies overcome by adding ribs (fillets) in tank and modifying corner radii. Final technical report issued. Final status report received. For additional information, contact Dave Pyrce, TACOM, (313) 574-6467.

Project 5067, TACOM. Plastic Battery Box (Phase II). Results show polyethylene is a durable material which will last the life of the vehicle. Retainer exhibited cracks after dropping from a certain angle, but modification will correct the problem. Final technical report is being forwarded separately. Final status report received. For additional information, contact Dave Pyrce, TACOM, (313) 574-6467.

Project 5090, TACOM. Improved and Cost Effective Machining Technology (Phase II). All machining operations for Phase ii completed. Data has been computerized. An interim report has been written. A machineability handboo, will be published at the conclusion of Phase III. Final status report received. For additional information, contact Dave Pyrce, TACOM, (313) 574-6467.

Project 6054, TACOM. Advanced Metrology Systems Integration. This project was cancelled The remaining funds were diverted to another program. This effort will be resumed later. For additional information, contact Dave Pyrce, TACOM, (313) 574-6467.

Project 6100, TACOM. Engineering Support Directorate Technology Modernization Program. this project is complete. A scope of work for a comprehensive evaluation of the engineering support directorate was established. The results from the proposed work will provide a plan for technical modernization of design, test, and manufacturing capability. For additional information, contact Dave, Pyrce, TACOM, (313) 574-6467.

Project 3604, MERADCOM. Solid State Power Switch. CMOS devices came to market that meet the requirements of the SSPS. The CMOS devices proved simpler and more reliable. Project was discontinued. Final status report received. For additional information, contact F. Perkins, MERADCOM, (703) 664-5724.

Project 3604, MERADCOM. Solid State Power Switch. Considerable effort was expended in attempting to locate and solve the many problems encountered which prevented the SSPS from functioning properly. The FY78 + FY79 projects both were terminated without a satisfactory product. Final status report received. For additional information, contact F. Perkins, MERADCOM, (703) 664-5724.

Project 3717, MERADCOM. High Temperature Turbine Nozzle for 10 KW Power Unit. Project work was completed. Turbine nozzles were fabricated and will be tested in the follow-on Project 3717. Metal shrouds were fabricated and assembled with the nozzles. Final inspection and flow checks were completed. Final status report received. For additional information, contact J. Arnold, MERADCOM, &703) 664-5459.

Project 3745, MERADCOM. MMT Aluminum Skin-Graphite/Epoxy Sandwich Bridge Reinforcement. No work has been accomplished because R&D funds to develop the prototype material in support of this MMT effort were withdrawn to be used on higher priority R&D. This effort has been terminated. For additional information, contact E. Rudy, MERADCOM, (703) 664-5176.

Project 0001, DESCOM. Voice Controlled Programming of Computers. A voice input unit was linked with a CAD/CAM Graphics System at Tobyhanna Army Depot. The integrated system was demonstrated to be able to operate effectively, efficiently, and with little or no degradation to the graphics controller. Final status report received. For additional information, contact F. Estock, DESCOM, (717) 894-7099.

Project 7052, AVRADC(OM. Ultrasonically Assisted Cold Forming of Titanium Nose Caps. Equipment is modified and technical personnel are instructed in its use. Final status report received. For additional information, contact A. Ayvazian, AVRADCOM, (617) 923-5233.

Project 7340, AVRADCOM. Composite Main Rotor Blade. Project is completed. The effort is continuing. Final status report received. For additional information, contact J. Tutka, AVRADCOM, (314) 263-1625.

Project 7371, AVRADCOM. Integrated Blade Inspection System (IBIS). Final software debugging is presently being accomplished in preparation for a scheduled end of contract briefing. Final status report received. For additional information, contact B. Park, AVRADCOM, (316) 263-1625.

Project 7199, AVRADCOM. Surface Hardening of Gears, Bearings and Seals by Lasers. The final report has been published and distributed. The project was terminated since there was no logical course of action within the funds available. Final status report received. For additional information, contact R. Mulliken, AVRADCOM, (804) 878-2771.

Project 7284, AVRADCOM. Superplastic Forming/Diffusion Bonding of Titanium. Final technical report being drafted by Hughes Helicopter Company. Final status report received. For additional information, contact A. Ayvazian, AVRADCOM, (617) 923-5233.

Project 7286, AVRADCOM. High Quality Superalloy Powder Products F/Turbine Components. This is a joint Air Force & Army multiyear effort. GE has completed Items 7 and 9 of the effort which was funded under this project. Final report is under preparation. For additional information, contact S. Isserow, AVRADCOM, (617) 923-5504.

Project 7286, AVRADCOM. High Quality Superalloy Powder Products F/Turbine Components. This project supported in-house engineering for prior year (1797286) joint service effort. The prior year effort has been completed. Final status report received. For additional information, contact S. Isserow, AVRADCOM, (617) 923-5504.

Project 7338, AVRADCOM. Composite Tail Section. Due to funding caused schedule slippages, this program has been terminated. A final report has been submitted. Final status report received. For additional information, contact J. Tutka, AVRADCOM, (314) 263-1625.

Project 7298, AVRADCOM. High Temperature Vacuum Carburizing. This project has been completed. The process specification for AISI 9310 has been completed. BMS-7-223 and AISI 9310 Steel Test Specimens are being produced for test and evaluation of the vacuum carburizing process. Final status report received. For additional information, contact P. Fopiano, AVRADCOM, (617) 923-5327.

Project 7300, AVRADCOM. Improved Low Cycle Fatigue Cast Rotors. A dynamic similarity evaluation of the subject rotor concluded that all requirements could be met with existing tooling. Final status report received. For additional information, contact J. Lane, AVRADCOM, (804) 878-2771/3977.

Project 3708, MERADCOM. Coated Fabric Collapsible Fuel Tank-Circular Seam Weaving. This effort established the feasibility of producing seamless fabric suitable for collapsible fuel tanks. Coating of this seamless fabric with compatible polymer yet to be realized. Manufacturing technology continuing. Final status report received. For additional information, contact C. Browne, MERADCOM, (703) 664-5781.

Project × 7382, AVRADCOM. Low Cost Composite Main Rotor Blade for the UH-60A. Contract awarded to Sikorsky, preliminary design refinement, manufacturing compatibility studies, selection of blade configuration, and specimen tool design and fabrication has been completed. Blade external configuration same as current blade. Final status report received. For additional information, contact N. Calapodas, AVRADCOM. (804) 878-5732.

Project 5071, TECOM. Toxic Gas Measurements During Weapon Firings. Testing has been conducted using a nonportable toxic gas measuring unit in conjunction with a wind machine. The data obtained will be reduced and analyzed during the next phase of this task. Final status report received. For additional information, contact N. Pentz, TECOM, (310) 278-2375.

Project 5071, TECOM. Dispersion Data for Automatic Weapons at Long Range. Using data gathered during a literature search on the M240 machine gun and the squad automatic weapon system, it was determined that the long range dispersion for automatic weapons could be predicted based on short range dispersion data. Final status report received. For additional information, contact N. Pentz, TECOM, (301) 278-2375.

Project 5071, TECOM. Improved Engine Wear Analysis. Separation of suspended metallic particles in oil by filtration and centrifuging were investigated. A procedure based on column chromatography has been procured. Final status report received. For additional information, contact N. Pentz, (301) 278-2375.

Project 8053, NLABS. CADCAM of Parachute Hardware. Operational Feasiblity of the CAD/CAM software was established. Restructuring of the APT program is necessary for the system to become usable. A final report is available. For additional information, contact Frank Civilikas, NLABS, (617) 651-4883.

Project 3592, MERADCOM. Improved Graphite Reinforcement—Phase 3. Contractor task is completed except for preparation of final report. In-house portion of work to evaluate fiber strands and composites has begun. Contract for final phase of project is being processed. For additional information, contact F. Harris, MERADCOM, (703) 664-5471.

Project 7055, AVRADCOM. Ultrasonic Welding of Helicopter Fuselage Structures. Project terminated. Results of coupon testing of weld bonded specimens unsatisfactory. Final status report received. For additional information, contact R. Rodgers, AVRADCOM, (804) 878-5732/ 5476.

Project 7339, AVRADCOM. Filament Wound Composite Flexbeam Tail Rotor. Work is continuing on Phase III under a revised scope of work necessitated by funding constraints. All work is completed except the final report, which is in process. For additional information, contact S. Weisenberg, AVRADCOM, (314) 263-1301.

Project 7197, AVRADCOM. Fabrication of Integral Rotors by Joining. Pilot production successfully completed. Fracture mechanics data generation complete. Machining of rotors for spin test and engine test complete. Final status report received. For additional information, contact J. Pratcher, AVRADCOM, (314) 263-1625.

Project 7342, AVRADCOM. Pultrusion of Honeycomb Sandwich Structures. All work is completed. The effort is to continue. Final status report received. For additional information, contact N. Tessier, AVRADCOM, (617) 923-5172.

Project 7091, AVRADCOM. Processing Aircraft Components Using Pultruded Materials. All work has been completed. The final report has been approved and has been printed and distributed. The pultrusion and post-forming technique was successfully shown. Implementation is anticipated on future ACAP helicopter designs. Final status report received. For additional information, contact N. Tessier, AVRADCOM, (617) 923-5172.

Project 7342, AVRADCOM. Pultrusion of Honeycomb Sandwich Panels. The effort is continuing. Final status report received. For additional information, contact N. Tessier, AVRADCOM, (617) 923-5172.

U.S. Army ManTech at Work

The Army's Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir, Va., has awarded a $4.82 million multiyear contract to a York, Pa. firm for the design and fabrication of a prototype heavy assault bridge. The experimental system, which will be built by Bowen-McLaughlin-York, will consist of a 100 foot span military load Class 70 bridge mounted on an M-1 tank chassis. The bridge will be designed utilizing composite materials for key components in order to reduce the system weight and reduce deflections.

Two New Systems Planned

A double-fold scissors design, the heavy assault bridge is one of two new bridging systems being developed by MERADCOM for the heavy and light divisions of the future. If the heavy assault bridge is ultimately accepted by the Army, it will replace the armored vehicle launched bridge currently in use.

Delivery of the prototype bridge is scheduled for March 1986. The command also recently awarded a four-year, $4.2 million contract to a Waltham, Mass. firm for prototypes for a 30 ton capacity light assault bridge. The technology for producing these bridge span systems was described in a feature article in U.S. Army ManTech Journal Vol. 7, No. 4, page 4.

MERADCOM is a major subordinate command of the U.S. Army Material Development and Readiness Command (DARCOM). The Fort Belvoir based organization employs more than 1200 military and civilian personnel who are involved in research, development, and initial acquisition in four areas that are critical to Army readiness: mobility/countermobility, survivability, energy, and logistics.