

PROJECT ADMINISTRATION DATA SHEET

☒

ORIGINAL

☐

REVISION NO. \_\_\_\_\_

Project No./(Center No.) E-16-616 R6258-OAO

GTRC/OTX

DATE 2 / 5 / 87

Project Director: Dr. E. W. Price

School/Dept AE

Sponsor: Office of Naval Research, Arlington, VA

Agreement No.: Grant No. N00014-87-G-0035

Award Period: From 10/1/86 To 9/30/87 (Performance) 11/30/87 Reports

Sponsor Amount: New With This Change Total to Date

Contract Value: \$ 135,000

Funded: \$ 135,000

Cost Sharing No./(Center No.) E-16-395/F6258-OAO Cost Sharing: \$ 45,000

Title: Instrumentation for a High Temperature Decomposition Facility

ADMINISTRATIVE DATA

OCA Contact E. Faith Gleason x. 4820

1) Sponsor Technical Contact:

2) Sponsor Issuing Office:

\* Dr. Richard S. Miller, Code 1132P  
Propulsion and Energetics Division  
Office of Naval Research  
800 N. Quincy Street  
Arlington, VA 22217-5000

Department of the Navy  
Office of Naval Research, Code 1513B:EBW  
800 N. Quincy Street  
Arlington, VA 22217-5000

Military Security Classification: Unclassified

ONR Resident Rep. is ACO; X Yes      No

(or) Company/Industrial Proprietary: \_\_\_\_\_

Defense Priority Rating: \_\_\_\_\_

RESTRICTIONS

See Attached \_\_\_\_\_ 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 Georgia Institute of Technology

COMMENTS:

Department of Defense University Research Instrumentation Program Grant

COPIES TO:

SPONSOR'S I.D. NO. 02.103.000.87.014

Project Director  
 Research Administrative Network  
 Research Property Management  
 Accounting

Procurement/GTRI Supply Services  
 Research Security Services  
 Contract Support Div. (OCA) (2) 74  
 Research Communications

103.025 GTRC  
 Library  
 Project File  
 Other \_\_\_\_\_

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEETDate 6/24/88Project No. E-16-616School/Lab AEIncludes Subproject No.(s) N/AProject Director(s) E. W. Price

GTRC/GIT

Sponsor Office of Naval Research, Arlington, VATitle Instrumentation for a High Temperature Decomposition FacilityEffective Completion Date: 9/30/87 (Performance) 11/30/87 (Reports)

## Grant/Contract Closeout Actions Remaining:

- ☐ None
- ☒ Final Invoice or Copy of Last Invoice Serving as Final
- ☒ Release and Assignment
- ☒ Final Report of Inventions and/or Subcontract:  
Patent and Subcontract Questionnaire  
sent to Project Director ☒
- ☒ 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  
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Research Security Services  
Reports Coordinator (OCA)  
Program Administration Division  
Contract Support Division

Facilities Management - ERB  
Library  
GTRC  
Project File  
Other \_\_\_\_\_



## REPORT DOCUMENTATION PAGE

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		TASK NO.	WORK UNIT NO.
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		Combustion, decomposition, energetic materials, propellants, experimental, laser pyrolysis.	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
<p>This report describes facilities capability developed with support from DOD equipment grants, including listing of equipment purchased under contract N00014-87-G-0035. The facility includes conventional thermal analysis equipment, a high heating rate CO<sub>2</sub> laser pyrolysis facility, high pressure combustion chambers, and supporting instrumentation to measure, record and play back relevant information about sample behavior during heating and/or combustion. Optical and electron microscopes are available for post-test sample analysis. Various equipment is available for preparation of small test samples.</p>			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL		22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL

INSTRUMENTATION FOR A HIGH TEMPERATURE  
DECOMPOSITION FACILITY

by

E. W. Price, R. K. Sigman and W. A. deGroot  
School of Aerospace Engineering  
Georgia Institute of Technology  
Atlanta, Georgia 30332

FINAL REPORT  
Contract N00014-87-G-0035

May 1988

for

OFFICE OF NAVAL RESEARCH  
800 North Quincy Street  
Arlington, VA 22217

## INTRODUCTION

The central objective of this project was to establish a facility for study of high temperature decomposition of ingredients of rocket propellants. Much of the equipment was for completion and instrumentation of a 1200 watt  $\text{CO}_2$  laser purchased on a previous DOD equipment grant. A large part of the present grant was used for laser beam delivery and conditioning optics, optical bench and fittings, laser control and data acquisition electronics, and for supporting measurement instrumentation for laser pyrolysis experiments (Fig. 1, 2). While the facility is still being assembled and tested, it has been "jury rigged" and in use for 18 months on a wide variety of experiments, including propellant ingredient pyrolysis, propellant ignition studies, rocket nozzle ablative char studies, and thermite ignition and combustion studies. In addition, roughly 50% of the grant was used for equipment supporting other propellant ingredient decomposition and propellant combustion experiments, and much of the laser support instrumentation is used also in other combustion experiments in the same facility. An underlying theme for the whole facility is the need to understand material decomposition and reactions at the elevated temperatures and heat fluxes actually present in combustion-propulsion systems, but in a controlled laboratory setting where relevant variables can be controlled, varied, and measured with modest test cost. Since high test sample temperatures can usually be reached only by very rapid heating (because samples heated at lower rates are "gone" before high temperatures are reached), equipment for high temperature tests must provide rapid heating, and measurements with high time resolution (surface heat fluxes of 50-500 calories per square centimeter per second, time response in the millisecond range). This facility achieves the required high heating rates by actual combustion experiments, and by  $\text{CO}_2$  laser heating. More conventional low heating rate tests are also used to provide a link between the high rate results and the by-now-large data sources in low rate decomposition.

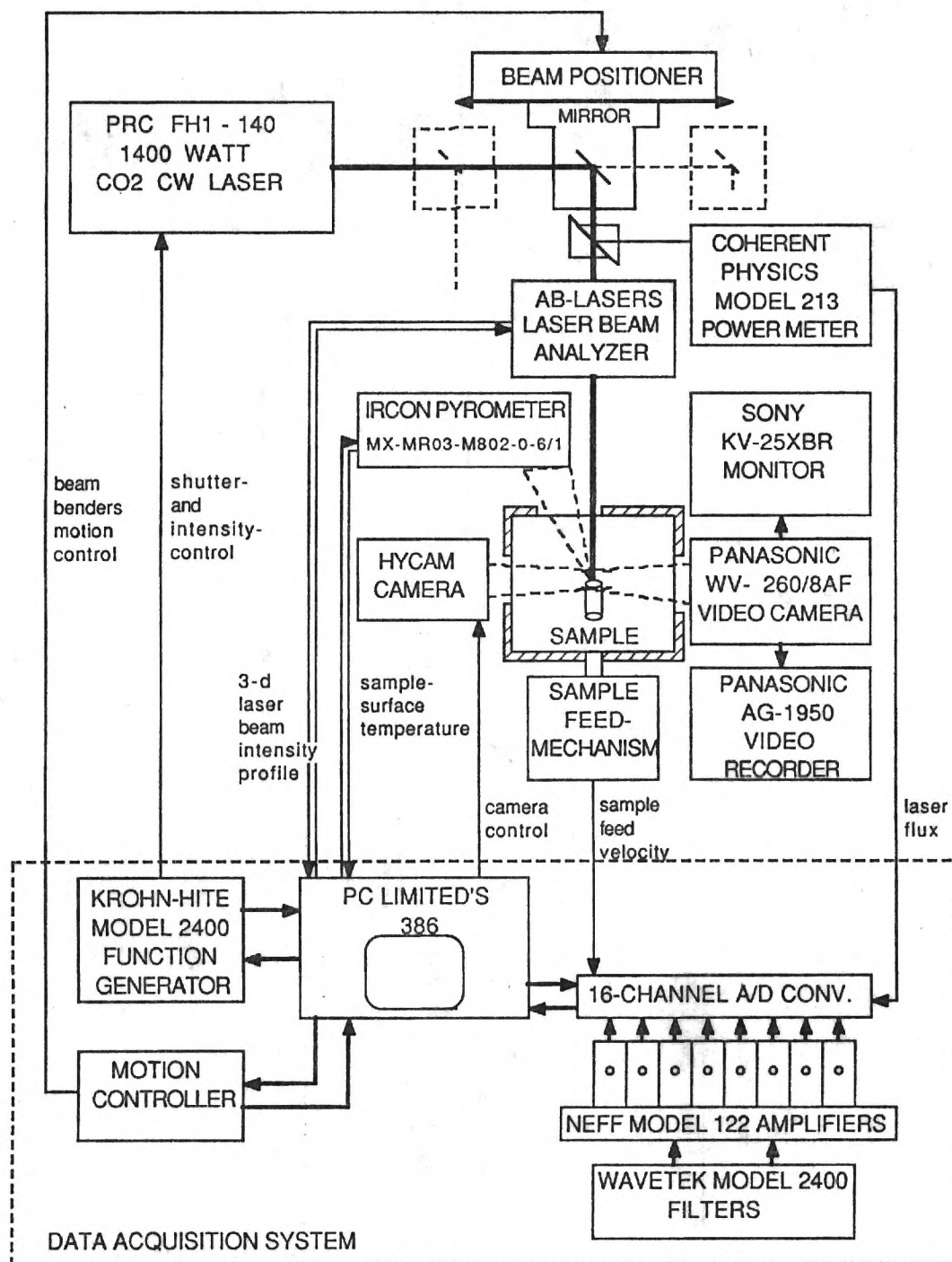


Fig. 1 Test equipment and data acquisition system for CO<sub>2</sub>-laser induced pyrolysis of polymeric material.

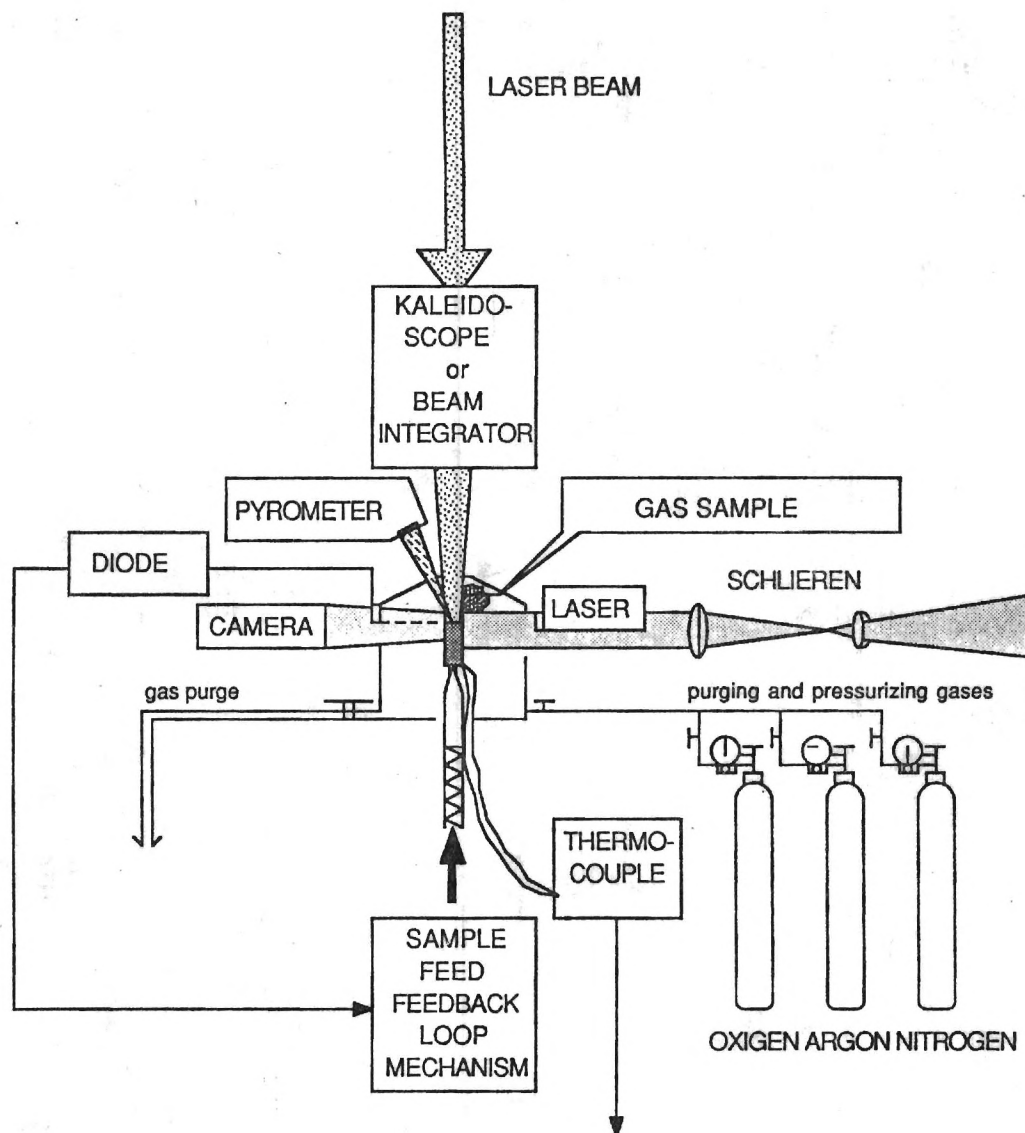


Fig. 2 Test vessel with diagnostics techniques for CO<sub>2</sub>-laser induced pyrolysis of polymeric material.

## GENERAL FACILITY CAPABILITY

The high temperature decomposition-combustion facility has the following permanent experimental installations:

1. 1200 watt continuous beam CO<sub>2</sub> infrared laser facility with beam delivery to support multiple experimental set-ups. Includes computer controlled beam intensity-time function from 1 millisecond to continuous, or periodic of prescribed wave form. Automated stop-start, instrumentation control, and data acquisition.
2. High pressure combustion bomb (0 to 2000 W.P.). N<sub>2</sub> flushed, equipped for illumination of test sample, and for high speed combustion photography by Hy Cam (500-6000 frames/sec), Lo Cam (100-1000 fps), and video camera photography (32 fps, 1/1000 sec "shutter"). Test samples are 0.5 x 1.0 cm (burning surface) x 1 to 2 cm long. Camera image is from 0.1 to 4.0 magnification.
3. High pressure quench bomb. N<sub>2</sub> pressurized, closed, similar operating range as (2), but equipped for rapid depressurization, which quenches burning of most materials. Samples are then analyzed by various methods, primarily high resolution scanning electron microscopy.
4. Optical and scanning electron microscopes. Used for characterization of particulate propellant ingredients, quenched samples and condensed combustion products. Also equipped with heating stages that permit real-time observation of sample behavior during moderate rate heating up to 1200° C.
5. Thermal analysis equipment. Conventional low-rate commercial instrument with TGA, DTA and DSL capability.
6. Diffusion flame gas burner. Built and equipped to study the leading edge of diffusion flames. Atmospheric pressure, coaxial-flow, porous plate burner and associated gas flow control equipment (built to help study the "primary" O-F flame in composite propellant combustion). Support instrumentation is combustion photography, Mach Zehnder interferometer now being added.



7. Various units for sample preparation including hydraulic press and dies, vacuum oven, particle grinder, particle size analyzer, dry glove box, propellant mixer, fume hood, precision weighing apparatus, sputter coater.

8. Various general purpose instruments such as digital storage oscilloscope. IBM and McIntosh PC with laser printer, 16 mm and video play-back facility.

GENERAL DESCRIPTION OF EQUIPMENT  
OBTAINED UNDER THIS GRANT

A detailed listing of equipment purchased and installed under this grant is attached. It is grouped in categories that can be related to the foregoing description of the High Temperature Decomposition and Combustion Laboratory, as follows (numbers on the right show total expenditures in each area):

- I. Items used in direct support of the CO<sub>2</sub> Laser Pyrolysis Facility, primarily for control of the laser operation cycle and associated instrumentation, optical components for delivery of an appropriately conditioned beam to the test bench, components for measuring the beam characteristics and test sample surface temperature, and a data acquisition system.

\$ 69,066.52

- II. Components for a Laser Pyrolysis Test Chamber and for sample preparation.

\$ 2,005.63

- III. Instruments used to conduct sample analysis in the present electron microscope (real time observation of decomposition, and post test characterization of test samples from other pyrolysis experiments).

\$ 9,815.84

- IV. Instruments used in several experiments in the lab, either in preparation of test samples, control of gas flows, measurement or photography of test samples and flame behavior during tests, and conversion of test data into graphics, video tapes, etc., for final presentation of test results.

\$ 54,100.40

## I. LASER PYROLYSIS FACILITY

### A. Laser Beam Homogenizer

13,391.67

#### 1. Optical Bench 3922.65

Oriel #10840 two meter tubular bench		505.00
Oriel #11621 universal carrier (4)	60.00	240.00
Oriel #16941 x-y translator (3)	530.00	1590.00
Oriel #10710 end plate		46.00
Oriel #19812 x-z vertical adapter (3)	30.00	90.00
Oriel #17271 vertical jack		515.00
Oriel #16221 five-inch drive (2)	444.00	888.00
<u>Freight</u>		48.65

Oriel Corp.  
250 Long Beach Blvd.  
Stratford, CT 06497  
203-377-8282

#### 2. Zs-Se Lenses 4335.84

2 1/2" focal length (1 PC, 1 meniscus) (2)	305.00	610.00
5" focal length (2 PC, 2 meniscus) (4)	930.00	3720.00
<u>Freight</u>		5.84

Two-Six Incorporated  
Saxonburg Boulevard  
Saxonburg, PA 16056  
412-352-1504

#### 3. SPAWR Integrating Mirrors 5021.50

SPAWR integrator SI-061	3900.00
1.5" molybdenum mirror	269.00
4" copper mirror (concave)	479.00
4" copper mirror (flat)	351.00
<u>Shipping</u>	22.50

SPAWR Optical Research  
P. O. Box 1899  
Corona, CA 91720  
714-735-0433

#### 4. Copper Kaleidoscope 111.68

Material copper, 1"x11.75"x7.75"

General Copper and Brass Co.  
414 MacDade Blvd.  
Collingdale, PA 19023  
215-586-1800

B. Beam Benders		4200.00
PRC #CI-900-900	(2)2100.00 4200.00	
PRC Corporation North Frontage Roac Landing, NJ 07850 201-347-0644		
C. Mirrors for Beam Benders		1760.00
PRC #900-820-00	(8) 220.00 1760.00	
PRC Corporation (See I-B above)		
D. Lens Housing		1856.15
PRC #CI-900-029		
PRC #BI-900-137-0	1830.00	
<u>Freight</u> (B,C,D)	26.15	
PRC Corporation (See I-B above)		
E. Beam Intensity Programmer		1757.51
Kron-Hite Model 2400 Function Generator		
Kron-Hite Corp. Avon Industrial 255 Bodwell St. Avon, MA 02322 617-580-1660		
F. Beam Intensity Profiler		8218.19
Laser Beam Analyzer Model LBA2A		
AB Laser 336 Baker Ave. Concord, MA 01742 617-371-2922		
G. Power Probe		190.16
0-1000 Watt Power Probe		
Lasercraft 3300 Coffey Lane Santa Rosa, CA 95401-1973 707-528-1060		



H. Pyrometer		13726.38
IRCON Maxline Model	13700.00	
MX-MR803-M802-0-6/1-0-0 with		
MX-XXXX-M802 sensing head and XAI		
lens		
<u>Shipping</u>	26.38	

IRCON Inc.  
P. O. Box 72176  
Chicago, IL 60678  
312-967-5151

I. Laser Controller and Data Acquisition System	17394.23
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1. PC Limited 386-16 computer	7438.80
1 Meg memory upgrade	

Dell Computer Corp.  
Dept. RB #0835  
P. O. Box 550  
Austin, TX 78789-0835  
512-338-4400

2. A-D, D-A converter		3626.02
Data Translations DT2821	2995.03	
DT-707 Screw Terminal Panel	179.00	
Atlab Software SP0143-CN	449.00	
<u>Freight</u>	2.99	

DATA Translations  
100 Locke Drive  
Marlboro, MA 01752  
617-481-3700

3. Laser Printer		2018.10
H.P. Laserjet II Printer &		
Memory Upgrade	1915.80	
Cable	31.00	
Toner Cartridge	71.30	

Hewlett Packard  
P. O. Box 105005  
Atlanta, GA 30348  
404-955-1500

4. Tape Backup System		867.10
Sysgen TS600E		

Hallmark Electronics  
11333 Pagemill Rd.  
Dallas, TX 75266  
214-343-5000

5. 80287-10 Math Coprocessor 289.10  
 Eczel  
 1252 Avenue T  
 Grand Prairie, TX 75050  
 214-641-2511
6. Metrabyte Interface Board 356.12  
 Metrabyte  
 440 Myles Standish Blvd.  
 Taunton, MA 02780  
 617-880-3000
7. Optima Desk and Rack MD286034 for  
 P.C. Limited, Filters, Amplifiers 824.09  
 Optima Enclosures  
 2166 Mountain Industrial Blvd.  
 Tucker, GA 30084  
 404-496-4000
8. Qualogy Card 275.00  
 P.C. Warehouse  
 2121 Newmarket Parkway, Suite 114  
 Marietta, GA 30067  
 404-953-0088
9. Amplifiers and Rack 1700.00  
 Neff 122-123 (2) 820.00 1640.00  
 Neff MC122 Connectors (3) 20.00 60.00  
 Neff Instrument Corp.  
 700 South Myrtle St.  
 Monrovia, CA 91016  
 818-357-2281
- L. Precision Rotatable Optical Mounts 3715.00  
 Newport 472-A 360 degree rotation  
 stage with large aperture (5) 743.00 3715.00  
 Newport Corp.  
 18235 Mt. Baldy Cir.  
 Fountain Valley, CA 06497  
 714-963-9811

P. Broadband Power Meter  
Coherent Lasers model 213  
power meter system

2857.23

2857.23

Coherent Lasers  
3210 Porter Dr.  
Palo Alto, CA 94304  
415-493-2111

SUBTOTAL \$69,066.52

## II. POLYMER PYROLYSIS EQUIPMENT

A. Pyrometer (Modifications to I-J)			855.00
Ircon Maxline lens XZ2 for MX	600.00		
Ircon Maxline lens XA2 for MX	255.00		

IRCON Inc.  
(See I-J)

F. Thermocouples			170.98
Unsheathed thermocouples	(4) 31.00	124.00	
Female connectors	(5) 4.00	20.00	
Ceramic insulator		25.00	
<u>Freight</u>		1.98	

Omega  
One Omega Drive  
Box 4047  
Stamford, CT 06907  
203-359-1660

G. Test Chamber Windows			403.00
Zinc Selenide Window, 6 mm thick, 1.5" dia, #10.6 P/N, WZ1.5-AR-2487		403.00	

Laser Power Optics  
12777 High Bluff Drive  
San Diego, CA 92130  
619-755-0700

H. Polymer Curing Oven			576.65
NAPCO #5831 Vacuum Oven		547.40	
Fisher 13-262-3 Door Gaskets	(3) 9.75	29.25	

Fisher Scientific  
2775 Pacific Drive  
P. O. Box 4829  
Norcross, GA 30091  
404-449-5050

<u>SUBTOTAL</u>	\$2,005.63
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### III. THERMAL DECOMPOSITION EQUIPMENT

B. Heating Substage for ISI		2910.36
Super 60 SEM	2900.00	
<u>Freight</u>	10.36	

Ernest F. Fullam, Inc.  
900 Albany-Shaker Rd.  
Latham, NY 12110

C. Robinson Probe for Chemical Distinction		6905.48
Robinson Backscattered Secondary		
Electron Probe for ISI-Super 60		
RBSE-4RT (260476)	6200.00	
Adapter from 4" to 3" stage	700.00	
<u>Freight</u>	5.48	

International Scientific Instruments, Inc.  
1457 McCarthy Blvd.  
Milpitas, CA 95035  
408-945-2233

<u>SUBTOTAL</u>	\$9,815.84
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#### IV. GENERAL LABORATORY EQUIPMENT

A. Controlled Atmosphere Glove Box		5882.42
Fiberglass cabinet & interchange,		
Box #16-103	3838.60	
Gas drier #16-103-5	494.19	
Mettler Balance EL210G	1456.35	
Gloves #92-050B	93.28	

Fisher Scientific  
(See Item II-H)

B. Rotary Evaporator		3755.30
Buchi Rotary Evaporator RE121A		
(Fisher #09-548-105F)	1700.00	
Buchi Vacuum Controller MDL-B161		
(Fisher #09-548-167)	1100.75	
Buchi Water Aspirator w/Valves		
(Fisher #09-548-168)	273.70	
Buchi Vacuum Pump Valve		
(Fisher #09-548-169)	119.85	
Buchi Vacuum Bottle Cooling		
(Fisher #09-548-170)	102.00	
Welsh Vacuum Pump		
(Fisher #01-103)	459.00	

Fisher Scientific  
(See Item II-H)

C. Motorized Press		5207.53
Carver #2089 Model M Press	1375.00	
Carver #2822 Motorization Package	2795.00	
Carver #2725 Safety Shields (2)	285.00	570.00
Carver #2472 T.C.O. Heating Jacket	310.00	
Carver #2169 Gauge Damper Kit	40.00	
Freight	192.53	
University Discount	(75.00)	

Fred S. Carver, Inc.  
W142 N9050 Fountain Blvd.  
Menomonee Falls, WI 53051  
414-255-2540

D. Pressure Detection (High Frequency Resp.)		2953.28
Kistler 601B1 High Freq.	(4) 370.50	1482.00
Kistler 5004 Amplifiers	(2) 693.50	1387.00
Kistler 1631A3 Cables	(4) 21.07	84.28

Kistler  
75 John Glenn Dr.  
Amherst, NY 14120  
716-691-5100

E. Signal Filters			10875.12
Wavetek 753A Low/High Bandpass	(2)	4550.00	9100.00
Wavetek Option 002 IEEE 488			
Interface	(2)	875.00	1750.00
<u>Shipping</u>			25.12

W. A. Brown Instruments  
6760 Jimmy Carter Blvd., Suite 110  
Norcross, GA 30071  
409-441-2980

G. KLLEF Burner			1966.97
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1. Pressure Gauges			282.23
Wika gauge	(5)	27.95	139.75
0-160 psi gauges	(5)	27.95	139.75
<u>Freight</u>			2.73

Flo Control  
P. O. Box 102732  
Atlanta, GA 30368  
404-875-8084

2. Pressure Regulators			1280.68
8-2-350 Regulator			247.00
8-2-346 Regulator			247.00
8H-350 Regulator			173.00
8H-346 Regulator			173.00
346 Cylinder Connector	(2)	12.00	24.00
508 Bench Cylinder Holders	(5)	31.00	155.00
Flowmeters	(2)	126.00	252.00
<u>Freight</u>			9.68

Matheson Gas Products  
P. O. Box 136  
Morrow, GA 30260  
404-961-7891

3. Flowmeters			221.66
Tefton Rotameter FL-30638A			219.00
<u>Freight</u>			2.66

Omega  
One Omega Drive  
Box 4047  
Stamford, CT 06907  
203-359-1660

4. Control Valves			182.40
Check Valves B-4C4-1/3	(5) 11.50	57.50	
Valves B-4MG2	(5) 24.70	123.50	
<u>Freight</u>		1.40	

Georgia Valve & Fitting Co.  
3361 West Hospital Ave.  
Atlanta, GA 30341

H. Graphics Design System 7004.16

1. Apple Graphics System			6864.00
Mac Plus		1425.00	
Laserwriter Plus		4095.00	
20 MB Hard Disk SCSI		995.00	
Appletalk Connector Kit		35.00	
System Connector Kit		35.00	
SCSI Cable		35.00	
Terminator		21.00	
Mac Draw		119.00	
Mac Paint		79.00	
<u>Freight</u>		25.00	

Georgia Tech Bookstore  
350 Ferst Drive, N.W.  
Atlanta, GA 30332  
404-894-2377

2. Lights			140.20
Besco lamp	(4) 26.96	107.84	
Paper files		32.36	

Besco  
1080 Brady Ave.  
Atlanta, GA 30318  
404-875-7711

I. Ammonium Perchlorate Cutter			2550.75
Isomet Low Speed Saw BL11-1180-160		2185.00	
Diamond Blade Wafer BL11-4253		128.25	
Diamond Blade Wafer BL11-4243		128.25	
Chuck BL11-1185		30.40	
Chuck BL11-1186		19.00	
Chuck BL11-1194		59.85	

VWR Scientific  
1230 Kennestone Cir.  
Marietta, GA 30066  
404-423-1354



J. Ammonium Perchlorate Die Finisher		2165.53
Buehler Ecomet III Polisher/Grinder	1828.75	
Carbimet disks Pk-100 320 grit	104.50	
Carbimet disks Pk-100 400 grit	104.50	
Carbimet disks Pk-100 600 grit	104.50	
Microcloth Pk-10	23.28	
VWR Scientific (See Item IV-I)		
K. Video Camera System		4038.00
1. Camera System		1985.00
Panasonic Camera WV-3260	1190.00	
Panasonic Titler WVKB-12	150.00	
Panasonic Slide Adapter WVAD-15	180.00	
Panasonic Power Supply WV-3203	65.00	
Lens Adapter (Nikon) WV-AD-16	20.00	
Remote Controller WV-CR-12	380.00	
Showcase 2323 Cheshire Bridge Rd. Atlanta, GA 30324 404-325-7676		
2. Recorder-Video		1077.00
Panasonic AG1950	1077.00	
Showcase (See Item IV-K-1)		
3. Monitor		976.00
Sony KV-25XBR	976.00	
Capitol TV 2975 North Druid Hills Rd., N.E. Atlanta, GA 30329 404-321-3060		
L. Security Cabinet for Item IV-K		468.30
Bretford TV Cabinet VTRC50E	468.30	
The Stevens Co., Inc. 3427 Oakcliff Rd., N.E. Atlanta, GA 30340 404-455-4640		

## M. Camera Mount and Positioner

3513.09

## 1. Panasonic WVP10 Pan Tilt Head

505.00

Wolf Camera & Video  
 150 14th St., N.W.  
 Atlanta, GA 30318  
 404-892-1707

## 2. Precision Rails and Translators

3008.09

Oriel 12 inch Table Rail #11482	104.00
Oriel 24 inch Table Rail #11512	165.00
Oriel Precision Translator #16326	(2)812.00 1624.00
Oriel Clamping Carrier	(2)133.00 266.00
Oriel Vertical Jack-Large	806.00 806.00
<u>Freight</u>	43.09

Oriel Corporation  
 250 Long Beach Blvd.  
 Stratford, CT 06497

## N. Video to Still Image Transfer System

2245.00

Polaroid Freeze Frame Video Image Recorder	1895.00
35mm Slide Back	350.00

Showcase  
 (See Item IV-K-1)

## O. Video Editing System

1475.00

Panasonic AG-1950 Editing VTR with jog dial, 21 step shuttle ring and rotary erase head	1150.00
Panasonic AG-A95 Editing Controller	325.00

Showcase  
 (See Item IV-K-1)

SUBTOTAL	54,100.40
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TOTAL	<u>\$134,988.39</u>
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(prcpt.616)