SAND76-0413
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DESIGN DEFINITION AND FABRICATION

Sandia Laboratories Technical Capabilities

Design Definition and Fabrication

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87115
and Livermore, California 94550 for the United States Energy Research
and Development Administration under Contract AT (29-1)-789

Supersedes SAND74-0084

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Printed in the United States of America

Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy $4.50; Microfiche $2.25

SAND76-0413
Unlimited Release
Printed December 1976

Supersedes SAND74-0084

SANDIA LABORATORIES TECHNICAL CAPABILITIES

DESIGN DEFINITION AND FABRICATION

ABSTRACT

This report characterizes the design definition and fabrication capabilities at Sandia Laboratories. Selected applications of these capabilities are presented to illustrate the extent to which they can be applied in research and development programs.

FOREWORD

Sandia Laboratories, a multiprogram laboratory of the Energy Research and Development Administration (ERDA), is located in Albuquerque, New Mexico, and Livermore, California, with a remote testing facility at Tonopah, Nevada. In fulfilling its responsibilities to ERDA in the fields of national security, energy, and other programs, Sandia has acquired extensive capabilities in research, development, testing, and evaluation, and has made numerous contributions in scientific and engineering fields. These technical capabilities are integrated by management for the definition and solution of scientific and engineering problems.

A series of reports has been written describing these capabilities and showing typical applications. The reader will find the capabilities summarized in a separate paper, or may choose any of the 17 separate reports, or, if he wishes a compendium, can find all the reports and the summary compiled in a single publication. Identifying numbers for the entire series are given below.

C. Donald Lundergan, Technical Editor
P. L. Mead, Publication Editor

TECHNICAL CAPABILITIES OF SANDIA LABORATORIES

Summary
(SAND74-0091)

Aerosciences	SAND74-0075	**Instrumentation and Data Systems**	SAND74-0083
Applied Mathematics	SAND74-0079	**Materials and Processes**	SAND74-0073A
Biosciences	SAND74-0076	**Measurement Standards**	SAND74-0077
Computation Systems	SAND74-0080	**Physical Sciences**	SAND74-0074
Design Definition and Fabrication	SAND76-0413	**Safety and Reliability Assurance**	SAND74-0090
Earth Sciences	SAND74-0085	**Systems Analysis**	SAND74-0089
Electronics	SAND74-0086	**Testing**	SAND74-0088
Engineering Analysis	SAND74-0087	**Auxiliary Capabilities**	SAND74-0082
Explosives, Electrochemistry, and Electromechanisms	SAND74-0081	**Environmental Health**	
		Information Sciences	

Compilation of
Sandia Laboratories Technical Capabilities
(SAND74-0092)

DESIGN DEFINITION AND FABRICATION*

Research and development programs, as well as follow-on production programs at contractor's plants, are supported by design definition activities such as preparing and maintaining drawings and specifications, developing and applying computer-aided design and definition systems, and developing and applying engineering information control systems.

Fabrication facilities provide comprehensive processing capabilities. Processes are developed and hardware fabricated to provide experimental vehicles and models required by engineering and scientific organizations. Complementing the fabrication and development facilities are inspection, equipment repair, and process engineering services, as well as fabrication services which interact with Sandia's Primary Standards Laboratory.

Design Definition and Fabrication
Technical Staff and Investment in Equipment

	Professional Staff	Skilled Staff	Investment in Equipment (in $1000)
Design Drawings and Specifications	43	236	3200
Computer-Aided Design and Definition	11	26	
Information Control Systems	24	3	
Metal Processing	13	201	8226
Glass and Ceramic Processing	6	28	1228
Composites and Plastic Processing	10	25	1110
Electrical Component Processing and Fabrication	6	32	3931
Heat Treating and Finishing Processes	2	10	732

*Compiled in September 1976.

DESIGN DEFINITION

Graphic drawings and written specifications are provided for electrical and mechanical components and systems, equipment, and structures. Advanced methods are developed for applying computers to design and definition of complex components in fields such as microelectronics. Internal and contractor engineering documentation, communication, and control systems are developed and coordinated. Increasing amounts of design definition and status information are maintained in cost-effective computer and microfilm files.

Design Drawing and Specifications

Design concepts provided by the engineering and research staff are translated into finished graphic and written form. Special equipment used to test and evaluate components and systems is designed, and material, fabrication, and test specifications are generated. (Item 1)*

Current Activities

- Drafting
- Specification writing
- Design coordination
- Calculations (including computerized programs)
- Implementation of metric system in designs
- Creation of drawings by photographic processes
- Preferred parts coordination

Computer-Aided Design and Definition

Facilities, procedures, and computer programs are developed to improve the efficiency of producing designs and to assure their accuracy through computer-aided design, process definition, and manufacturing techniques. (Item 2)*

Current Activities

- Interactive digitizing
- Interactive network investigation
- Interactive graphics
- Direct numerical control
- Word processing

Information Control Systems

Systems, procedures, and standards are developed for preparation of drawings and specifications, implementation of product changes, and identification of product. Current and historical records of drawings and design changes are maintained. Microfilm facilities permit space-efficient retention and distribution of drawings and specifications. Interactive computer systems are developed to provide fast and accurate information handling and record-keeping. (Items 3 and 4)*

Current Activities

- Development and application of computerized engineering communication systems
- Development and application of computerized drawing and record-keeping systems
- Unitized aperture card microfilming
- Design information management and processing
- Establishment of product test-data record requirements and record of assembly requirements
- Design information consultation and cataloging
- Coordination of technology utilization

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*See Highlights below.

* * * * * * *HIGHLIGHTS* * * * * * *

Item 1. *Determination of Inertial Properties of a Design*

Interactive digitizing equipment (Figure 1) is available for the analyst wishing to obtain weight, center of gravity, and moment of inertia of a design rapidly and accurately. The designer can digitize his drawing and determine the properties in minutes. The geometric data and material properties form a base that is processed through two computer programs for calculation of inertial properties.

Program DIGITIZ computes the properties of interest for solids of revolution and objects with constant cross sections. The geometry can be bounded by straight lines and circular, elliptic, or parabolic arcs. The program can determine the resultant properties of any collection of items, up to a maximum of 98 items. DIGITIZ has a maximum capacity of 400 points.

The CLAMP program computes the weight, center of gravity, and moments of inertia for solids of revolution and has a summing capability that can include point-mass items. It can store the properties of 30 items and 1000 points at any given time. The geometry can consist of straight lines and circles.

Item 2. *CADDAMS*

The Computer Aided Design, Definition, and Manufacturing System (Figure 2) is an evolving integrated system that permits the input of creative thought at the design stage, after which the encoded information is computer-processed via a unified data-base system to provide for the needs of design, analysis, definition, and manufacture. The activity consists of three basic subsystems and their interrelationships:

1. Design input systems.
2. Major computer (common data bases).
3. Processing systems (graphic definition, manufacture, and engineering release).

All subsystems are computer-augmented and are in communication with each other via major computers.

Item 3. *Interagency Communication*

A close operating relationship is maintained with ERDA agencies responsible for production. Engineering information, changes, and computerized drawings are rapidly exchanged through a computer-controlled network that operates between Sandia and the production agencies. For example, Material List drawings are maintained in a computer file, updated daily, and transmitted overnight to production agencies, whose computer files are automatically updated. Appropriately revised official drawings are printed out the next day. As information is transmitted, related computer files at Sandia are automatically updated.

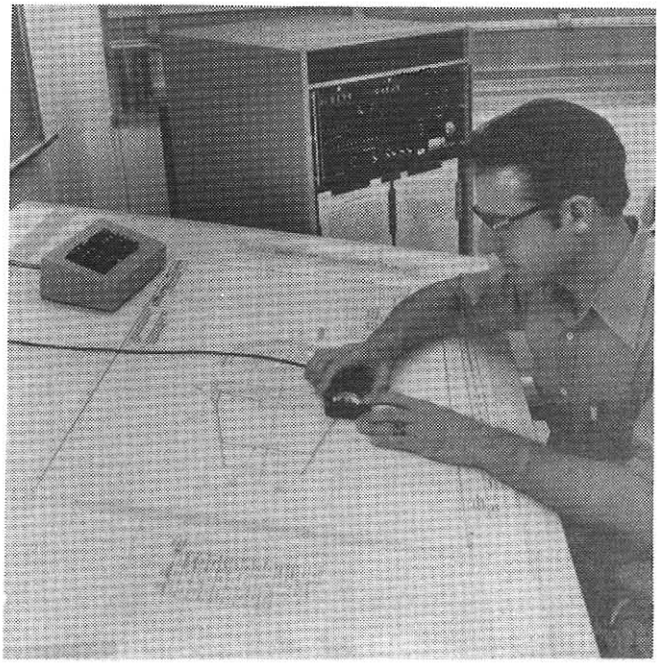


Figure 1. Using interactive digitizing equipment, a design draftsman obtains coordinate information of a part geometry which will be used for computing properties of interest for solids of revolution.

DESIGN DEFINITION

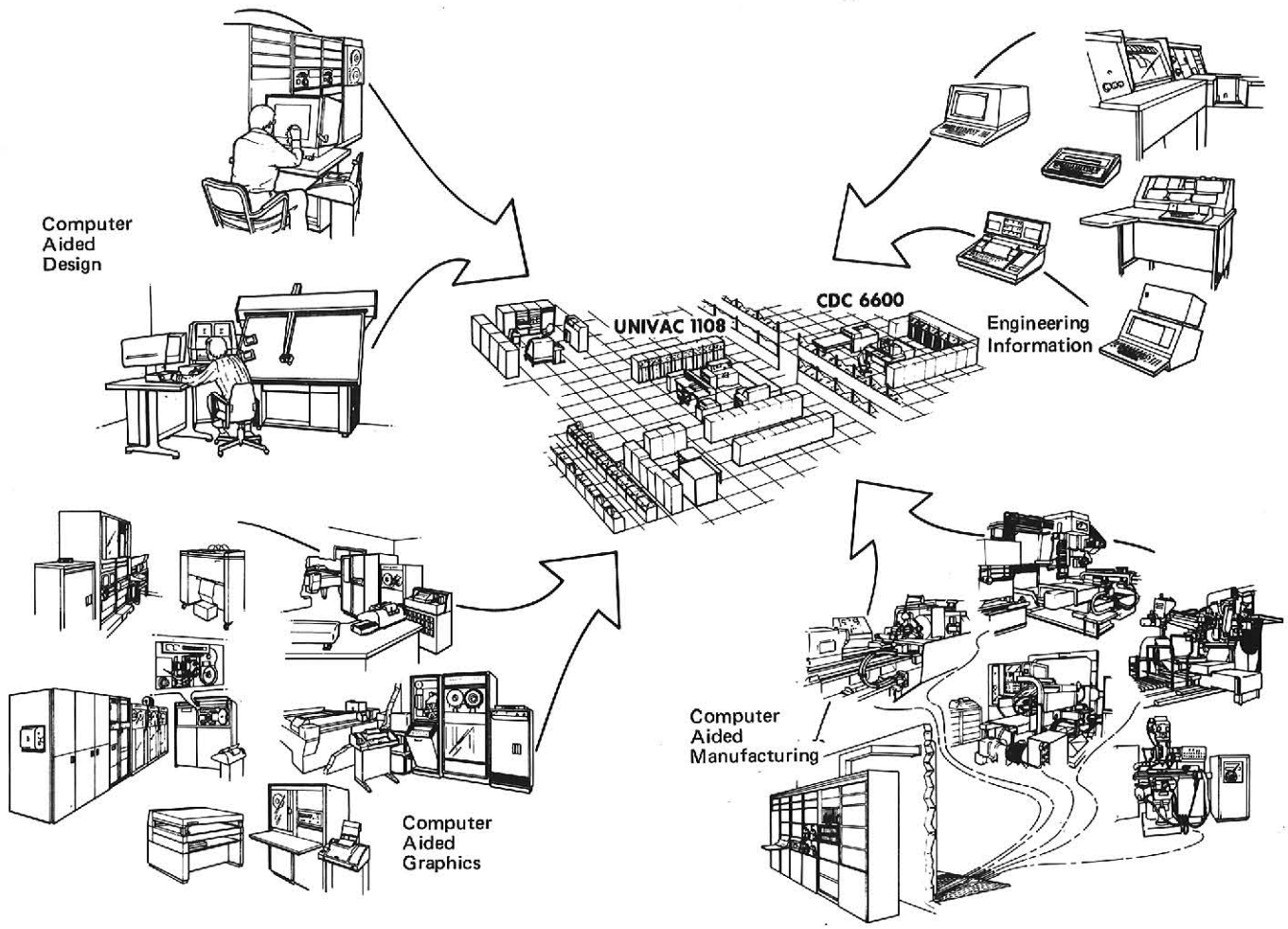


Figure 2. CADDAMS (Computer Aided Design, Definition and Manufacturing System)

Item 4. *Product Traceability*

Design definition includes requirements for identification of manufactured products, retention of selected product test data, and retention of selected records of assembly. Any modification of a design can be identified and related to corresponding parts. Production test data collected on system components are transmitted to Sandia and retained for correlation with system performance and testing throughout the system's life. Records of assembly retained by computer permit correlation of significant component changes with higher-level systems. Critical reliability requirements which must be met by the end product make important this traceability of product configurations throughout system life.

DESCRIPTION OF MAJOR FACILITIES USED IN DESIGN DEFINITION

COMPUTER-AIDED DESIGN. An integrated system of major computers and supporting equipment that permits the input of creative thought at the design stage, after which the encoded information is computer-processed to provide for needs of design, analysis, definition, and manufacture.

COMPUTER-AIDED GRAPHICS. Computer-driven plotting machines and supporting equipment capable of producing precision artwork (photomasks, assembly drawings, and related data) required in the design and manufacture of printed circuit boards, integrated circuits, hybrid microcircuits, optical gages, etc.

COMPUTER-AIDED WORD PROCESSING. Several stand-alone minicomputer-controlled word processors used to create and revise typewritten engineering specifications and procedures. These processors provide instantaneous merge, edit, delete, and paragraph arrangement capability, with storage in magnetic tape cassettes.

REPROGRAPHICS. Cameras, projectors, and supporting photographic equipment used to create new, original drawings on wash-off polyester photographic film, based on previously existing microfilm or full-size drawings. Design definition changes can be accomplished during the process of creating the new original, as well as afterwards (after moist erasure of old image from new original).

MICROGRAPHICS AND DISTRIBUTION. Cameras, film processors, duplicators, printers, electronic accounting machines, etc., which support engineering activities by (1) production of standardized microfilm aperture cards, microfiche, and roll microfilm, (2) storage and distribution of drawings via unitized microfilm system, (3) full-size diazo-type and reduced-size electrostatic reproductions from original or intermediate drawings, and (4) offset printing of engineering release telecommunications.

TELEPROCESSING TERMINALS. A network of terminals located in design definition and engineering offices which permits user access to, and interaction with, central computers. This integrated system facilitates computations, design, and record-processing on a time-sharing basis.

METAL PROCESSING

Metal fabrication facilities are used to fabricate, modify, and assemble research and development items, and to develop new metal-processing techniques. Facilities include numerically controlled as well as conventional machines for machining, grinding, precision metal forming, patternmaking and metal casting, welding, and joining.

Machining

The machine shop provides facilities for the fabrication of piece-parts, subassemblies, and assemblies. Both conventional machining equipment and numerically controlled machines are used. Facilities are available for fabricating and assembling miniaturized components. (Items 1,2)*

Current Capabilities

- Conventional, numerical-control, and miniature machining
  - Turning
  - Milling
  - Drilling
- Electrical discharge machining
- Ultrasonic machining
- Grinding
  - Surface
  - Cylindrical
  - Internal
  - Jig
- Chemical milling
- Carbon and ceramic machining
- Hazardous-material machining
  - Explosives
  - Toxic materials

Precision Metal Forming

Precision prototypes are fabricated. Forming dies are used to provide complex shapes built to close tolerances.

Current Capabilities

- Shearing
  - Punching
  - Trimming
  - Notching
  - Ring and circle cutting
- Forming
  - Rolling
  - Bending
- Joining
  - Spot welding
  - Seam welding
  - Riveting
  - Electrodeposition

Foundry and Patternmaking Facility

A wide variety of patterns, wood models, and wood tooling is fabricated in the patternmaking facility. A nonferrous foundry complements the wood-pattern facility, and is capable of producing a variety of quality sand castings. Furnace capacity varies with the alloy being poured, but, for example, aluminum shapes weighing up to 2000 pounds can be cast. (Item 3)

Welding and Joining

An extensive welding and joining laboratory is maintained for prototype fabrication. The structural welding facility includes complete welding and cutting equipment. (Item 4)

Current Capabilities

- Structural welding
  - Brazing
  - Gas welding
  - Shielded metal-arc welding
  - Gas tungsten-arc welding
  - Electron-beam welding
  - Hot press brazing and bonding
- Microwelding
  - Resistance spot welding
    - Opposed electrode
    - Parallel gap
  - Resistance butt welding
  - Percussive arc welding
  - Thermal compression bonding
  - Ultrasonic bonding
  - Microsoldering and brazing
  - Furnace brazing
  - Vacuum brazing
  - Laser-beam welding

*See Highlights below.

* * * * * * *HIGHLIGHTS* * * * * * *

Item 1. *Five-Axis Direct Numerically Controlled Milling Machine*

A five-axis milling machine is used for complex configurations. The term "five axis" describes the orientation of the machine head relative to the part being machined. The orientations are the three orthogonal rectilinear axes, rotation of the part, and rotation of the machine head by 90 degrees to the vertical position. The machine control unit receives instructional commands directly from a process computer, performs certain arithmetic operations, and converts the information into analog signals to provide continuous control of the five axes. Figure 1 shows a part in an intermediate stage of the machine operation.

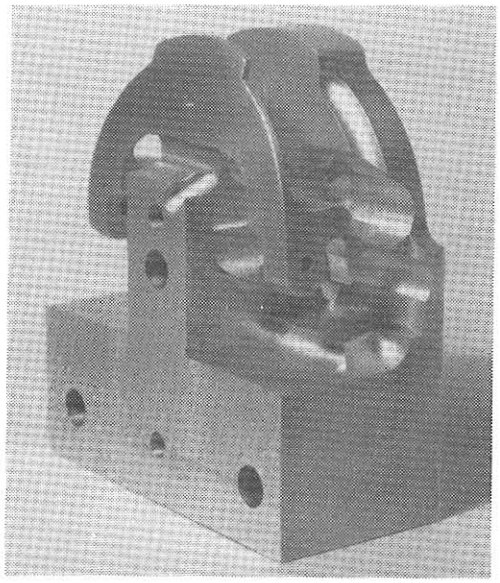


Figure 1. Part in an intermediate stage of machining

Item 2. *Miniature Machining and Assembly*

A switch was designed to sustain extreme abnormal environments without having its open contacts close or vice versa. The assembly contains 243 parts in a volume of 56 cubic centimeters (Figure 2). Units used in the development of the switch were fabricated in the miniaturization shop.

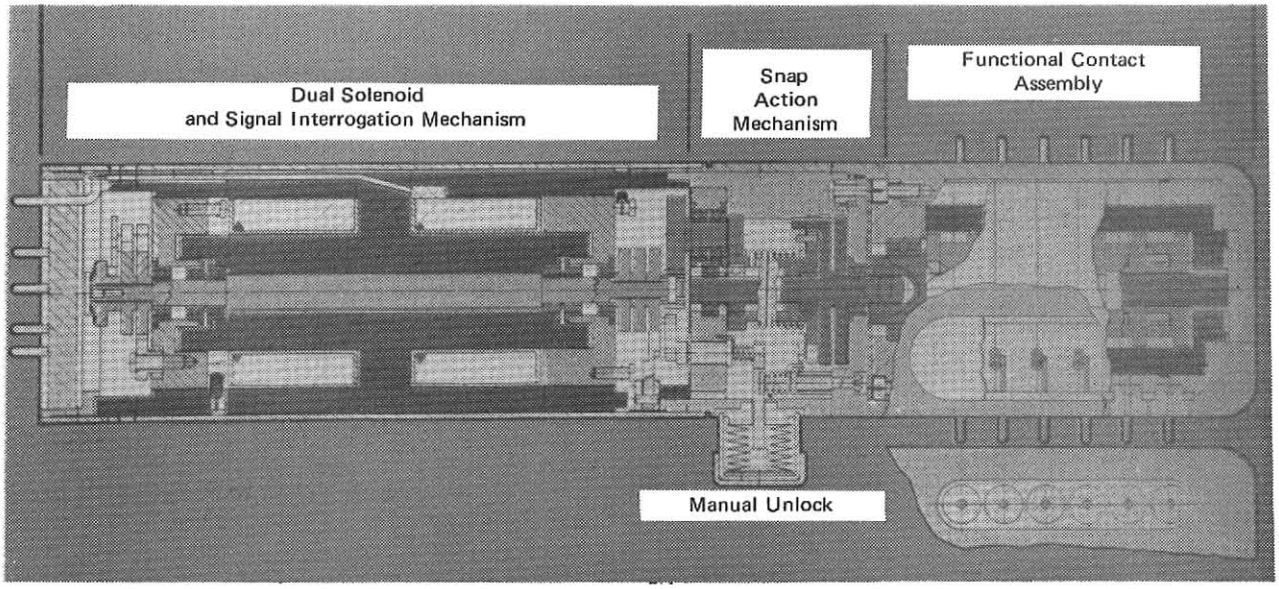


Figure 2. Miniaturized switch containing 243 parts within a cylinder about 11.4 cm long and 2.5 cm in diameter.

METAL PROCESSING

Item 3. *Quality Castings*

High-quality castings produced in the foundry are being used on a missile where forged or rolled components would normally be required (Figure 3). This has resulted in a considerable saving of time and money.

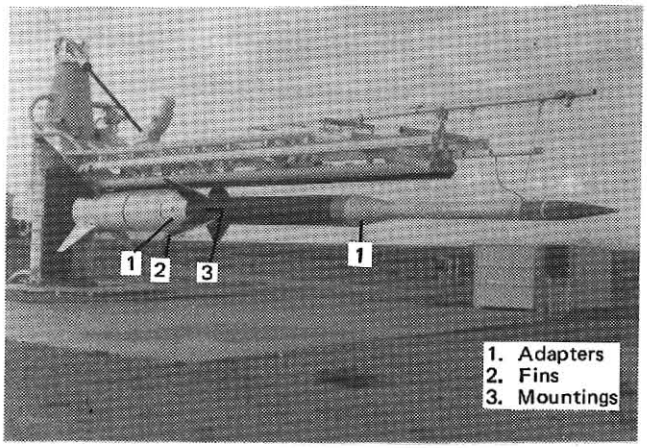


Figure 3. Missile components indicated by arrows are aluminum alloy castings.

Item 4. *Laser Fusion Vacuum-Chamber Weld Assembly*

A sphere 3 feet in diameter to be used in the study of laser-beam fusion was fabricated using gas-tungsten-arc and electron-beam welding techniques (Figure 4). Fabrication of the sphere called for precise alignment and position tolerances and vacuum tight welds.

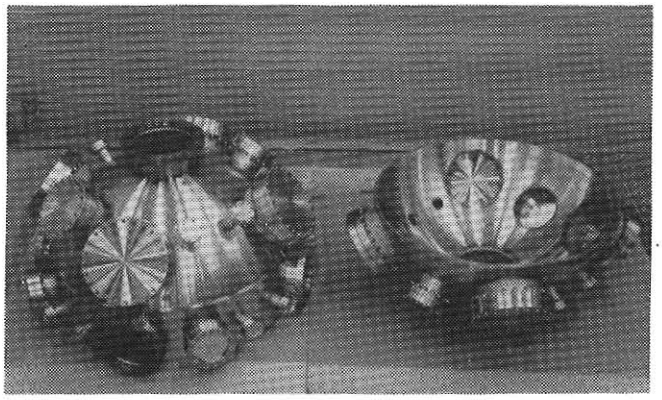


Figure 4. Vacuum chamber for electron-beam fusion facility.

GLASS AND CERMIC PROCESSING

The glass fabrication and melt laboratory was established for the development of processes and for the fabrication of a wide variety of products requiring special glass applications.

The ceramics laboratory and the abrasives, composites, and toxic machining facilities are used to fabricate experimental, developmental, and prototype ceramic components using existing ceramics and machining technology and, as required, for developing or assisting in the development of new ceramic fabrication and materials-processing technology.

Glass Seals, Coatings, and Fabrication

The glass laboratory has wide capabilities, ranging from traditional glass-blowing of laboratory apparatus to new methods for bonding and sealing glasses into complex structures. (Items 1,2)*

Current Capabilities

- Glass blowing
- Forming
- Reflecting coatings
  - Silver
  - Aluminum
- Conductive coatings
  - Gold
  - Platinum
  - Silver
  - Tin oxide
- Vacuum baking, processing, and final sealing
- Glass-to-metal seals
  - Fusion sealing
    - Tubular
    - Edge
    - Butt
    - Window
    - Single and multiple seals
  - Header design and development for:
    - High-voltage isolation
    - High current
    - High or low operating temperature
    - Thermal shock resistance
    - Mechanical shock resistance
    - Static or dynamic loads
    - Corrosive environments
  - Electrical field assisted glass sealing (sealing well below the softening point of glass)
- Glass coatings and bonds
  - Screen printing
  - Spraying
  - Electrophoretic deposition
  - Transfer tape
  - Vacuum hot pressing (for precision, pore-free bonds)
- Special glass formulation by melting and drawing
  - Fabricating new and unusual glasses
  - Altering or tailoring properties (mechanical, physical, chemical, optical, electrical)
  - Glass tube drawing
- Glass characterization
  - Differential thermal analysis
  - Thermomechanical analysis
  - Differential scanning calorimetry
  - Thermogravimetric analysis
  - Thermal evolution analysis
  - Hot-stage microscopy

Ceramic Fabrication

In the ceramics laboratory are facilities for fabricating ferroelectric transducers, thermoelectric materials, and alumina and electrooptic ceramics. The facilities include equipment for batch formulations, calcining, milling, cold and hot pressing, sintering, machining, slicing, grinding, lapping, polishing, and glazing.

Current Activities

- Ferroelectrics (lead-zirconate titanate)
  - Batching
  - Pressing
  - Sintering
  - Slicing
  - Electroding
  - Polarizing
  - Transducer assembly

*See Highlights below.

GLASS AND CERAMIC PROCESSING

Thermoelectric (silicon germanium)
- Vacuum hot pressing
- Precision slicing

Alumina ceramics
- Isopressing and bisquing of billets
- Precision forming
- Controlled high firing
- Surface finishing of fired ceramics

Ceramic Process Development

The ceramics laboratory performs process development for ceramic capacitors, electrooptic ceramics, lanthanum-modified lead-zirconate titanate (PLZT), thermistor materials, chemical-vapor deposition of silica, ceramic transducers (PZT), and alumina ceramics.

Facilities available for process development include a clean room, freeze-drying equipment, vacuum and atmospheric hot presses, plasma and induction chemical vapor deposition equipment, and thin-sheet casting equipment. (Item 3)

Current Activities

Material Processing
- Preparation of high-purity PLZT powders
- Characterization of ceramic powders
- Development of thermistor materials

Fabrication techniques
- Isopressing and hydraulic dry pressing
- Thin-sheet casting (doctor blade)
- Vacuum and atmospheric hot pressing
- Chemical vapor deposition
- Slip casting
- Refractory casting
- Machine forming

Firing processes
- Drying and curing
- Bisquing
- High-firing

Powder Characterizations
- Particle size distributions
- Surface area

* * * * * * *HIGHLIGHTS* * * * * * *

Item 1. *Gas Discharge Tube*

The tube in Figure 1 was designed and fabricated to reduce the thermal gradient over its entire length during operation. To achieve this, the discharge chamber is suspended by its electrical leads and gas inlet tube in liquid nitrogen. The liquid nitrogen is maintained in a vacuum jacket which surrounds the entire tube and incorporates a glass bellows to minimize undue stresses in the glass because of differential thermal expansion and contraction. There is a double-vacuum-jacketed optical view port in the discharge chamber for light output and observation.

The problems of fabricating such a device are illustrated by the glass-blower's skill in forming a multitude of ring seals in very tight quarters, including double-ring seals, glass-to-metal seals (electrical leads), and by the precise temperature control needed to allow the sealing of optically flat windows onto a tube without window distortion.

Item 2. *Glass Headers*

Glass-to-metal seals are used in headers to hermetically seal together terminals and end-plates with a strong bond having high electrical resistance (Figure 2). One problem during fabrication was that during the seal cycle the glass at the terminal interface flowed upward instead of forming the desired gentle radius. The type of glass being used had an affinity for iron oxide and continued to wet the surface as long as iron oxide was present. The problem was solved by fixturing the terminals so that during the preoxidation cycle, oxide was formed only in the seal area of the terminal.

Item 3. *Electrooptic Ceramics*

Lead-zirconate titanate is a transparent ceramic with optical qualities that can be changed electrically. It can hold a photographic image, "remember" signals as does a computer memory, and switch from transparent to opaque in 50 microseconds. A lead-zirconate titanate slug 5-1/4 inches in diameter and a window 3 x 4 x 0.25 inch thick, sliced from such a slug, are shown in Figure 3.

The electrooptic material is prepared from liquids by precipitation. It is then vacuum-hot-pressed to about the density of steel, and sliced in the ceramics development laboratory. Polished slices of electrooptic material like that illustrated are used to fabricate a mosaic window for military aircraft.

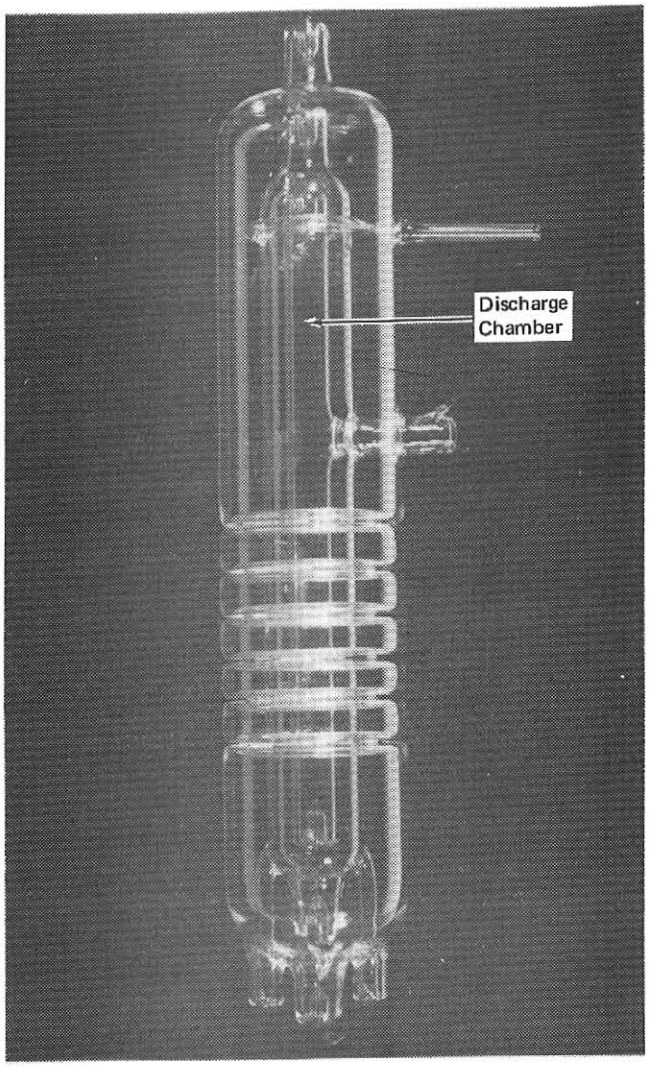


Figure 1. Special glass apparatus made by glass blower

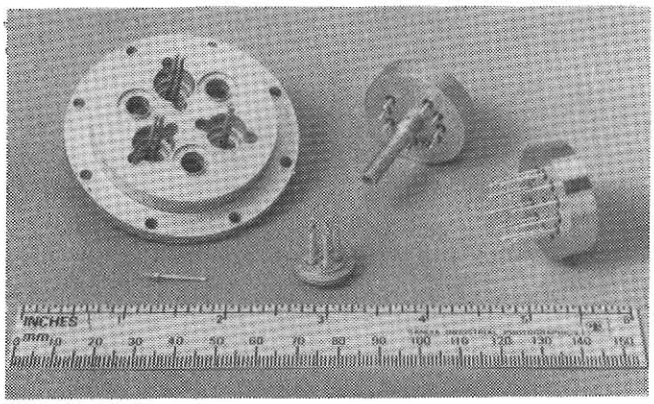


Figure 2. Glass headers

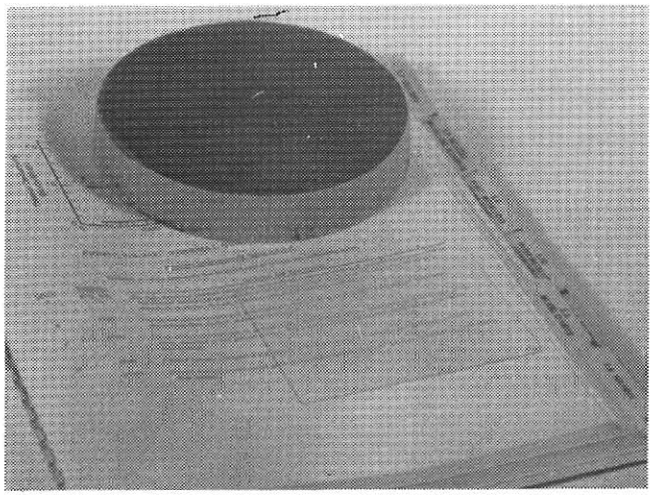


Figure 3. Hot pressed 5-1/4-inch-diameter PLZT slug and 3- x 4-inch-electrooptic window sliced from a similar slug

COMPOSITES AND PLASTIC PROCESSING

Composite materials and components are developed, processed, and fabricated. Processes include filament winding, resin impregnation, carbonization and graphitization, chemical vapor deposition, and plasma spraying.

Polymeric materials are processed and fabricated for various applications. Processes are developed for the formulation of new plastics.

Carbon-Carbon Composites

Carbon-carbon composites are developed for various applications in which the unique high-temperature and erosion-resistant qualities of carbon are required. Helical-wound, continuous carbon filaments and continuously felted substrates are fabricated. Parts are provided for evaluation of chemical vapor deposition (infiltration) and pyrolized organic (impregnation) matrices. Reinforcement materials include carbon, graphite, glass, and metal. Matrix materials include plastics, carbon, and metals; (e.g., boron/epoxy, boron/aluminum, boron/copper, or stainless steel/aluminum). (Items 1,2)*

Current Capabilities

- Matrix development
  - Chemical vapor deposition (infiltration)
  - Pyrolyzed organics (impregnation)
- Fabrication
  - Filament winding
  - Carbonization
  - Infiltration
  - Graphitization
- Insulation
  - Carbon foams
  - Carbon composites with tailorable compressive and thermal properties for applications to 3000°C
- Chemical vapor deposition of carbon
  - Chemical kinetics and equilibrium thermomechanical calculations
  - Reaction modeling and experimental confirmation
  - Instrumentation methods
  - Deposit characterization

Plastics

In response to the needs of research and development groups, basic materials are modified by incorporation of plasticizers and fillers to improve characteristics such as mechanical and chemical properties and resistance to extremes of temperature and moisture. Capabilities have been developed in a number of phases of plastics technology including thermoplastic, thermosetting, and elastomeric materials.

Representative Materials

Polyolefins	Polyesters
Vinyl chloride polymers	Polysulfides
Fluorine-containing polymers	Epoxide resins
Acrylic plastics	Polyurethanes
Polyamides	Silicones
Polycarbonates	Miscellaneous plastic materials
Phenolics	

A processing facility is used to develop procedures for handling new materials. Included is a clean room for casting and encapsulating contaminant-free components. (Item 3)

Representative Processes

Molding	Formulating
Compression	Thermoforming
Transfer	Laminating
Injection	Coating
Compounding	Bonding
Milling	Sealing
Blending	Foaming

*See Highlights below.

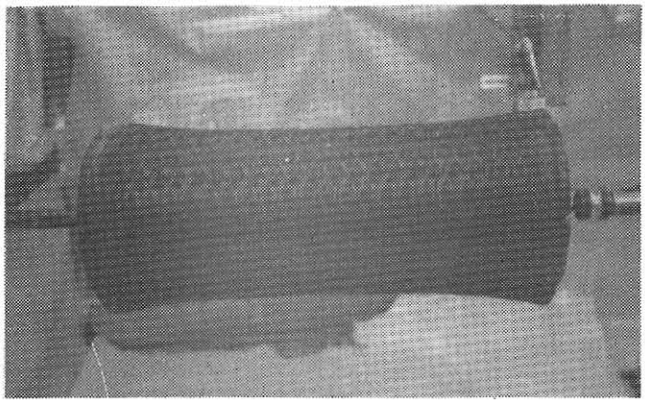
* * * * * * *HIGHLIGHTS* * * * * * *

Item 1. *Filament Windings*

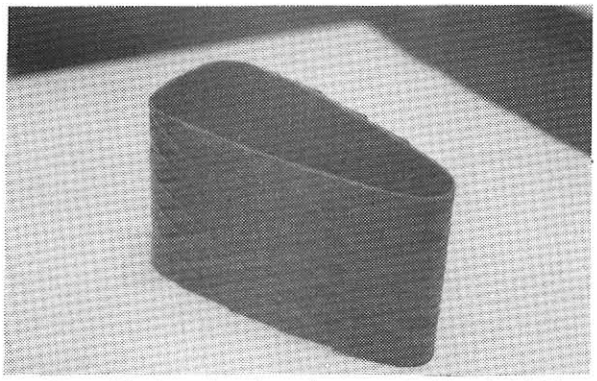
Figure 1 shows a filament-wound leading edge for a rocket sled. View A shows the part wound on a collapsible round mandrel. The part is then shaped into a wedge on a graphite mandrel before densification, which permits optimum use of the continuous filaments by preserving the filament-winding pattern. View B shows a segment of the final shape. Figure 2 shows the winding and laminating process for development of a prototype magnetically suspended, rotated, and/or coupled flywheel.

Item 2. *Carbon Foams*

A facility was set up to investigate the characteristics of carbon foams. Use of the facility ranges from exploratory research to the fabrication of full-scale prototypes. Specific operations include organic synthesis, formulation, curing, carbonization, graphitization, evaluation, and testing. Carbon foam is a cellular material that combines high structural strength, high temperature resistance, and low density. The carbon structure is obtained from carbon precursors of cellular organic polymers by controlled pyrolysis in an inert atmosphere. The foam can be made in a wide range of densities.



A. Filament-wound leading edge



B. Final wedge-shaped segment of heat shield

Figure 1. Rocket sled heat shield

Item 3. *Foam Encapsulation*

The encapsulation of fuzing and arming subassemblies required the use of a void-free foam having a density of 22 lb/ft^3. Mockup units were used for developing encapsulation process techniques. After encapsulation each mockup unit was checked for foam density and external and internal defects such as voids and cracks. Process techniques were thus developed, including location of mold pour points and vents. Using these techniques, production subassemblies were fabricated and tested successfully.

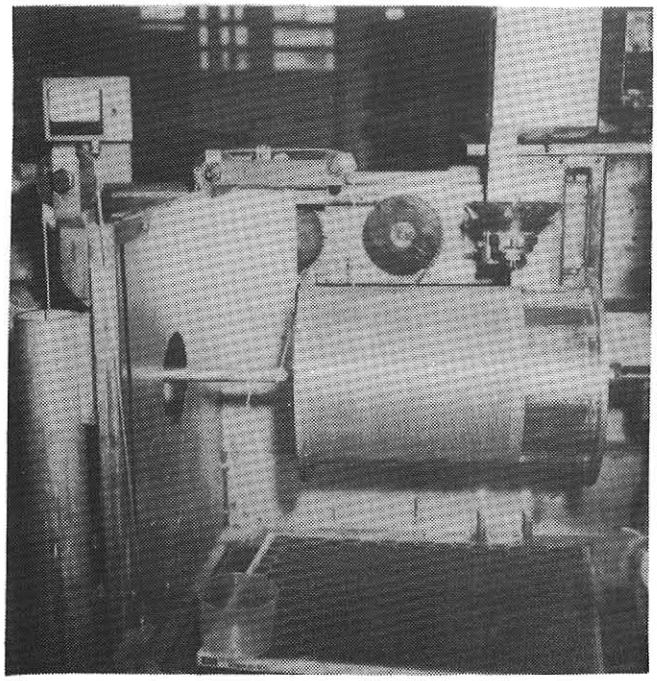


Figure 2. Winding and laminating process Kevlar 49 and epoxy.

ELECTRICAL COMPONENT PROCESSING AND FABRICATION

Capabilities include process development and the fabrication of special electrical and electronic devices. Operational electronic equipment, such as testers and monitoring devices, is fabricated for testing and inspection purposes. Conventional hard-wiring is used, as well as state-of-the-art microcircuitry. Discrete components such as resistors, inductors, transformers, and capacitors for unusual applications or special demands are also developed and fabricated.

Thin-Film Deposition and Vacuum Devices

In the vacuum processes laboratory the emphasis is on vacuum deposition of thin films, while in the tube laboratory a variety of vacuum tubes and devices is designed, developed, and processed. (Item 1)*

Current Activities

- Thin-film vacuum deposition methods
  - Resistance evaporation
  - Electron-beam evaporation
  - Ion plating
  - Sputtering
    - Direct current
    - Radio frequency
- Film deposition
  - Elemental
  - Refractory
  - Alloy
  - Dielectric
  - Compound
  - Organic
- Characteristics produced using thin films
  - Optical
    - Antireflecting
    - Degrees of reflectivity or transmission
    - Variable-density filters
  - Mechanical
    - Modification of coefficient of expansion
    - Dispersion of stress waves
    - Diffusion processes
    - Energy absorption
    - Protective films
  - Electrical
    - Conductor size
    - Capacitor element values
    - Resistive element values
- Design, development, and processing of vacuum devices
  - Neutron tubes
  - Switching tubes
  - Spark gaps
  - Thermionic converters
  - Electron-beam guns
  - Ion tubes
  - Triode tubes
- Vacuum-device production processes
  - Wet and dry hydrogen and vacuum brazing
  - Chemical treatment of ceramics and metals
  - Ceramic metalizing and nickelizing
  - Ceramic-to-metal joining
  - Pumpout, bake, and gas backfill devices
  - Welding: tungsten inert gas and electron-beam resistance
  - Phosphor deposition, settling, and vacuum

*See Highlights below.

Hybrid Microcircuits

Processes are developed for new technology studies and prototype fabrication of hybrid microcircuits. The facilities include a Class 100 downflow clean room containing fine-line photolithographic and cleaning equipment. (Items 2-4)

Current Activities

- Thin-film deposition
  - Tantalum nitride
  - Chrome
  - Gold
- Photolithographic chemical processes
- Cleaning processes
  - Ultrasonic
  - Chemical
  - Cascade deionized water
  - High-temperature firing

- Bonding
  - Hydrogen flame soldering
  - Hot wire and infrared
  - Thermal compression on beam lead devices
  - Fine wire
  - Parallel-gap ribbon
- Substrate sizing
  - Laser
  - Diamond wheel
  - Wire saw
- Tantalum resistor trimming
  - Laser
  - Anodizing
- Testing
  - Bond and adhesion strengths
  - Life cycling
  - Temperature coefficient of resistance on thin-film resistors
  - Functional testing of complete units

Electronic Fabrication

In this facility is equipment for fabricating, modifying, and packaging electronic components and highly specialized electronic equipment and instrumentation. Such units are used in simulation testing of components, telemetry packages, and weapon systems, and may be incorporated with minicomputers for test automation. (Items 5,6)

Coil Winding

This laboratory, as the name implies, is used in building normal and special electrical coils, most of which are prototypes for testing and evaluation.

ELECTRICAL COMPONENT PROCESSING AND FABRICATION

Current Capabilities

- Machine winding
  - Layer
  - Toroid
- Wire size range: 0.25 to 460 mil
- Form size range: 0.010 inch ID toroids to rectangles 4 x 5 feet

Component Testing

Electrical components are tested for their performance under anticipated operating conditions, including parametric testing in controlled environments.

Current Capabilities

- Burn-in, aging, and life testing
  - Voltage supplied to 10,000 V
  - Current supplied to 200 A
    - Steady state
    - Ramp
    - Pulse
- Thermal
  - Temperature chamber -65 to 300°C
    - Steady state
    - Cycle
    - Shock (200°C)
- Time measurements
  - Silicon-controlled rectifier
  - Digital integrated circuits
- Lead fatigue tests
- Radiation tests on solid-state devices and tubes in the reactor facility
- Automatic testers
  - Build
  - Modify
- Environmental testing and evaluating

ELECTRICAL COMPONENT PROCESSING AND FABRICATION

* * * * * * *HIGHLIGHTS* * * * * * *

Item 1. *Electrical Switching Tube*

A tube used for electrical switching (Figure 1) typifies the components and processes developed by the vacuum processes and electronic tube laboratories.

Item 2. *Hybrid Microcircuits in Artillery-Fired Projectiles*

A microwave telemetry transmitter was constructed for use in an artillery shell. By the use of hybrid microcircuits, the telemetry package was reduced to a volume of 13 cubic centimeters. A signal is transmitted continuously from ignition, when axial acceleration is 12,000 x gravity, throughout the flight of the projectile.

Item 3. *Photochemical Processing and Microminiature Assembly*

Photographic techniques are used to reduce photographs of printed circuit layouts. Photographic processes are used to define and mask areas to be etched so that chemical attack occurs only where material is to be removed. Direct reductions of 150 to 1 are achieved. Printed circuits and integrated-chip masks are typical products of this process.

Associated with this activity is precision assembly. By the use of skills typical of watchmaking, miniature components are mounted, positioned, welded, and calibrated to form working systems of unusual operating limits and reliability.

Other applications of photoreduction include a variety of precision glass and metal parts for acceleration sensors, particle collectors, microminiature vacuum deposition masks, electrooptic ceramic lens grids, and other items of extremely small size or close tolerances.

Item 4. *Hybrid and Integrated-Circuit Masks*

Order-of-magnitude reductions are routinely made on such related items as hybrid-circuit and integrated-circuit masks. These masks permit the deposition of metals in precise patterns on substrates. A complete set of seven or more registering masks may be required to build an integrated-circuit chip whose final dimensions may be only 0.323 square centimeter.

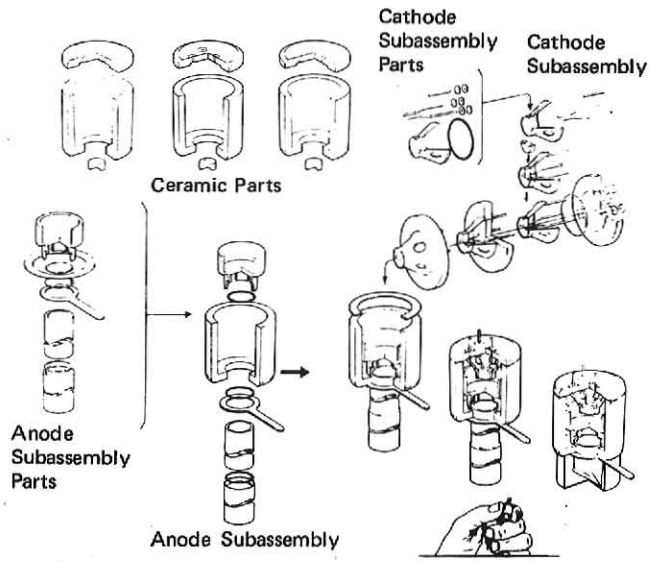


Figure 1. Electrical switching tube and assembly methods

Item 5. *Wire-Wrapping Machines*

These are numerically controlled indexing machines operated by computer-generated punched tape. Pin-type printed circuit boards with integrated circuit plug-ins are wired using connections made by wrapping the connecting wires around the terminals. This method of circuitry packaging is effective when a high density of parts is required. Circuit boards up to 50 x 75 centimeters can be wired.

Item 6. *Force Balance Accelerometer*

A commercial force balance accelerometer is being extensively redesigned to meet anticipated requirements of future inertial guidance systems and/or arming and fuzing systems in missiles. The instrument (Figure 2) must be packaged in a volume of 1 cubic inch and must be capable of measuring accelerations from fractions of a

ELECTRICAL COMPONENT PROCESSING AND FABRICATION

gravity to 200 x gravity in either direction along its sensitive axis, with an overall error of less than 0.25 percent across a range of stringent operating environments.

The Force Balance Accelerometer operation is based on the principle of a sensing mass being supported against gravity forces by the electromagnetic force on a current-carrying coil in a permanent magnetic field. The working element starts with a glass wafer ground and polished to a flatness that is measured in wavelengths of light. Delicate flexures are chemically etched, conductor paths are applied by vapor deposition, coils are mounted, leads microwelded, and a component produced whose shock resistance is measured in hundreds of gravities but whose sensing accuries are in hundredths of a gravity.

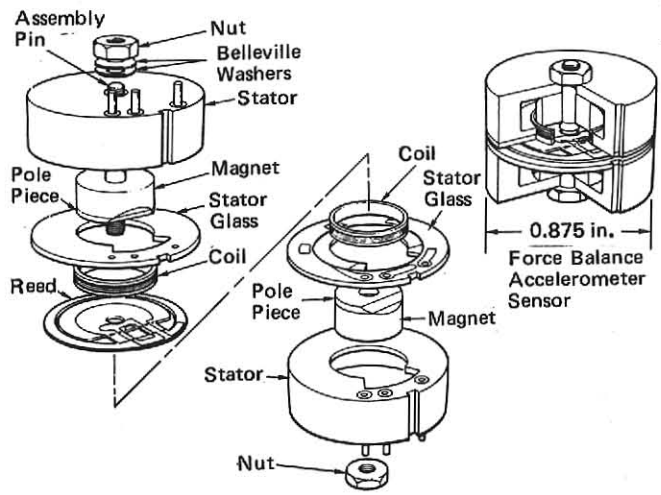


Figure 2. Sandia-modified force balance accelerometer packaged in a volume of 1 cubic inch

HEAT TREATING AND FINISHING PROCESSES

The heat-treat facility is equipped to perform a wide range of processes required in the heat treatment of ferrous and nonferrous alloys. Finishing services are provided by using flame and plasma spray as well as the plating and coating facilities. Finishes are applied for numerous reasons: wear resistance, corrosion or oxidation resistance, insulation or conductivity for electrical applications, and eye appeal.

Heat Treating

Strict process control is maintained and recorded for research and development programs requiring the heat treatment of unusual alloys to rigid specifications.

Current Capabilities

- Hardening
- Tempering
- Annealing
- Normalizing
- Carburizing
- Stress relieving
- Stabilizing

Flame and Plasma Spraying

A metal and ceramic spray facility is maintained for applying coatings that are insulative and resistant to corrosion, erosion, and high temperature.

Current Capabilities

- Oxyacetylene flame spray
  - Metal wire
  - Ceramic rod
  - Ceramic powder
- Plasma spray
  - Metal powder
  - Ceramic powder

Electroplating and Coating Laboratory

The plating laboratory provides metallic and oxide finishes on ferrous and nonferrous metals for many purposes including corrosion protection, wear resistance, low electrical resistivity, high dielectric properties, diffusion and thermal-compression bonding, and solar-energy absorption. Special capabilities range from color anodizing of prototype models to electroforming of miniature all-gold pressure vessels (targets for the electron-beam fusion energy study).

A full range of organic coatings can be applied in the coating laboratory, including systems for ordnance materials, ablation and heat-resistant coatings for rockets, satellite coatings, dry-film lubricants, and chemical and corrosion-resistant systems. Recent applications have included spraying of silver and copper onto the back surfaces of parabolic glass mirrors for the solar energy program.

Current Capabilities

- Specimen preparation
- Contaminant analysis
  - Atomic absorption spectrophotometer
- Nondestructive plating and coating thickness control instruments
- Organic coating application techniques
  - Spray
  - Fluidized bed
  - Electrostatic
  - Airless
  - Hot spray
  - Electrophoretic
- Coating laboratory testing
  - Total solids (evaporation of solvent residue)
  - Vehicle solids (centrifuge separation of pigment)
  - Percent pigment
  - Abrasion resistance
  - Salt-spray resistance
  - Scratch and mar
  - Impact
  - Accelerated high humidity
  - Outdoor exposure

DESCRIPTION OF MAJOR FACILITIES USED IN FABRICATION

METAL PROCESSING. These facilities include numerically controlled, conventional and miniature machining capabilities along with grinding, metal forming, pattern making, nonferrous casting, welding and joining.

The automated and heavy equipment shop provides facilities for fabrication of complex and/or large piece parts. There is a complement of nine numerically controlled machines, up to five axis, of which five machines receive the control information via a direct computer link. Conventional machines provide large part turning (89 inch diameter, 114 inch long) milling and boring (100 inch x 70 inch x 70 inch) capabilities.

GLASS AND CERAMIC PROCESSING. The glass laboratory provides glass blowing, glass formulation and melting and glass drawing devices for fabrication of custom glass apparatus, glass-to-metal, and glass-ceramic-to-metal seals, headers and vacuum of gas filled devices. Some of the special or unique equipment in use in this facility:

- Glass melt furnaces
- Glass rod and tube drawing tower
- Oxygen plasma silica melt unit
- Thermal analyzer
- Dilatometer
- Vacuum furnaces
- Hydrogen furnaces
- Belt furnace for glass sealing
- Glass annealing, nucleating, and crystallizing furnaces
- Vacuum bake-out and backfill station
- Hot press for glass molding
- Polarimeter

The ceramics laboratory formulates and develops processes for fabrication of ceramic materials such as ferroelectric, thermoelectric and electrooptic as well as materials processing thermal and electrical insulative properties. The facility is equipped with blenders, gas and electric furnaces and ovens, hydraulic and hydrostatic presses, cutting and lapping machines and an analytical laboratory.

COMPOSITES AND PLASTICS PROCESSING. These areas are equipped to handle the range of materials from thermoplastics through rubbers, thermosetting plastics, and carbon matrix composites. The size range from injection molded gram scale through full size composite solar collectors and reentry heat shields. Also included in the equipment are laminating presses, filament winders, compression and transfer molding presses, vacuum forming, and vacuum encapsulation systems. The electronic encapsulation module features a full-ceiling down draft clean room. The induction heated chemical vapor deposition and graphitization furnaces will operate at low or atmospheric pressures, in inert atmospheres at temperatures typically in the range 900 C to 3000 C.

DESCRIPTION OF MAJOR FACILITIES USED IN FABRICATION

ELECTRICAL COMPONENT PROCESSING AND FABRICATION. The Electrical Component Processing and Fabrication facilities are equipped for:

Thin film deposition by resistance and electron beam evaporation, ion plating and sputtering.

Fabrication of hybrid microcircuits including a class 100 downflow clean room containing the fine-line photolithography and cleaning equipment.

Photochemically producing high precision parts for microminiature components.

HEAT TREATING AND FINISHING PROCESSES. The heat treat facility is equipped to perform heat treatment of ferrous and nonferrous alloys with strictly maintained and recorded process control.

Finishing process facilities include equipment for flame and plasma spray, electroplating metallic and oxide finishes on ferrous and nonferrous metals along with capabilities for applying a full range of organic coatings.

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