GEORGIA INSTITUTE OF TECHNOLOGY | OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. G-41-658 (R5931-0A0) GTRC/~~XXX~~ DATE 4 /22 / 85

Project Director: Dr. Donald O'Shea School/~~Lab~~ Physics

Sponsor: United Merchants and Manufacturers, Inc.

Type Agreement: Research Project Agreement dated 4/1/85

Award Period: From 4/1/85 To 6/30/85 (Performance) 6/30/85 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$ 17,579	$ 17,579
Funded:	$ 17,579	$ 17,579 + $1,758 P & D Rights

Cost Sharing Amount: $ None Cost Sharing No: N/A

Title: Use of Laser Technology

ADMINISTRATIVE DATA OCA Contact Brian J. Lindberg X4820

1) Sponsor Technical Contact:

Raymond J. Rice, Director
Manufacturing Support
MIS
United Merchants
P. O. Box 2148
Greenville, SC 29602 (803) 233-4641

2) Sponsor Admin/Contractual Matters:

Same as 1)

Defense Priority Rating: N/A

Military Security Classification: N/A
(or) Company/Industrial Proprietary: See Below

RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT

COMMENTS:

Sponsor to pay $1,758 for patent and publication review rights
Advanced payment of $4,395 has been requested.
Non-Disclosure Agreement is in effect for five years of effective date.

RECEIVED JUN 1985 Research Reports Office

COPIES TO: SPONSOR'S I. D. NO. 02.220.000.85.002

Project Director	Procurement/EES Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	Reports Coordinator (OCA)	Project File
Accounting	Research Communications (2)	Other Jones

GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 8/19/85

Project No. G-41-658 (R5931-0A0)

School/~~Lab~~ Physics

Includes Subproject No.(s)

Project Director(s) Dr. Donald O'Shea

~~GTRI / GIT~~ GTRC

Sponsor United Merchants and Manufacturers, Inc.

Title Use of Laser Technology

Effective Completion Date: 6/30/85 (Performance) 6/30/85 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [x] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [x] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No.

Continued by Project No.

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services

Library
GTRI
Research Communications (2)
Project File
Other Heyser
Jones

Form OCA 60:1028

Georgia Institute of Technology
Atlanta, Georgia 30332

404-894-3992

College of Sciences and Liberal Studies
School of Physics

April 30, 1985

Mr. Raymond J. Rice
United Merchants and Manufacturers, Inc.
P. O. Box 2148, 108 Fredrick Street
Greenville, S. C. 29602

Dear Ray:

This is an informal letter report on our project for United Merchants. It is understood that this is the method of report which best suits the aims of the project.

As you know from your visit, the treatment of fabric with CO_2 laser beam requires considerably more controlled conditions than our preliminary experiments. The experiments carried out so far and their results are:

1) Microscopic examinations of fibers and filaments in crossed polarized light. Differences could be seen but additional work is needed to characterize them and see if the differences between treated and untreated filaments are sufficiently great that they could be used for quality control purposes.

2) Diffraction of low power laser radiation by treated and untreated fabrics. RESULTS: Variations in fabric weave and changes in fabric tension cause unreproducible results. Further investigations discontinued.

3) Irradiation of S/1080 greige fabric with a 0.7 to 6.0 watt CO_2 laser beam. RESULT: A) Longitudinal scanning along the warp and fabric transport direction showed modest results at low powers (1.4 w) and modest speeds (2.5 to 5 inches/min.) This is probably due to the fact that the beam was stationary and the cloth was moving so the surrounding material was heated. B) Transverse scanning (scanning perpendicularly to the warp and the fabric transport direction) yielded poor results. It was believed that the moving beam did not allow the cloth to reach a stable local temperature. C) In both cases it was possible to crystalize areas with too much power.

Mr. Raymond J. Rice
United Merchants and Manufacturers, Inc.
Greenville, S. C.

April 30, 1985

These experiments suggest new experiments which will be carried out during the next month. 1) A more reliable method of preparing a fabric transport will be used. 2) A constant tension bar will be introduced to provide the fabric with an unvarying backing for the treatment region. Both conducting and non-conducting surfaces will be tried. Variations of beam power, mirror prism rotation speed and prism-to-fabric distances will be explored. Some model calculations will be done with the purpose of trying to predict scale-up for the 600 watt level. Finally, an additional database search will be made to include the keyword, "drying".

Sincerely yours,

Donald C. O'Shea
Associate Professor of Physics
Coordinator, Applied Optics Program

DCO:ec

Georgia Institute of Technology
Atlanta, Georgia 30332

TECH

College of Sciences and Liberal Studies
School of Physics

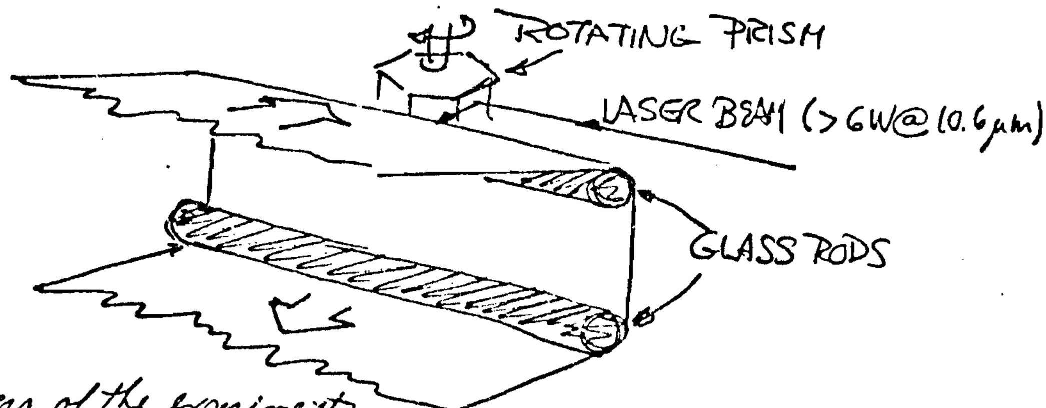
May 22, 1985

Raymond J. Rice
United Merchants
P.O. Box 2148
Greenville, SC 29602

Dear Ray:

In the interest of speed I have not handed this letter to the typist to decipher my handwriting. You will have to do that yourself.

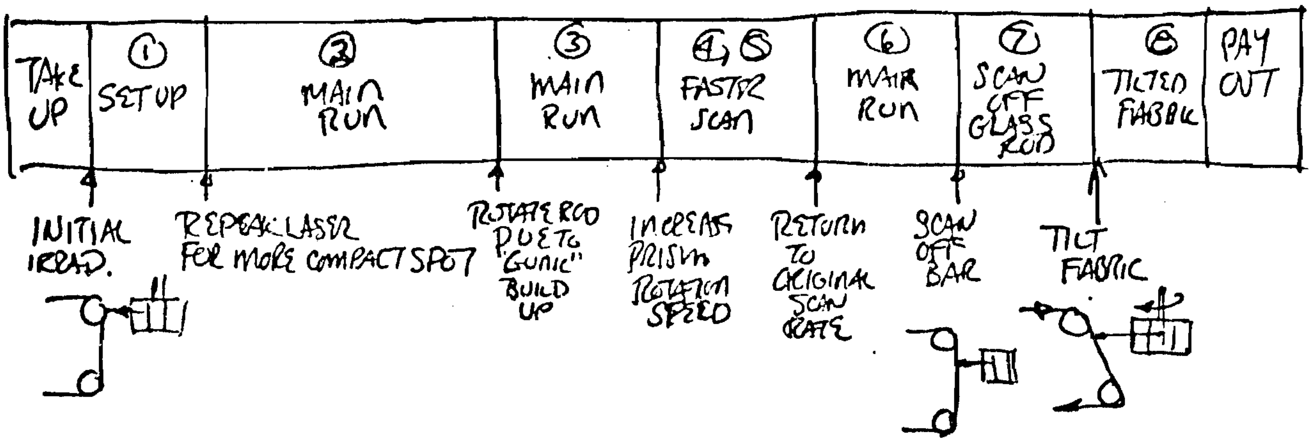
Enclosed is a run of 8/7080 greige fabric exposed to the laser beam under a number of conditions. The most consistent runs are Sections 2, 3 & 6. It is these sections that should be subjected to test. I think you will find that carmelization has taken place, but no cleaning. The geometrical set up is as follows



The parameters of the experiment:

Fabric velocity: 0.5"/min
Laser Power: $>6W$ @ $10.6\mu m$
Beam Diameter: ~2mm
Facet to Fabric Distance: ~25mm (varies during rotation)
Prism Rotation: 0.1 rotations/sec or 0.6 facets/sec
~~Fabric~~ Laser Spot is on fabric at a rod contact point in all cases except Sections 7 & 8.

The sections on the cloth are as follows



This series represents the maximum we can do with a 6 Watt scanned beam. I am looking into alternative CO_2 laser sources and to increasing the power of our current CO_2 laser. According to the gentleman in charge of that laser it is capable of powers of 30 to 50 Watts.

Please call me when your personnel has a chance to examine these radiated samples.

Sincerely yours,

Donald

Associate Professor of Physics

School of Physics
Georgia Institute of Technology
Atlanta, GA 30332
July 8, 1985

TO: Raymond J. Rice, United Merchants and Manufacturers
FROM: Donald C. O'Shea
SUBJECT: Laser Treatment of Fiberglass Fabrics

Recent work has involved increasing the scan velocity and the laser power available to provide a larger range of delivered energy over a wider range of scan speeds. Establishment of a compatible and safe scan geometry was also a concern in this work.

After the most recent samples were delivered to you, a search was made for higher power CO_2 lasers in the Atlanta area both on and off campus. When an attempt to use a system under the supervision of an outside consultant failed, a laser was located at the Textile Engineering Department of North Carolina State University. Despite its distance from the Georgia Tech campus this system proved to be ideal for the purpose of this study. In addition to a power range substantially beyond those previously available, the programmability of the laser head made the control of the experimental variables extremely easy.

On July 2 in the company of yourself and Rick Porter, a series of 18 scans of Stlye 1080 greige fabric at various power levels, scan velocities and scan spacings were made. Based upon evaluations of bidirectional raster scans with 0.3" scan separations, it was determined that a power-scan velocity ratio of about 1 Watt/m/min produced the best cleaning with the least amount of damage. Higher values showed increased damage; lower values showed incomplete cleaning. Some damage was noted in all three power-velocity choices (40W @ 40 m/min, 60W @ 60 m/min, amd 80W @ 80 m/min). Evaluations of scans at these values lead to the conclusion that the combination with the highest power and highest velocity did the least damage. A series of overlapping scans (0.09" separation) were made to provide sufficient sample area for tensile and material removal tests. These samples were delivered to you at the test site for further testing and characterization.

Because of the amount of damage in the latest test samples and the poor strength retention of the earlier samples, I do not recommend that any planning be started for a prototype system. I would suggest instead that further testing be carried out at the NC State facility be carried out with my assistance before August 9 and after that date with my consultation while I am at the Optical Science Center at the University of Arizona. I concur with your suggestion that after these latest samples are characterized that a meeting between you, Joel Murray, and me would be useful.

Georgia Institute of Technology
Atlanta, Georgia 30332

College of Sciences and Liberal Studies
School of Physics
August 5, 1985

MEMORANDUM

TO: Raymond J. Rice, United Merchants, Inc.
FROM: Donald C. O'Shea D.C.O'S
SUBJECT: Laser Project Final Report (G-41-658 (R5931-0A0))

During the past four monthS a series of experiments have been conducted to determine the feasibility of processing fabrics using laser radiation, particularly that of a carbon dioxide laser. This memorandum constitutes the final report on this research.

SUMMARY

- A survey of literature using the Textile Technology Database was quite fruitful in terms of the fraction of relevant items to the total number in the printout, but the total number of laser-related articles was small (less than 50 in 7 years). This indicates that either the industry is either very secretive or that little has been done up to now in the field of laser processing of fabrics. In either case, one must explore the possibilities of laser fabric treatment or run the risk of being left behind.
- Cleaning with a CO_2 laser at the powers and velocities available to us is not workable. There are indications that at lower velocities, higher powers, and lower irradiances there may be a regime that could be used for cleaning. The laser optics prevented us from exploring this region. If a simple optical component is purchased, additional tests of laser cleaning can be run.
- Based on some of the results from the cleaning experiments, it would appear that the singeing of fabrics is a viable application of laser technology to the textile processing. A possible design is presented in the body of this report
- Drying fabrics using lasers must be researched before it is possible to determine if there is any application of lasers to this part of the field. Tests may be done in conjunction with further laser-cleaning runs
- There is a need for research on physical modeling of the fabric treatments of both laser and non-laser based processes.

LATEST RESULTS

The limitations in power of the CO_2 laser at the Georgia Tech Research Institute required us to seek another source. A programmable laser fabric cutter at the Department of Textile Management and Technology at North Carolina State University was ideally suited to continue the set of experiments. A bidirectional raster pattern was programmed into the computer that controlled the cutting head. To reduce the irradiance of the beam the focusing lens, used to concentrate the CO_2 laser beam it a small spot, was defocused to provide a spot calculated to be about 1 millimeter in diameter (e^{-2} points). Twenty runs in all were conducted, varying the power of the laser, the velocity of the scan, and the scan pattern. The most meaningful parameter was the power per velocity since it is a measure of the energy deposited on the material. A number of power/velocity ratios were tried with both overlapping and non-overlapping rasters.

It was found that a power/velocity ratio in the vicinity of 1 Watt/m/min (0.6 J/cm) produced carmelization without visible damage. Increases or decreases of more than 30% produced substantial visible damage or no visible cleaning, respectively. This indicated that the "window" for cleaning, if it existed, was a small one. The laser-treated fabric was given to United Merchants staff for examination and tests including micrographs of the treated sections.

Examination of the micrographs of the exposed material at 40X and 100X indicated there was unacceptable damage at all levels, even those 50% below the carmelizing power/velocity value (1 W/m/min). However, except at the highest power/velocity value all of the damage occured in the filler fibers. The warp fibers suffered little or no damage. There were also some indications that at the lower velocity values, the damage seemed to be slightly reduced

Based on the micrographs it would appear reasonable to attribute the differences between the effects on the two fiber types to their ability to conduct heat away from the treated areas. In the case of the warp the tightly wound fiber under tension can conduct heat both along the filament and transversely from filament to filament with in a fiber bundle. This would also explain the slightly reduced damage in the filler fibers at the lower velocity runs in the constant power/velocity experiments. To extrapolate on this basis one is led to the conclusion that if laser cleaning is going to work it would do so at lower velocity scans so that the filler fibers can conduct heat away from the immediate area. However, this will be uneconomical unless the beam is diverged and the laser power is turned up so that large areas can be treated for the required period of time. **Conclusion:** A simple short focal length lens should be purchased and inserted in place of the focusing lens in the programmable laser fabric cutter to create a diverging beam. After another set of experiments it should be possible to determine if wider coverage, lower velocity scans will produce clean, undamaged fabrics.

While the laser-cleaning of fabrics would appear to be require more experimental work and substantial engineering to produe constant irradiance scans over large areas, the latest micrographs indicate that there is strong possibility that laser-singeing of fabrics has a good chance of success. One sees in the micrographs that isolated filaments in the filler tend to melt and, one would assume, crystallize. Thus, in the case of removing isolated filaments above the surface of the fabric, the complex scanning geometry of laser-cleaning gives way to an extremely simple design for laser-singeing. All that is required is a well-collimated laser beam (such as the one from any commercial CO_2 laser) set at grazing incidence to the fabric under treatment. As shown below geometries for treating both sides of a fabric simultaneously should not be hard to design. **Conclusion:** A series of simple proof of principle experiments should be devised. With appropriate modification the N. C. State laser fabric cutter could be used to determine the amount of power needed for singeing. Assuming the results are positive, a modest power (20-40 Watts) CO_2 laser could be leased or purchased to enable in-plant tests of the system.

In addition to cleaning and singeing there is also the possibility of using a CO_2 laser to dry fabrics. Although it will depend on the absorption coefficient of water and any trace materials, the difficulty with laser-drying is similar to that of laser cleaning, the need to cover the entire fabric surface until dry. Here, preliminary studies of present fabric liquids to determine the absorption at 10.6 μm (the CO_2 laser wavelength) are needed. **Conclusion:** Preliminary studies could be carried out in conjunction with the laser-cleaning studies using diverged laser beams. This would be done by placing wet fabric in the beam and determining the drying time as a function of beam irradiance and extent of damage due to laser exposure.

Finally, as an outsider brought in to observe your incredibly interesting industry, I was amazed at how much of the cleaning operations are done by guesswork. As a physicist I wonder (on paper) why there is no effort to characterize the operations. Modeling of the processes used and the variation of process variables should be done as a long-term modest level effort. There won't be any immediate payoffs, but in the long run the operations of processes can be planned and run more efficiently. **Conclusion:** A study of the basic physical processes in fabric treatment should be carried out with the object of producing realistic models of fabric treatment.

CONTRACT FULLFILLMENT

The questions raised by preliminary experiments and stated in the proposal to United Merchants were:

1. What is the exposure, the product of the laser beam irradiance (W/m^2) times the irradiance time, needed to clean the fabric? How complete is the cleaning? **Contract Action:** Exposure information was found and indicated that lower velocities, lower irradiances, and larger area coverage is needed for laser-cleaning. The results point ot laser-singeing as a potentially successful application of this technology.
2. Has the integrity of the fabric been reduced to an unacceptable level by exposure to the laser beam of sufficient irradiance to provide cleaning? **Contract Action:** The integrity of the fabric was, indeed, reduced by laser exposure at all power/velocity ratios.
3. How does one characterize the materials easily after exposure? Is there an alternate optical method to a tensile strength test that could help to determine the integrity of irradiated fibers? **Contract Action:** Polarization characterization experiments were carried out. The size of the individual filaments and the need for additional characterization of light transmission made it impossible to construct any definitive technique in the time available.
4. What kind of a system could be designed for in-line operation? **Contract Action:** The in-line operation system has been considered and some preliminary design for a singeing system will be presented in the final section.

5. What is a preliminary estimate of the cost of a prototype and production systems? Would the benefits outweigh the costs of construction and maintainence? **Contract Action:** A preliminary estimate on a singeing system would premature since the power of the laser is not known.
6. How reliable would such systems be in a mill environment? **Contract Action:** Reliability can only be made after some system operation parameters are more fully known.

RECOMMENDATIONS FOR FUTURE WORK

On the basis of the current work the following recommendations are made:

- The preliminary measurements for and design of a laser-singeing system should have first priority in any effort to complete the current investigations. It would be poor research policy not to capitalize on the knowledge gained so far. A schematic laser-singeing system is shown in Fig. 1. It consists of a CO_2 laser, a series of beam directing mirrors and a detector to monitor power. The specific geometry will depend on how close to the surface the isolated filaments must be cut off or melted down.

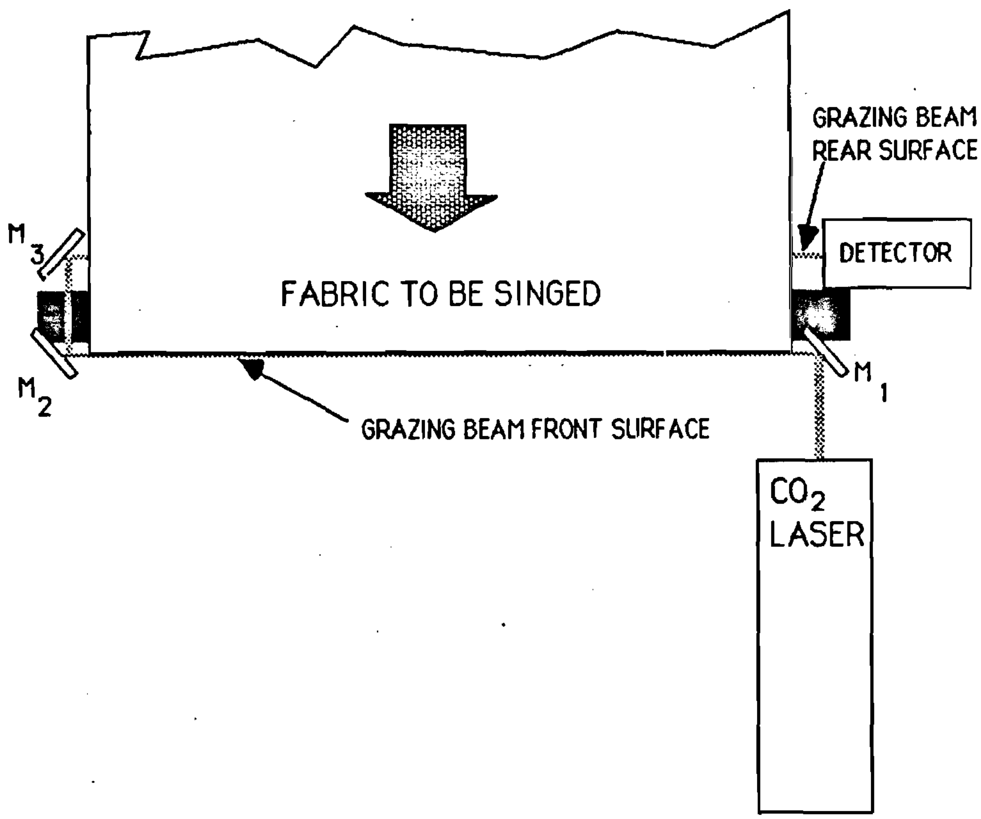


Figure 1. Schematic layout of a laser-singeing system.

- While the description of even the simplest fabric treatment process is quite complex, a study of the processes of singeing, drying, and cleaning should be started. The modeling of these operations through computer simulations should provide engineers and managers with a consistent picture to check against what, at times, are subjective judgements of the current state of a process. Physical modeling, for example, would begin with the absorption of heat by an uncoated ifber and its conduction of heat along and the fiber and across adjacent fibers.
- Work on drying fabrics can be done in tandem with additional work on laser-cleaning. Purchase of a short focal length negative lens to be inserted into the programmable laser cutter at N. C. State as noted in the conclusion on laser-cleaning stated earlier, would allow this part of of the work to proceed.