

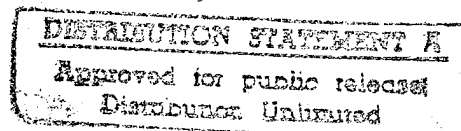
DE83011130
BDX-613-2906

Laser Cutting Plastics

By R. A. Van Cleave

Published April 1983

Final Report



19960321 071

DEPARTMENT OF DEFENSE
PLASTICS TECHNICAL EVALUATION CENTER
MILWAUKEE, WISCONSIN 53201

Prepared for the United States Department of Energy
Under Contract Number DE-AC04-76-DPO

DTIC QUALITY INSPECTED 1



Kansas City
Division

PLASTED 45687

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

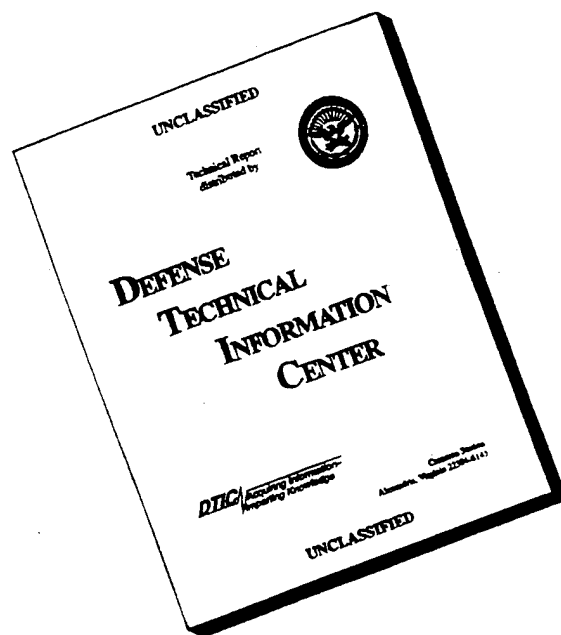
Printed in the United States of America

Available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Price: Microfiche \$4.50
 Paper Copy \$7.00

dtr9/d

DISCLAIMER NOTICE



**THIS DOCUMENT IS BEST
QUALITY AVAILABLE. THE
COPY FURNISHED TO DTIC
CONTAINED A SIGNIFICANT
NUMBER OF PAGES WHICH DO
NOT REPRODUCE LEGIBLY.**

BDX-613-2906
Distribution Category UC-38

LASER CUTTING PLASTICS

By R. A. Van Cleave

Published April 1983

Final Report
R. A. Van Cleave, Project Leader

Project Team:
D. S. Douglass
S. M. Marten
D. C. Powell

Technical Communications



**Kansas City
Division**

WE QUALITY ENGINEERED

LASER CUTTING PLASTICS

BDX-613-2906, Final Report, Published April 1983

Prepared by R. A. Van Cleave

Laser cutting and drilling various types of plastic and ceramic materials have been investigated. Nearly 100 different parts currently use laser technology as part of their production processes. A brief discussion of the 1000 W CO₂ laser development activities and typical production of parts is presented. The 1000 W CO₂ laser proved to be a reliable, practical, and cost-effective machine tool.

RGS:TR24/H

This report was prepared as an account of work sponsored by the United States Government. Neither the United States, nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

The Bendix Corporation
Kansas City Division
P. O. Box 1159
Kansas City, Missouri 64141

A prime contractor with the United States
Department of Energy under Contract Number
DE-AC04-76-DP00613

CONTENTS

Section	Page
SUMMARY.	9
DISCUSSION	11
SCOPE AND PURPOSE.	11
PRIOR WORK	11
ACTIVITY	11
<u>Material Cutting Results</u>	14
<u>Tooling and Cutting Techniques</u>	14
<u>Marking</u>	15
<u>Glass</u>	15
<u>Shape Cutting</u>	15
<u>Ceramic</u>	17
<u>Production Applications</u>	17
ACCOMPLISHMENTS.	22
REFERENCES	23

ILLUSTRATIONS

Figure		Page
1	Three-Axis CO ₂ Laser Cutting System (P104697).	12
2	Laser Work Station (P104689)	14
3	General Purpose Holding Fixture (P117636). . .	16
4	Typical Ceramic Substrate Manufactured With a CO ₂ Laser (P117642)	18
5	Ceramic Substrate Holding Fixture (P113320). .	19
6	Typical Shapes Laser Cut in Fiberglass Laminates (P117643).	20
7	High Strength Composites Cut With a CO ₂ Laser (P117644).	21

SUMMARY

The 1000 W CO₂ laser has been developed and was proven a reliable, practical, and cost-effective machine tool for processing plastic and ceramic products. The laser operations include cutting, drilling, marking, scribing, and insulation removal. Laser processing techniques and tooling concepts developed on this project allowed the fabrication of nearly 100 different product parts. A cost savings above one million dollars is estimated to result from laser processing.

DISCUSSION

SCOPE AND PURPOSE

The laser process produces a high quality edge at a high feedrate in Kevlar (a normally difficult material to machine). Because of this, it seemed reasonable to expect an equally high cutting performance in laminates reinforced with materials other than Kevlar. This project was initiated to develop production processes to support applications of a three-axis 1000 W CO₂ laser as a production machine tool. In addition to Kevlar-reinforced composites, applications that might use the laser's benefits were to be explored; processes and tooling concepts necessary to support the manufacture of these products were to be developed; and the reliability and control of the CO₂ laser as a cutting machine tool were to be established.

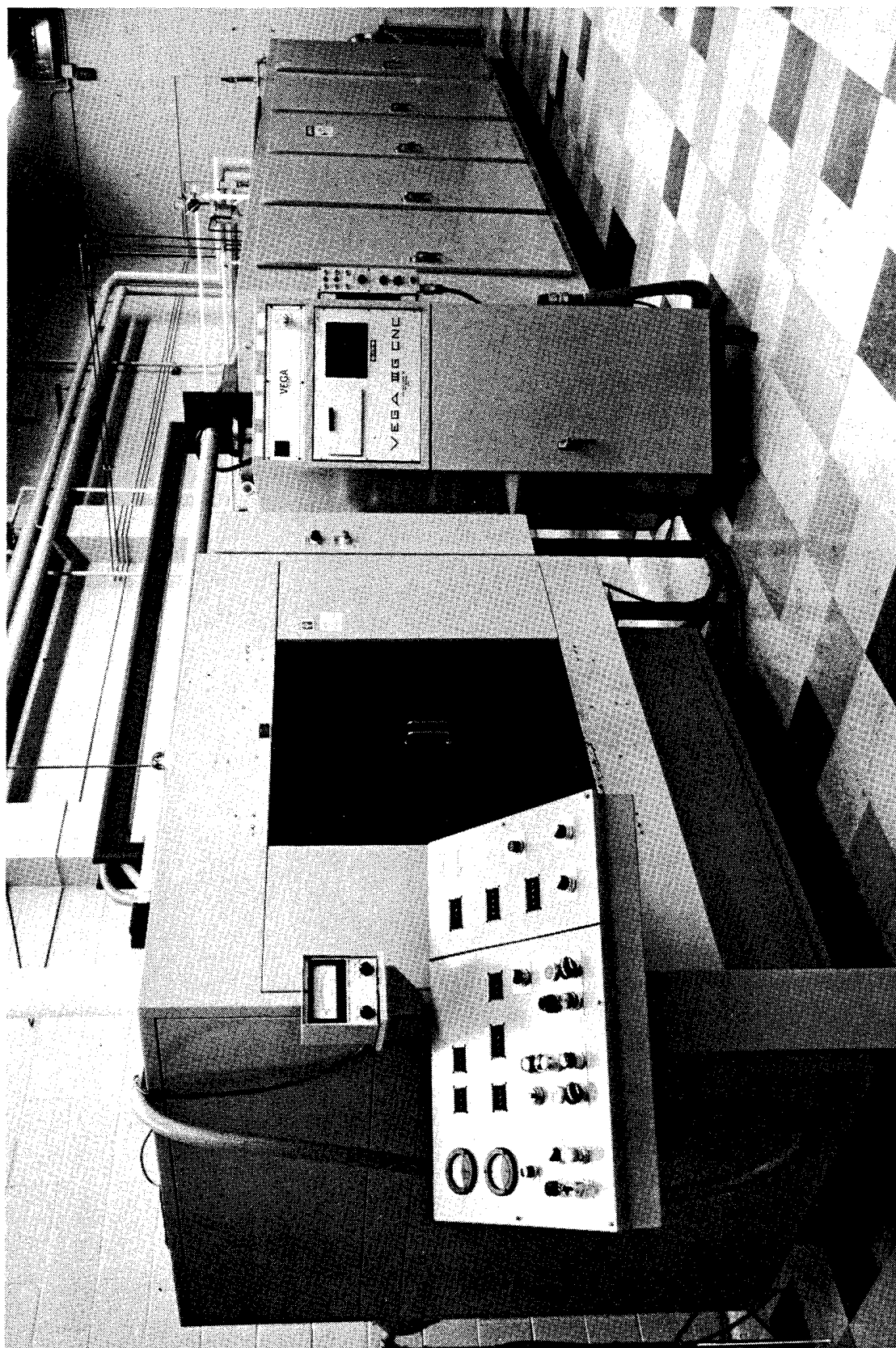
PRIOR WORK

Previous developmental work demonstrated the CO₂ laser to be the most efficient process for cutting Kevlar-reinforced epoxy laminates.^{1,2} Therefore, a three-axis 1000 W CO₂ laser had been procured to cut products fabricated from Kevlar. Application of this laser to cutting other types of plastics had not been developed.

ACTIVITY

Development activity for this project was performed on a 1000 W CO₂ laser (Figure 1), which includes a work station with three axes of motion (Figure 2). Because laser cutting applications for plastics other than Kevlar had not been considered in detail prior to this project, the technical approach was divided into three sections.

In the first section, various types of plastic materials were to be selected, the feasibility of cutting with the CO₂ laser was to be determined, and the resulting cutting characteristics were to be identified. The second phase was to determine what type of geometry or shapes were practical with the Bendix Kansas City three-axis laser system. The third section was to apply the experience gained from the material and geometry cutting phases to develop product-related processes. These three sections are summarized in the remainder of this report. A more detailed account of this work may be found in References 3 and 4.



a. FULL VIEW OF WORK STATION

Figure 1. Three-Axis CO₂ Laser Cutting System



b. CUTAWAY VIEW OF WORK STATION

Figure 1 Continued. Three-Axis CO₂ Laser Cutting System

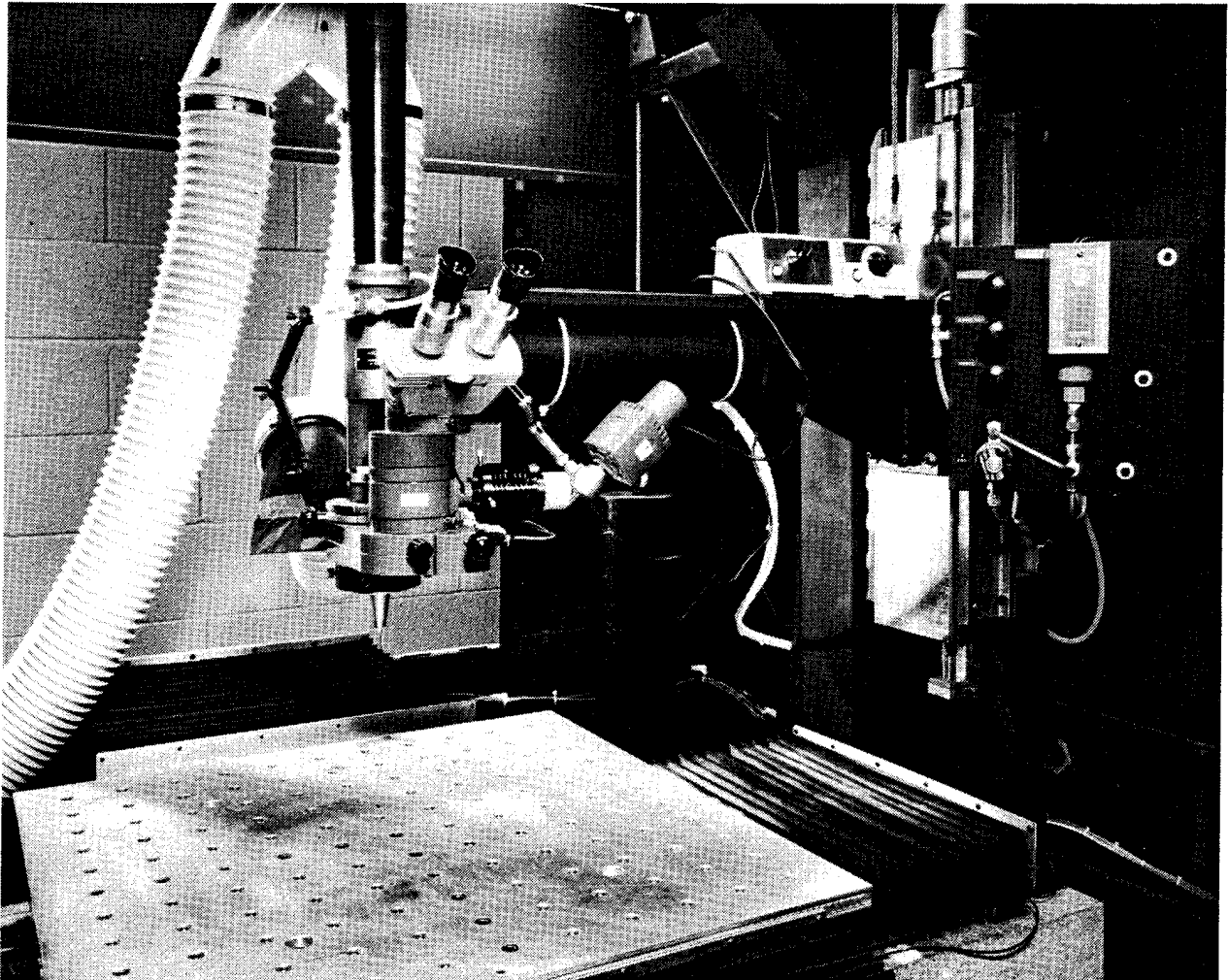


Figure 2. Laser Work Station

Material Cutting Results

Approximately 50 different types of thermoplastics, thermosets, reinforced thermosets, and reinforcing fabrics have been cut and their cutting characteristics identified. Most thermal set materials do not cut cleanly. A carbon char of burned material is left behind on the cut edge. This char can be surface cleaned with alcohol or completely removed with a glass-bead vapor-blast operation. The thermal plastic materials often cut cleanly without a char.

Tooling and Cutting Techniques

Aluminum holding fixtures usually are needed to process parts. These fixtures should provide a locating feature for the part and a 0.5-mm diameter hole placed relative to the locating feature to

permit positioning of the focal point of the beam in all three axes. The fixtures also should provide a means of collecting and exhausting fumes from the work station that are generated during laser cutting. Fixture setup is simple and often requires less than 15 min from one job to the next. A general purpose fixture (Figure 3) has been developed that permits the cutting of various shapes from flat sheet stock and from reinforcing fabrics without the use of additional special fixtures.

Process variables (or machine setup) that must be established for each process application include: power, feedrate, continuous wave or continuous pulse operation, length of pulse, number of pulses, nozzle orifice size, type of cover gas, and location of focal point. The change in any variable might improve or reduce cutting performance. Previous studies have established the relationship of some of these variables. An improved gas delivery system³ has been developed. It allows easy placement of the cover gas nozzle orifice to be coaxial with the laser beam. An improved beam locator also has been developed. It replaces the dovetail slide-type positioner originally supplied. The new locator eliminates the adjustment required for the dovetail slides and also minimizes the cover gas pressure loss through the slides.

Marking

Alpha and numeric characters are programmed on numerical control tape and can be incorporated to mark either a serial or part number on a product. The laser will produce a legible and permanent mark in both metals and plastics. The size of the character may be controlled to as small as 2 mm in height. The laser system computer executive software is not programmed to update for sequential serial numbers, but a Bendix-developed numerical control program has been developed to permit this type of sequencing.

Glass

A glass-to-glass laser seal was attempted with little success. Although the glass could be made to flow into a seal joint, cracking occurred within a matter of a few days. Another glass-working process has produced hole drilling capabilities in glass.

Shape Cutting

Thin-walled cones made from fiberglass and Kevlar epoxy were fabricated to demonstrate the capability of the three-axis system. Holes, triangles, and other irregular shapes were cut into the side of the cone to show the ability of the system to move the laser focal point (Z axis) simultaneously with the table X and Y axes at high feedrates (3000 mm/min).

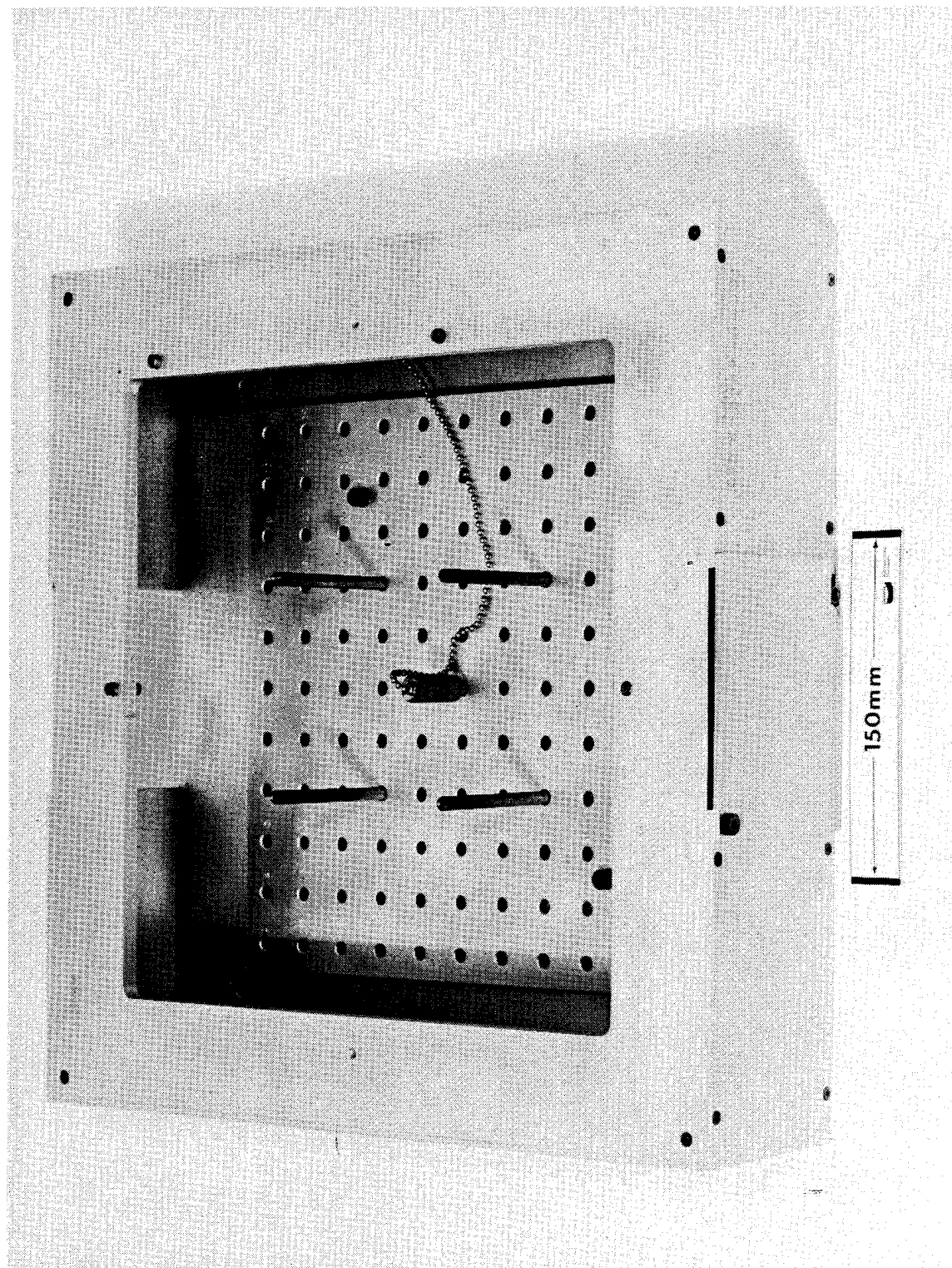


Figure 3. General Purpose Holding Fixture

Ceramic

The normally slow and expensive ultrasonic hole-drilling process for ceramic material has been replaced with laser drilling. Ceramic material now uses the laser's potential more than other materials. Instead of minutes, holes now are drilled in seconds (sometimes milliseconds) with no sacrifice in hole quality. The computer numerical control that controls the laser system allows for quick keyboard programming and changing of the hole patterns instead of the time-consuming Mylar tape method normally required for numerical control equipment. For customer redesigns, this capability reduces the turnaround time from weeks and months to hours and days, an advantage when numerous redesigns occur on a compressed schedule development project.

Techniques also have been developed to cut contours, to mark characters, and to scribe lines with a laser at high feedrates (3000 mm/min). Figure 4 shows an example of hole drilling, hole punching, character marking, and contour cutting in a 0.6-mm thick alumina substrate. The laser time required to process this example is approximately 5 min. Figure 5 shows the general purpose fixture that holds the standard size substrate from which the different patterns are processed. Detailed information regarding ceramic machining is available in Reference 5.

Production Applications

Descriptions of typical product types selected from the nearly 100 current products in production are listed below.

Reinforced Plastics

Several Kevlar- and fiberglass-reinforced epoxy laminate products are cut, marked, or drilled with the laser. Feedrates for cutting applications often are 3000 mm/min and thicknesses range from 0.2 to 4.0 mm. The laser has been most useful for cutting thin laminates whose profile is changed during development phases. A numerical control tape may be changed at a small expense instead of the costly rework of machining fixtures or steel rule dies. In addition to cutting, the laser can drill 0.2-mm diameter holes in fiberglass epoxy laminates in only milliseconds. Figures 6 and 7 show several reinforced plastics currently being laser produced.

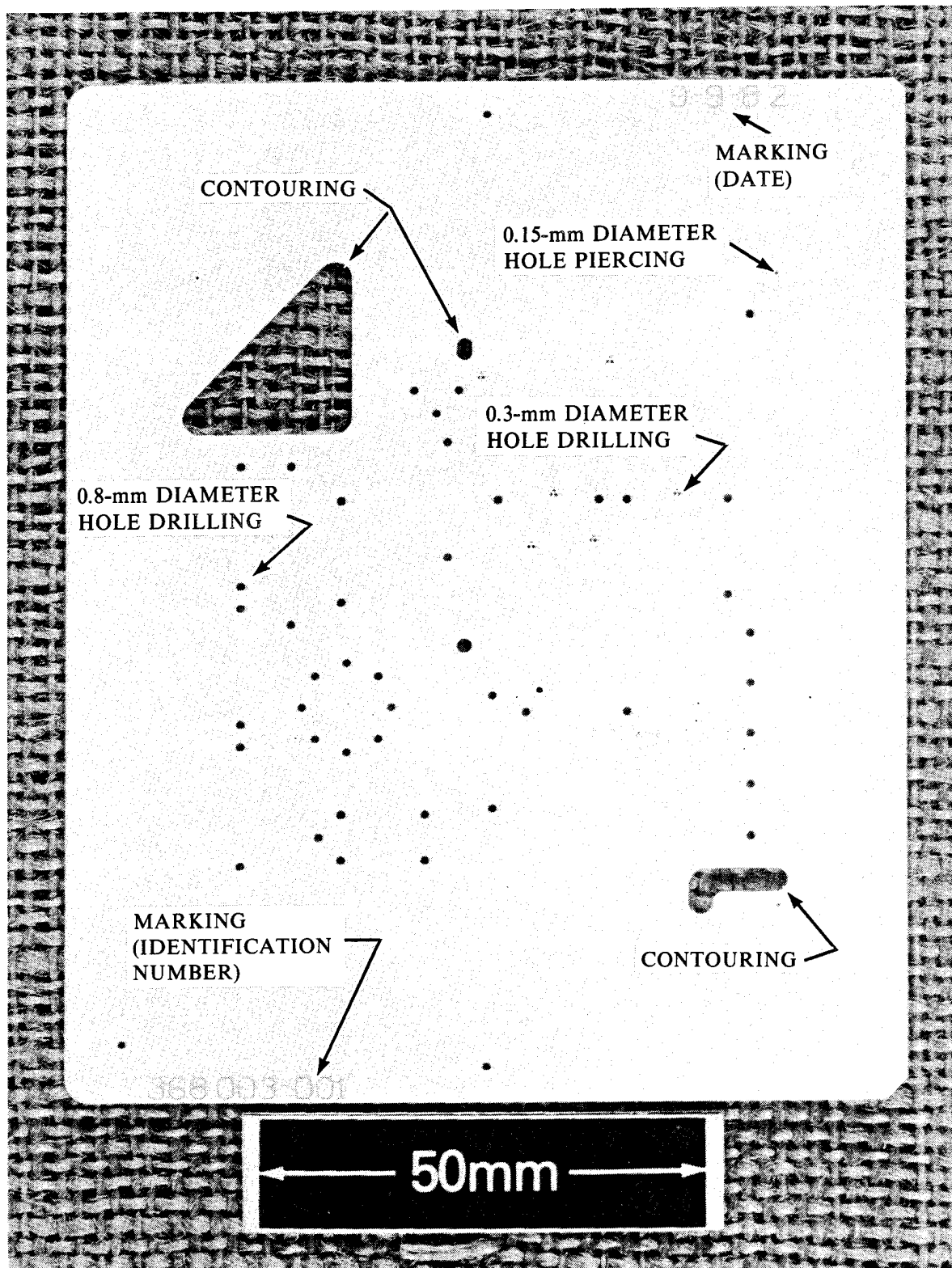


Figure 4. Typical Ceramic Substrate Manufactured With a CO₂ Laser

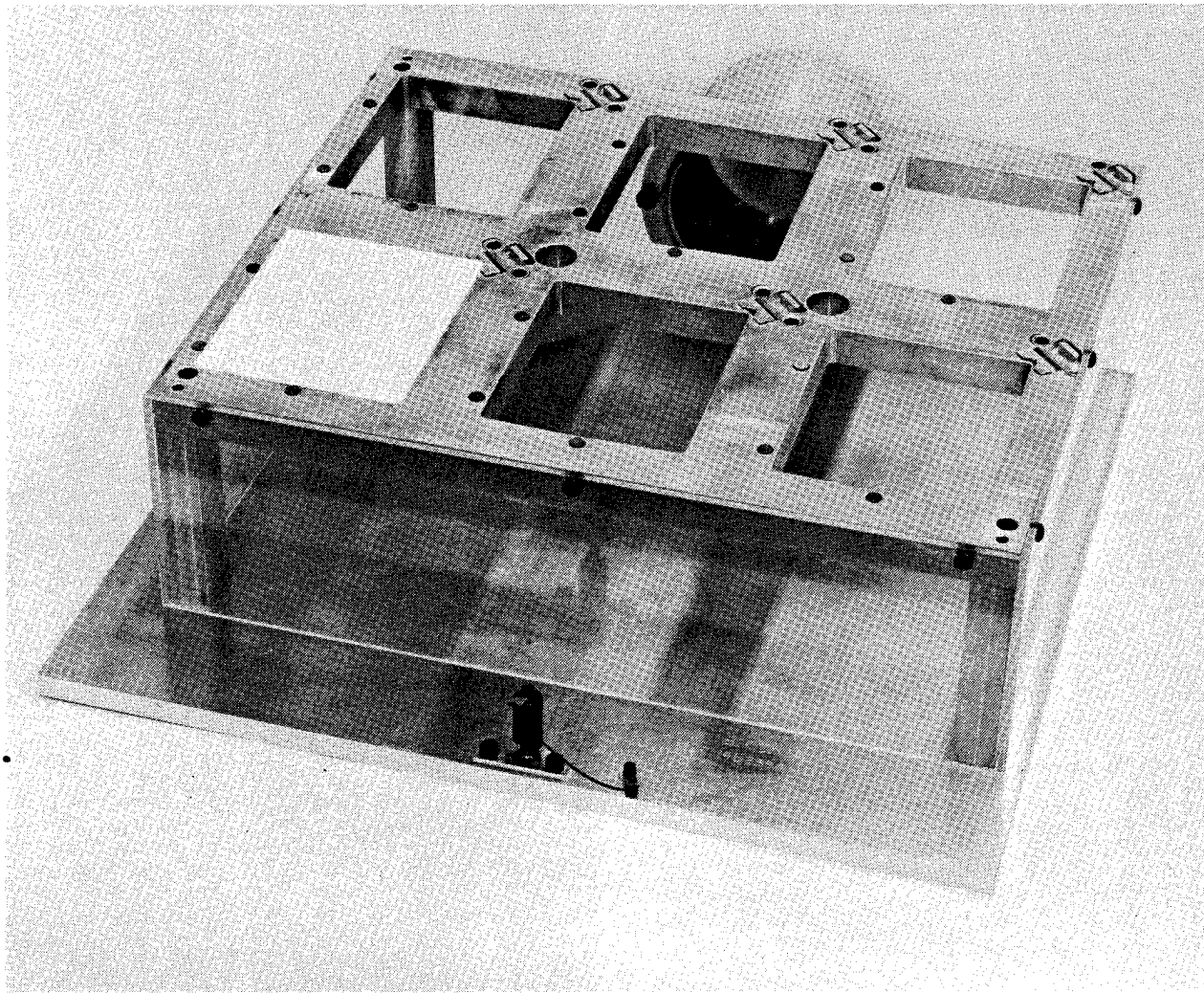


Figure 5. Ceramic Substrate Holding Fixture

Ceramics

Approximately 30 different patterns are drilled, cut, or marked with the laser. This number is estimated to exceed 100 during the next year. The laser process is so successful that future workload plans may require procurement of a laser to be used strictly for the processing of ceramic substrates. The various processes include: hole drilling, contour cutting, marking, and scribing.

Thermal Plastics

The number of thermal plastic laser-cut products is small because many products made from this material are injection molded to

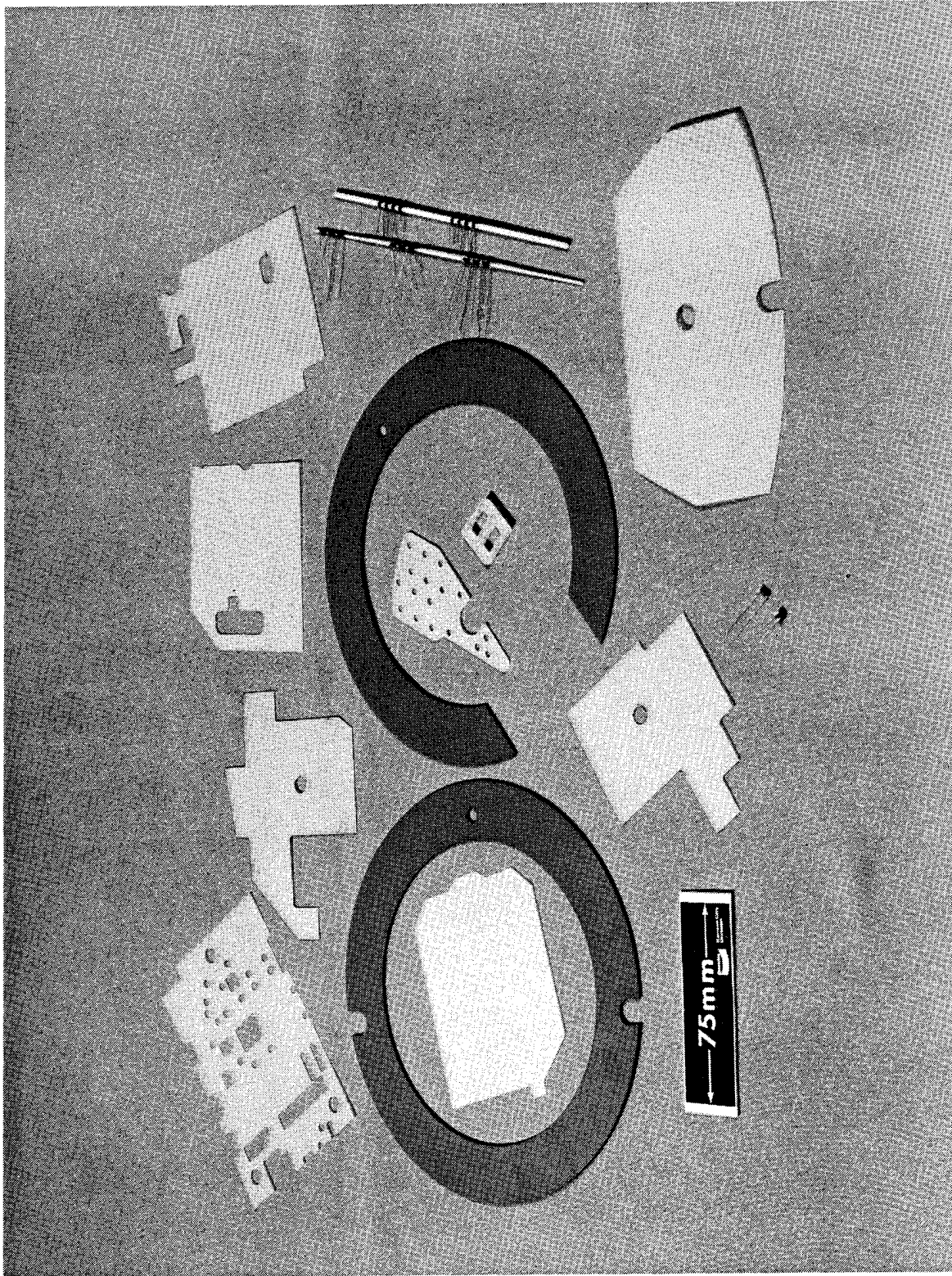


Figure 6. Typical Shapes Laser Cut in Fiberglass Laminates

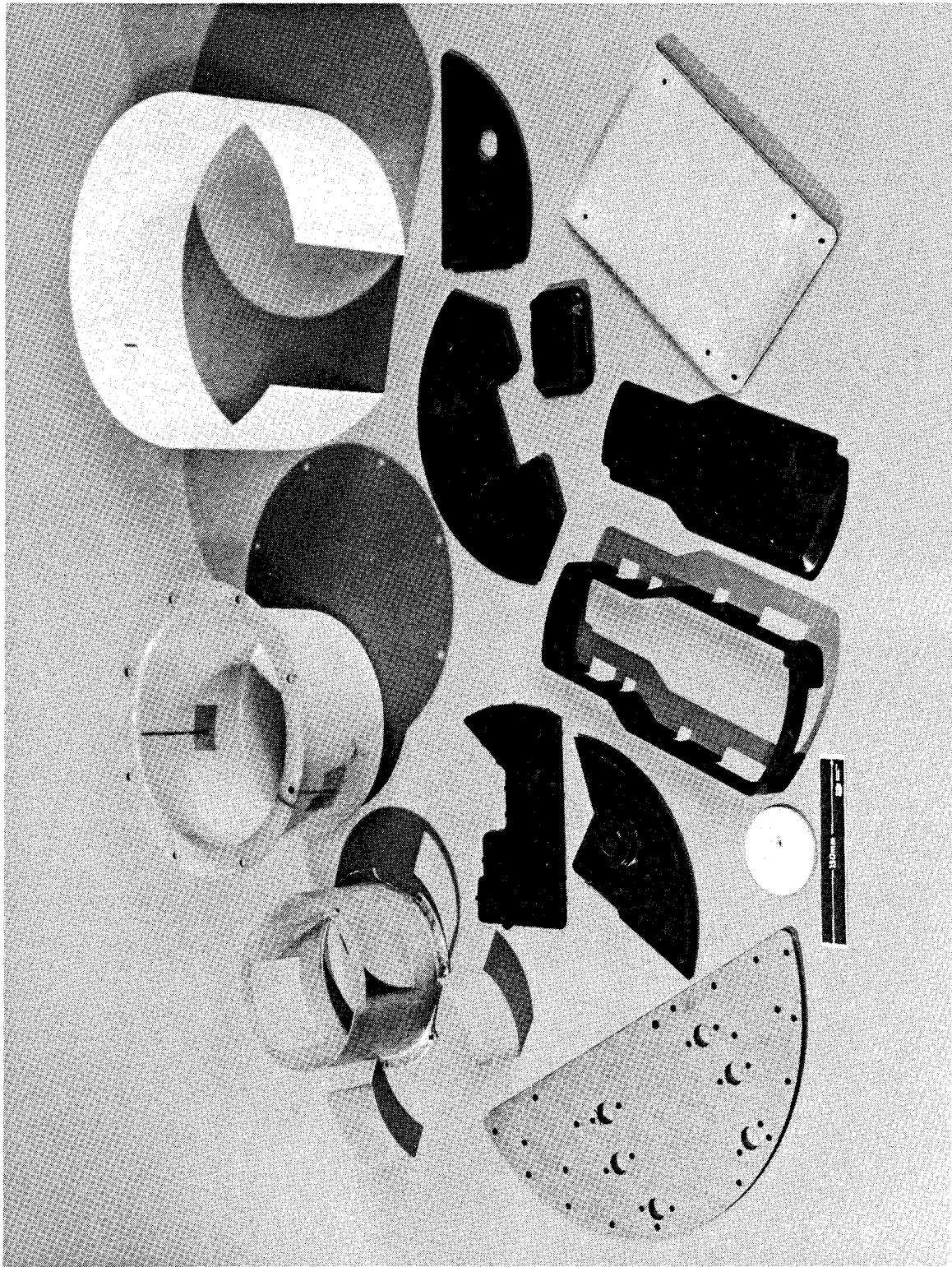


Figure 7. High Strength Composites Cut With a CO₂ Laser

finished size. Laser-cut production parts are made from either acrylic (plexiglass) or polycarbonate (Lexan). The acrylic cuts cleanly, resulting in a sharp, well-defined edge. The polycarbonate chars and discolors slightly.

Reinforcing Fabrics

Woven fabrics made from both Kevlar and fiberglass are laser cut in various shapes at feedrates of up to 3000 mm/min. The laser produces a heat-sealed edge in the fiberglass cloth preventing fraying or separation during handling and laminating. Because of Kevlar's toughness, the cloth is difficult to cut into complex shapes without the use of a laser. Excessive handling of the Kevlar cloth using techniques other than laser cutting results in distortion to the shape of the loosely woven 360° stretch fabric. Both the heat-sealed edge in the fiberglass cloth and the distortion-free shape cut in the Kevlar cloth make the laser an attractive process for cutting reinforcing fabrics.

Insulation Removal

A production process has been developed that removes insulation from magnet wire. The insulation is removed by passing the wire under the beam in incremental moves of 0.05 mm at a feedrate of 3000 mm/min. The laser is set at 200 W power and at a pulse rate of 1 mm on, 2 mm off to reduce the energy level. This operation is a backup for a 50 W CO₂ laser.

ACCOMPLISHMENTS

The three-axis 1000 W CO₂ laser has been established as a reliable, practical, and cost-effective machine tool. Tooling concepts, process variables, and cutting techniques have been identified and developed permitting the manufacture of products made from a variety of plastics and ceramics. Nearly 100 different parts use the laser's cutting and drilling capabilities as an operation of the production manufacturing process. More than 90 percent of these products are made from materials other than Kevlar. The cost savings realized as a result of the CO₂ laser processing is estimated to exceed one million dollars.

REFERENCES

- ¹R. A. Van Cleave, Characteristics of Laser Cutting Kevlar Laminates (Topical Report). Bendix Kansas City: BDX-613-2075 (Rev.), January 1979 (available from NTIS).
- ²R. A. Van Cleave, Laser Cutting of Kevlar Laminates (Topical Report). Bendix Kansas City: BDX-613-1877, September 1977 (available from NTIS).
- ³R. A. Van Cleave, Laser Cutting Plastic Materials (Topical Report). Bendix Kansas City: BDX-613-2476, August 1980 (available from NTIS).
- ⁴R. A. Van Cleave, Laser Cutting Shapes In Plastics (Topical Report). Bendix Kansas City: BDX-613-2727, December 1981 (available from NTIS).
- ⁵A. Laudel, Laser Machining of Ceramics (Topical Report). Bendix Kansas City: BDX-613-2507, January 1981 (available from NTIS).