NASA TECHNICAL MEMORANDUM

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SPACE PROCESSING APPLICATIONS BIBLIOGRAPHY

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
This document is a bibliography of articles, papers, and reports which discuss various aspects of the use of the space environment for materials science research or for commercial enterprise. Since the use of the space environment for materials science is a relatively new undertaking, it is the intent of this document to provide a consolidated reference for those new to the field.

The references are arranged chronologically, and several cross references are provided, as well as instructions for procurement of references.
The Space Processing Applications Program utilizes the unique aspects of the space environment, such as sustained low gravity, to fulfill the needs of materials sciences and manufacturing to process materials that cannot be made on Earth. Reduced gravity in space eliminates sedimentation of heavier particles and buoyancy of lighter particles and bubbles, in addition to reducing thermal convective mixing which is a natural phenomena on Earth. Space Processing can provide precise control of fluid processes, mixing of normally immiscible materials and containerless melting to achieve highly pure materials. NASA is exploring the potentialities of Space Processing and demonstrating the improved materials processes that are made possible by the new technology.

This document is a compilation of various articles, papers, and reports, which discuss aspects of the use of the space environment for materials science research which may lead to commercial enterprise. It is the intent of this document to provide a consolidated reference for those new to the field. The document will be updated as warranted.

Each of the referenced publications usually contains its own bibliography and provides additional reference materials.

The referenced publications generally are arranged in chronological order. Several cross references are provided.

Instructions for procurement of references are provided on the final page.

Erroneous entries or omissions should be reported to MSFC, PF11, with the correct entry typed out in the format desired.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORWORD</td>
<td>1</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>11</td>
</tr>
<tr>
<td>GLOSSARY/INSTRUCTIONS</td>
<td>iii-iv</td>
</tr>
</tbody>
</table>

## SECTION I: GENERAL SPACE PROCESSING
- A. SURVEY PAPERS .................................................... 1
- B. FACILITIES ................................................. 13
- C. GENERAL APPLICATIONS ....................................... 17

## SECTION II: SPACE MANUFACTURING MANAGEMENT AND PLANNING
- A. GENERAL PLANNING ............................................. 23
- B. SKYLAB PROGRAM PLANNING .................................. 26
- C. SOUNCING ROCKET PLANNING ................................. 28
- D. SPACE SHUTTLE PLANNING/UTILIZATION .................... 30
- E. SPACE SHUTTLE DESIGN/PAYLOAD INTERFACE ............... 34

## SECTION III: FLUID MECHANICS AND HEAT TRANSFER
- A. GENERAL FLUID MOTION STUDIES ............................. 39
- B. GENERAL HEAT TRANSFER STUDIES ............................ 47
- C. CONVECTION STUDIES ......................................... 54
- D. LIQUID FLOATING ZONE ....................................... 61
- E. APPLICATIONS ................................................ 63

## SECTION IV: SOLIDIFICATION PROCESSES
- A. SOLIDIFICATION STUDIES ...................................... 65
- B. IMMINCIBLES .................................................. 79
- C. COMPOSITES/EUTECTICS ........................................ 81
- D. CRYSTAL GROWTH ............................................. 88

## SECTION V: CONTAINERLESS PROCESSING
- A. GENERAL STUDIES .............................................. 100
- B. POSITION/CONTROL TECHNIQUES ............................... 101
- C. HEATING/COOLING TECHNIQUES ................................. 105
- D. APPLICATION STUDIES ......................................... 109

## SECTION VI: GLASS AND CERAMIC MATERIAL PROCESSING
- A. GENERAL STUDIES .............................................. 111
- B. METHODS OF PREPARATION ..................................... 115

## SECTION VII: ELECTROPHORETIC, CHEMICAL, BIOCHEMICAL PROCESSES
- A. GENERAL SEPARATION STUDIES ................................ 117
- B. ELECTROPHORETIC METHODS .................................... 119
- C. GENERAL CHEMICAL PROCESS STUDIES ....................... 133
- D. GENERAL BIOCHEMICAL PROCESS STUDIES .................... 134

### APPENDIX A - SUBJECT INDEX .................................. 136
### APPENDIX B - CONTRACT INDEX .................................. 140
### APPENDIX C - AUTHOR INDEX .................................... 146
### APPENDIX D - CORPORATE INDEX ................................. 159
### INSTRUCTIONS FOR ORDERING DOCUMENTS .................... 167
### ADDENDUM I - CONTINUED BIBLIOGRAPHY TO JANUARY 1978 ... 169

ii

ORIGINAL PAGE IS OF POOR QUALITY
GLOSSARY OF TERMS

The following is a list of acronyms used in this document:

AAS - American Astronautical Society
AIAA - American Institute of Aeronautics and Aeronautics
AIChE - American Institute of Chemical Engineers
AFB - Air Force Base
AGU - American Geophysical Union
ASME - American Society of Mechanical Engineers
Battelle Memorial Institute
ESA - European Space Agency
ESRO - European Space and Research Organization
GE - General Electric Company
GD - General Dynamics Corporation
GSFC - Goddard Space Flight Center
HDQTS - Headquarters
IAF - International Aerospace Federation
IEEE - Institute of Electrical and Electronics Engineers
IIT - Illinois Institute of Technology
IITRI - Illinois Institute of Technology Research Institute
JPL - Jet Propulsion Laboratory
Johnson Space Center
KSC - Kennedy Space Center
Lockheed Missiles and Space Company
Lewis Research Center
NASA - The National Aeronautics and Space Administration
NBS - National Bureau of Standards
North American Rockwell International
NASA - National Bureau of Standards
NAR - North American Rockwell International
Oak Ridge National Laboratory
Rensselaer Polytechnic Institute
Space Science Laboratory - Marshall Space Flight Center
Space Processing Applications Program
Space Processing Applications Rocket Project
Society of Aerospace Materials and Process Engineers
Society of Automotive Engineers
Southern Methodist University
Texas Instruments, Inc.
TRW - TRW System Group
University of Alabama
United Aircraft Corporation
University of Alabama in Huntsville
University of California at Los Angeles
United Kingdom
United States Air Force
University of Southern California
Universities Space Research Association
Veterans Administration
INSTRUCTIONS

Typical entry format is as follows:

Author, Paper or Article, Author's Affiliation or Company, Source of Article, Contract, Contractor Report Number, (NSIC Library ID Number), Date, Length or Page No.
SECTION I. GENERAL SPACE PROCESSING

A. SURVEY PAPERS ................................................................. 1
   1. GENERAL ................................................................. 1
   2. MEETINGS/ANNUAL REPORTS ........................................ 6
   3. MISSION SUMMARY REPORTS .......................................... 9
   4. EUROPEAN REPORTS .................................................... 11

B. FACILITIES ............................................................................. 13
   1. GENERAL ................................................................. 13
   2. FURNACE SYSTEMS ....................................................... 14

C. GENERAL APPLICATIONS ..................................................... 17
   1. ECONOMIC STUDIES ................................................... 17
   2. EQUIPMENT/SYSTEMS .................................................. 18
   3. PROCESSES ............................................................... 19
A. SURVEY PAPERS

1. GENERAL


Abstract: Zero-gravity experiments for manned orbital flight with emphasis on materials and biological aspects.


Abstract: Application of low and zero gravity manufacturing casting and blowing, surface tension casting, blow forming, foaming. Serpenthutor system for positioning and handling.


Abstract: Detailed discussion of fundamental effects of gravity, zero gravity and induced forces on fluids, assessment of orbital processing effectiveness, cost-effectiveness and operational considerations.


Abstract: Preparation of high value electronic single crystals, the melting of materials and other processes benefiting from zero gravity are discussed.
Section 1.A.1.


Abstract: Containerless manufacturing of new glasses, etc., synchronous orbit manufacturing stations, computerized electric field shaping of liquid metals, buoyancy-free mixing of differing density liquid components, and crystalline materials and fibers without lattice defects.


Abstract: Properties of space environment relevant to materials science and processing: gravitational field, space vacuum, radiation.


Abstract: Ceramics, metallurgy, crystal growth, refining; gravitational fields, radiation effects.


Abstract: Buoyancy- and thermal convection-sensitive manufacturing processes and molecular force controlled processes.


Abstract: Tabulation of unique space processes (zero and low gravity) and assessment of current technology and recommendations for future development.
Section T.A.1.


Abstract: Experiments in development for Skylab; NASA and industrial participation in "pace processing and manufacturing experiments.


Abstract: Float zone refining and semi-conductor crystal growth; electronic crystals grown from solution; melting and casting of metals, glasses, and ceramics; slip casting of metals; centrifugation and electrophoresis of biologicals.


Abstract: Skylab Orbital Workshop experiments: polycrystalline from eutectic Al-Co and monotectic Al-In alloys, metallic whisker composite from eutectic Al-Co with added sapphire whiskers; spherical castings of pure Ni, Ni 12% Sn, and alloy "Star J stellite"; single crystal growth; electron beam welding and cutting, exothermic brazing of stainless steel tubes.
Section I.A.1


Abstract: Survey of manufacturing, potential in orbital workshops. Methods and processes in chemistry, pharmaceuticals, optical components, crystal growth, metallurgy and composite materials. (In German)


Abstract: Spherical and hollow ball bearings, special metal shapes, metal foams, intermetallics; adhesion and containerless casting of metals; special composites; high quality crystals: glasses; vaccines and drugs. Apollo 14 and 15 materials processing experiments are described (electrophoresis, composite casting, heat flow and convection, and liquid transfer). Space Shuttle and Space Station roles in space manufacturing.


Abstract: Apollo 14 and Skylab experiments on electrophoretic separation, M551 metals melting, M552 exothermic brazing, M553 sphere forming, M554 composite casting, and M555 GaAs crystal growth.


Abstract: Application of gravity control and vacuum, temperature, pressure and radiation characteristics of space to liquid-matrix preparation of composites, fine grain castings, supersaturated alloys, immiscible liquid-phase combinations, containerless free suspension, surface tension casting and drawing, adhesion casting and controlled density casting.
Section I.A.1.


Abstract: Reduced gravity manufacturing experiments in support of Skylab, etc. Methods to obtain short periods of near zero gravity.


Abstract: Describes Skylab hardware, mission objectives and experiments.


Abstract: Brief summaries of experiment objectives and hardware to be flown on Skylab.


Abstract: New potential product areas based on Skylab results.


Abstract: Brief history of space processing activities through Skylab - drop tower, KC-135, Apollo, Skylab, rockets.
Section I.A.1.


Abstract: Space Processing Applications program goals for ASTP, sounding rockets, Shuttle payloads.


Abstract: Describes the status and results to date of the material science research in space and discuss future programs and new challenges for industry.


Abstract: Discussions of commercial use of space for research and manufacture. NASA rocket program (SPAR) and Shuttle flights.

2. MEETINGS/ANNUAL RESEARCHS

Section I.A.2.


Abstract: Electron beam welding in space.


Abstract: Various views of requirements for unique materials, e.g., glass, metal crystals; and benefits of gravitational fields, materials handling in space.


Abstract: Research and development work on materials manufacturing and production engineering in space, emphasizing effects of reduced gravity on crystal growth and metal working, exobiology, glasses, etc. Includes N 70-14652--N 70-14679.


Abstract: Production engineering aspects of materials processing and industrial manufacturing with applications to orbiting laboratories and workshops, especially the effects of reduced gravity. Includes N70-20518--N7C-20548.
Section I.A.2.


Abstract: Zero-G melting and solidification, space manufacturing processes, facilities and experiments, chemical and biochemical space manufacturing; positioning and handling in weightlessness.

(9) "Space Processing and Manufacturing", NASA/MSFC, Conference, November 1, 1970.


Abstract: Development of materials science and manufacturing facilities for installation aboard space stations.


Abstract: Economic zero-gravity processing of materials in liquid or molten state, single crystal electronic materials, and high-purity biologicals on space shuttle in the 1980's.


Abstract: Soviet test equipment, manual and automatic tools, program controlled plants and key factors (weightlessness, deep vacuum, and temperature) in their use.
Section I.A.2.


3. MISSION SUMMARY REPORTS


Abstract: Heat transfer, liquified gases, film boiling, weightlessness, etc.

Section I.A.3.


Abstract: Welcoming address, Introduction, Closing Remarks, and thirty-eight papers covering results of Materials Processing Experiments conducted on Skylab and several related activities. Individual papers contain preliminary Skylab experiment data.


Abstract: Preliminary results of nine of the twelve Skylab science demonstrations are presented: Diffusion in Liquids, Ice Melting, Liquid Floating Zone, Immiscible Liquids, Liquid Films, Rocelle Salt Growth, Deposition of Silver Crystals, Fluid Mechanics, Charged Particle Mobility.

(5) Skylab Space Processing Experiment Review, MSFC Meeting Results prepared by USRA, July, 1974.


Abstract: Skylab Materials Processing hardware evaluation - M512 and M518 facilities. Scientific evaluation of experiment samples is not covered, only hardware operation and experiment performance.


Abstract: Preliminary results of Skylab experiments.
Section I.A.3.


Abstract: Summary report of the ASTP experiments. Preliminary results included on the ten material science for electrophoresis experiments.


Abstract: Summary report of the nine materials science experiments flown on the first SPAR flight December, 1975.

4. EUROPEAN REPORTS


Abstract: An independent, impartial evaluation for ESRO of the results of Apollo and Skylab experiment results to obtain a realistic basis for planning experiments to be carried-out in Spacelab.
Section I.A.4.

(5) **Abstracts of Papers Presented at Second European Symposium on Materials Sciences in Space**, Frascati, Italy, April 6-8, 1976, 48 abstracts.

Abstract: Papers presented by both U. S. and European materials scientist, engineers, and managers.


Abstract: ESA Activities in materials science, first Spacelab payload recommended order of priority ESA study result in facility and furnace design.


Abstract: German space processing program discussed, study results of planning activities for Shuttle/Spacelab, and a sounding rocket program.
B. FACILITIES

1. GENERAL


Abstract: Integrated facility to conduct space manufacturing engineering experiments: vacuum chamber, 2 kw electron beam welding and heating systems.


Abstract: Space manufacturing processes based on the potentials and limitations of the low gravity environment.


Section I.B.1.


Abstract: Automatic control (three dimensional resolution, wavelength-sensitive perturbation response, amplification capacity) techniques applied to weightless liquid metal and plasma systems. (In Russian).


Abstract: Feasibility study of using solar concentrators for crystal growth and zone-refining in space.


Abstract: Evaluation of how well automatic control and material handling devices can satisfy hardware and operational requirements for space processing.


Abstract: Detailed description of the Skylab M512 facility including systems and associated experiment hardware.

2. FURNACE SYSTEMS

Section I.B.2.


Abstract: Comparison of M518 performance predicted from ground-based data and the actual performance in flight.


Abstract: Discussions of various types of furnace designs from Apollo through ASTP.

Section I.B.2.


Abstract: A highly efficient radiation furnace for space processing of materials has been constructed. Temperatures exceeding 23000K can be achieved.
C. GENERAL APPLICATIONS

1. ECONOMIC STUDIES


   Abstract: Technical, resource planning and marketing steps necessary for space research and development by industrial groups.

   Abstract: Economic analysis using econometric and cost benefit analysis techniques was performed to determine feasibility of space processing high priority tungsten targets for medical x-ray tubes, turbine blades for jet engines, and electrophoresis for biological applications.
Section I. C. 1.


Abstract: Phase I involved identification of over 100 ideas for potential products, processes and services that might possibly be developed or produced in space facilities. Phase II investigated the technology and programmatic involved in development of 4 products chosen from Phase I list. Phase III was concerned with the business analysis and planning for the commercial development and product of the four Phase II products.


2. EQUIPMENT/SYSTEMS


Abstract: Serpentuator, powered mechanical linkage device, can serve as means of transport, guidance, stabilization and rendezvous for space manufacturing operations.

Section I.C.2.


Abstract: In Russian - Review of Soviet equipment designed for technological experiments on manned space missions and description of ground based test facilities.


Abstract: Various design considerations (such as size, weight, power, heat, etc.) are imposed on equipment used in spacecraft. The Skylab M518 furnace system and the ASTP MA-010 system are used as examples.

3. PROCESSES

Section I.C.3.

Abstract: Review of earth manufacture of boron filament technical literature. Techniques for space manufacture: substrate deposition, glow discharge, and RF positioning with induction or hot gas heating. Boron compounds, filaments.


Abstract: Prospects for space manufacturing of glasses, crystals, filaments, solid lubricants, cermets, cast composites, perfect spheres, sinters, seed materials, vaccines, enzymes, isotopes, antibiotics, and polymers. Liquid phase physical chemistry of zero-g instrumentation, and scaling laws are reviewed.


Section I.C.3.

Abstract: Potentials, limitations, and priorities of twenty-four processes for space manufacturing. Defines scientific and engineering criteria used in determining feasibility.


Abstract: Degassing and bubble migration in liquified materials without gravity. Metal and optical lens casting, crystal growth.


Abstract: Effect of nongravitational environments on the development of homogeneous materials that cannot be manufactured on earth.


Abstract: Ground based low-g experiments verification of space process capabilities. Defines a minimum equipment inventory of modular design. Procedures for synthesis and definition of dedicated and mixed rocket payloads.

Section I.C.3.


SECTION II. SPACE MANUFACTURING MANAGEMENT AND PLANNING

A. GENERAL PLANNING........................................ 23
B. SKYLAB PROGRAM PLANNING................................. 26
C. SOUNING ROCKET PLANNING................................... 28
D. SPACE SHUTTLE PLANNING/UTILIZATION..................... 30
E. SPACE SHUTTLE DESIGN/PAYLOAD INTERFACE.................. 34
A. GENERAL PLANNING


Abstract: Proposed program to develop space manufacturing in three phases: investigation of zero gravity effects on processes in earth orbit by packaging in Apollo Applications Program Orbital Workshop; improved space manufacturing chamber; and room size manufacturing module.


Abstract: Plans for space processing and manufacturing experiments on AAP Workshops, space station and shuttle.


Section II.A.


Abstract: Space Shuttle preparations for possible manufacturing operations on permanently orbiting space stations.


Abstract: Future development is based on current efforts in aeronautics, meteorology, telecommunications. Use of Spacelab as part of the Space Shuttle.


Abstract: (In German) Remote sensors, earth resources, air pollution; space manufacturing, mission planning, space shuttle, Spacelab economic factors.
Section II.A.


B. SKYLAB PROGRAM PLANNING


Abstract: Discussion of experiments (in science, technology, materials science and manufacturing in space) and support facilities on Skylab.


Abstract: Application of gravity control and vacuum, temperature, pressure and radiation characteristics of space to liquid-matrix preparation of composites, fine grain castings, supersaturated alloys, immiscible liquid-phase combinations, containerless free suspension, surface tension casting and drawing, adhesion casting and controlled density casting.


Abstract: Includes materials science/manufacturing in space.
Section II.B.


Abstract: Strength of adhesion and cohesion of melted metals appears undiminished by zero gravity. Brazing is practical for joining or repairing in space and is tolerant of dimensional gap variation.


Abstract: Space manufacturing as a minor topic.

C. Sounding Rocket Planning


Abstract: Summary of ground-based zero-gravity simulation techniques. Characteristics of sounding rockets are discussed.


Abstract: Announcement of Opportunity for the NASA Space Processing Applications Rocket Program (SPAR).


Abstract: Handbook provided to assist NASA and associated experimenters and apparatus suppliers to successfully perform SPAR experiments.


Abstract: A review of the possibilities and constraints of sounding rockets for space processing. The available facilities at Esrange, Sweden and the resources of the Swedish Space Corp. for managing a European sounding rocket program are presented.
Section II.C.


Abstract: Publication describing the Swedish sounding rocket launch facilities.


Abstract: Discussion of new developed sounding rocket furnaces.
D. SPACE SHUTTLE PLANNING/UTILIZATION


Abstract: Shuttle ground rules, manufacturing facilities requirements, ground requirements and verification test facilities, operations requirements, and interrelationships.


Abstract: Float-zone refined semi-conductors, oxide crystals, veral insecticides, vaccines, and biological cells.


Abstract: Initiation of a research and development program on the Space Shuttle missions, to prepare for possible commercial manufacturing operations on permanently orbiting space stations.


Section II.D.

Abstract: Feasibility of orbiting solar reflection and space power generation and distribution plants; space manufacturing.


Abstract: Space processing without convection or sedimentation and the high intrinsic values of some biologicals and electronic materials may warrant the efforts of space transportation.


Abstract: European industrial role in European space program definition and relationship (via ESRO and NASA) with U. S. firms.


Section II.D.


Abstract: Shuttle capabilities for satellite delivery, revisit, sortie mission, and delivery to higher orbits with the Tug.


Abstract: Space can routinely be made available to the Langley researcher via the shuttle-compatible spaceborne advanced technology laboratory with sortie flight operation mode.


Abstract: Management concepts and operating procedures for shuttle spacetlab operations, experimenter involvement, experiment development and data handling.


Section II.D.


Abstract: Spacelab users; shuttle interfaces, crew, models and configurations. Decision to be made by European governments. English translation.


E. SPACE SHUTTLE DESIGN/PAYLOAD INTERFACE


Abstract: Mission planning process in many areas including materials processing and space manufacturing. Working group reports.


Abstract: Payload definition, design and planning techniques in Space Shuttle program.


Abstract: Examination of subsystems resulting in common support system for integrated payload providing standardization and reduced turnaround time.


Abstract: Vol. 1 - Description of shuttle interface, operational analyses of experiment integration. Project and design guidelines given by ESRO are included.

Vol. 2 - Requirement assessment, trade-off studies and resulting preferred concept for each subsystem. Cost effectiveness and flexibility applied to arrive at a preferred configuration.
Section II.E.

Abstract: Vol. 3 - Technological implications, preliminary assessment of system costs, safety aspects, potential system growth (to 6 crew, 30 day mission).


Abstract: Description of ESRO organization for Space Shuttle payload planning. Evaluation of Sortie Lab design activity.


Abstract: Characteristics of Space Shuttle System, mission and performance baselines, orbital parameter/payload capability relationships, scientific and applications operating modes.


Abstract: Space Shuttle System, payloads and utilization including cost effectiveness.


Abstract: Results of Sortie Lab/Pallet system study. Sponsored by ESRO.
Section II. E.


Abstract: Areas recommended for investigation: effects of weightlessness on levitation, mixture stability, control over heat and mass transport in fluids. Research and development projects: metallurgical and non-metallic materials and processes, electronic materials and biological applications. Payload allocation; experiment acceptance and flight qualification; private use of shuttle.


Abstract: Final Report. Definition of skills required of crew in support of Sortie Lab space shuttle experiments.


Abstract: Summary of Sortie Lab (SL) analysis, source of systems requirements and experimental support for SL baseline. Configuration definition, mission analysis, experiment integration, safety and logistics.
Section II. E.


Abstract: (in German) Background, research objectives and design of Spacelab.


Abstract: Definition of facilities using modular, reusable research equipment in partial and dedicated payloads in Spacelab.


Abstract: Spacelab description and potential.


Abstract: Space Processing Applications activities in materials science, disciplines - Unique Space-lab and STS requirements.


Abstract: Potential of Shuttle-Spacelab combination to future users. Topics covered include attainable flight parameters, mission flexibility, data management, user services and programme schedules.

37

Abstract: Results of pulinmary accomodation study for a material science payload which was performed by Messerschmitt - Belkow - Blohm under ESA direction.
SECTION III. FLUID MECHANICS AND HEAT TRANSFER

A. GENERAL FLUID MOTION STUDIES......................... 39
B. GENERAL HEAT TRANSFER STUDIES.......................... 47
C. CONVECTION STUDIES........................................ 54
   1. GENERAL................................................. 54
   2. THERMODIFFUSION........................................ 57
   3. MARANGONI CONVECTION.................................. 59
   4. CONVECTIVE EFFECTS.................................... 60
D. LIQUID FLOATING ZONE..................................... 61
E. APPLICATIONS................................................. 63
A. GENERAL FLUID MOTION STUDIES


Abstract: During three-quarters of a second free-fall in a Dewar, adhesive forces caused liquid to "rise" into original gas space.


Abstract: Some key words: boundary layers, electrical discharges, electrical fields, electrophoresis, fluid dynamics, heat transfer, weightlessness.


Abstract: Some key words: heat transfer, radiant heating, saturation, temperature distribution, weightlessness.


Abstract: Some key words: camera, cylinder, Euler-Lagrange equation simulator.


Abstract: Translated by Andre L. Brechant
Some key words: cylinder, dynamics, flask, meniscus, pressure, rotation, surface tension, weightlessness, wetting.
Section III.A.


Abstract: Wall wetting fluids will distribute about the container with vapor centrally located, and can be accumulated in desired volumes by use of baffles. Based on interfacial surface energy configurations.


Abstract: Some key words: heat transfer, liquid, sloshing, liquid-vapor interfaces.


Abstract: Ground based experimental apparatus for filming liquid behavior in free fall for 0.9 seconds. Results for water and mercury. Translated from Russian (A6411349).


Abstract: Three and two dimensional analyses of gas pressure-pulse method; surface tension method of liquid transfer. Translated from Russian (A63-18195).
Section III. A.


Abstract: (In Russian) Processes occurring in a partially-filled spherical container during transition to zero gravity. (Translation, A65-20539).


(In English and French)


Abstract: Investigation of equilibrium configuration of fluid in absence of gravity field based on intersurface energy considerations. See also A63-15876.


Abstract: Weightless liquid propellant behavior - dynamics of liquids with a free surface, heat transfer to liquids in motion.


Section III. A.


Abstract: Effect of surface tension on weightless liquid behavior.


Abstract: Small linear oscillations of ideal fluid in the presence of surface tension in weightlessness or weak gravitational fields. English translation.


Abstract: Surface tension and equilibrium surfaces in weightless liquids, with application to spacecraft systems design.


Abstract: Complex hydrostatic and hydrodynamic behavior of liquids in low and zero gravity, laboratory simulation, and control of weightless liquids.
Section III. A.


Abstract: Effects of weak forces on weightless fluid, filling and emptying vessels and tubes, bubbles in a fluid, absence of convection. English translation.


Abstract: Hydrostatic and hydodynamic parameters important to liquid propellant altitude control system designers. Preliminary treatment of zero gravity heat transfer.


Abstract: Temperature control, pressure measurement, dynamic behavior, induction in a liquid drop, behavior in electrical and acoustical fields.


Abstract: (In Russian) Ideal liquid small oscillations, surface tension, equilibrium conditions and solution by decomposing vector function space.

Section III. A.


Abstract: Hand pump transferred liquids between surface tension baffled tanks within two percent of liquid residual design value without gas ingestion.


Abstract: In low-g environments, convective driving forces other than gravity will be comparable or predominant importance. Convections driven by steady low-g accelerations, g-jitter, internal thermal volume expansions, surface tension and interfacial tension, electric field, and liquid/solid phase change are covered.

Section III. A.

Abstract: Twelve MSFC science demonstration preliminary results are presented. Most of these demonstrations dealt with fluid motion in low-g.


Abstract: The state of knowledge of fluid motions in low-g environments is reviewed and the dimensional analysis approach used to assess the relative importances of various driving forces for fluid flow in four of the Skylab experiments is outlined. Space data is compared to dimensional analyses results.


Abstract: Skylab liquid film demonstration results are presented. Also discussed are 1-g acceleration experiments in which the unprovoked rupture of films was photographed and a mathematical discussion regarding minimal surfaces, and isoperimetric problem, and liquid films.


Abstract: Data analysis of two ASTP demonstrations.
Section III. A.


Abstract: Solutions or equations describing natural convection in a planar, horizontal layer of liquid with a constant linear temperature gradient along the unbounded top and bottom surfaces. Results are compared to earlier analyses for unbounded liquid layers and applied to low-g solidification.


Abstract: In the absence of gravity, it is shown that certain types of menisci lend themselves to estimating the magnitude and variation of long-range forces. Paper presents theoretical approach to an experiment proposed for operation in zero-gravity environment.

(39) Hayes, J. M., "Capillary Instabilities in l-g and 0-g", University of Bristol, United Kingdom, Second European Symposium on Material Sciences in Space, Frascati, Italy, April, 1976.

Abstract: Capillary hysteresis in the equilibrium behavior of fluids in porous media demonstrates that equilibrium is reached via a thermodynamically irreversible process.


Abstract: Preliminary results of SPAR I experiment 74-18.
B. GENERAL HEAT TRANSFER STUDIES


Abstract: Basic forces that influence nucleate-boiling heat transfer at zero gravity, with brief literature survey.

Abstract: Review of zero gravity research, specializing in cryogenic liquid behavior, including venting, heat transfer and instrumentation performance.

Abstract: Analysis of the heat conduction and vapor condensation between a fluid and its enclosing surface under conditions of weightlessness.

Abstract: Basic forces that influence nucleate-boiling heat transfer at zero gravity.
Section III. B.


Abstract: Nucleate pool boiling in near zero gravity environment.


Abstract: Bubble migration in zero and normal gravity. Drop tower study of surface tension effects.


Abstract: Magnitude of heat transfer coefficient of sodium condensation and electrophoresis for lubricant coatings on complex shapes.


Abstract: Nineteen articles. Experimental and numerical analyses of unsteady state heat and mass transfer. Soret coefficient.
Section III. B.


Abstract: Free and forced convection, boiling, condensation, forced flow and fuel combustion.


Abstract: Free convective heat transfer between hot and cold rotating disks in laminar steady azimuthally symmetric flow in a zero-gravity field.


Abstract: Momentum, continuity, and energy equations for one dimensional heat flow to a confined ideal gas are solved numerically. Thermal gradients induced acoustical fluid motion.


Abstract: (In Russian) Vibrations in absence of forced circulation produce higher heat and mass transfer than molecular transfer mechanism under conditions of weightlessness.


Abstract: Coupled heat and mass transfer equations for non-reactive chemical systems are analyzed.
Section III. B.


Abstract: (In French) Heat flux variation in boiling processes is a function of gravity. Experimental results from three second exposures are compared to theoretical predictions.


Abstract: Surface tension gradient effect is important in bubble motion and boiling in zero gravity.


Abstract: Translation from Russian. Equipment and procedure for studying heat transfer during boiling under short term weightlessness. Water boiling on flat plates in a cylindrical channel at 0.02 to 0.34 m/sec.


Section III. B.

Abstract: Summary of thermodynamic properties of liquid metals, heats of fusion and heat capacities.


Abstract: Experiment design, materials selection, and identification of system elements requiring further development.


Abstract: Procedure for computing pressure rise in a closed cylindrical container due to side wall heat flux.


Abstract: (In Russian) Blow gas extraction of fluids from tanks, vibration enhanced transport, analysis of bubble and droplet motion, steady and unsteady viscous flows in slots with non-parallel walls.
Section III. B.


Abstract: Flow observations and thermal data of Apollo 14 experiments have shown that: (i) there are, as expected, convective motions caused by surface tension gradients in a plane liquid layer with a free upper surface, (ii) heat flow in enclosed liquids and gases occurs mainly by diffusive heat conduction, (iii) some convective processes add to heat transfer.


Abstract: Results of Apollo 14 and 17 demonstrations are analyzed - two types of low-g natural convection.


Abstract: Steady state data on nucleate boiling heat transfer in nearly zero gravity liquid helium.
Section III. B.


Abstract: Simplified expressions neglecting Soret Coefficient, the Dufour effect and friction.


Abstract: The equations describing heat and particle flow during crystal growth by the travelling solvent method are described.

C. CONVECTION STUDIES

1. GENERAL


Abstract: Two experimental arrangements eliminate the effect of continued air circulation due to inertia. A procedure is proposed for a wickless flame experiment.


Abstract: Experimental simulation via analogy between unsteady heat conduction and species diffusion, extended also to include cubical tank geometry. Thermal mixing in Apollo Service Module cryogenic oxygen storage system.


Abstract: Liquid transfer, electrophoresis, composite casting and heat flow and convection experiments are reviewed.

Section III. C. 1.


Abstract: In less than 0.000001 g, data indicate 1) surface tension gradients produce convective motion; 2) heat flow in fluids is mainly by diffusive conduction; and 3) some convection (characteristics unknown) increases heat transfer.


Abstract: A finite difference technique for solving the differential equations for thermal convection of compressible fluids in low gravity. One-dimensional radial model of Apollo 14 heat flow and convection experiment.


Abstract: Convection of molten metals and their solidification in reduced gravity.
Section III. C. 1.


Abstract: Cellular, surface tension-driven convection and convection in confined fluids caused by spacecraft and astronaut movements.


Abstract: The modes and driving forces of natural convection in space are examined. Design considerations are advanced to minimize detrimental effects due to convection in microgravity.

Section III. C.1.

Abstract: G-jitter convection, caused by time-varying accelerations imparted on a heated container of fluid in low gravity is analytically investigated.


Abstract: Theoretical analysis of convection present in ground tests and Skylab processing of experiments M556, M559, M560 and M562.

(22) Ostrach, S., "Convection at Reduced Gravity", Case Western Reserve University, Cleveland, Ohio, Second European Symposium on Material Sciences in Space, Frascati, Italy April, 1976.

Abstract: Various modes of flow possible with the driving forces. Criteria for determining the extent and nature of the resulting flows and heat transfer.

2. THERMODIFFUSION


Section III. C. 2.


Abstract: Translated into English. Exact solution for measuring the coefficient of ordinary diffusion and the Soret coefficient in experiments of short duration.


Section III. C. 2.

Abstract: Definition of future research program based on Skylab and ASTP experiment results.

3. MARANGONI CONVECTION


Section III. C. 3.


Abstract: Theoretical considerations and experiments proposed to measure the temperature dependence of the surface tension and the motions in the melt.

4. CONVECTIVE EFFECTS


Abstract: Analytical and mathematical studies of floating zone and Czochralski techniques of single crystal growth.


D. LIQUID FLOATING ZONE


Abstract: Analysis of the Skylab liquid floating zone experiment data to examine the stability constraints in low-gravity for application to Shuttle-era processes.


Abstract: Liquid floating zones studies on Skylab are of interest in the containerless handling of melts for possible future space processing crystal growth experiments. Three basic types of zone deformation and instability were observed and analyzed for the rotational modes used.
Section III. D.


Abstract: Four aspects of fluid dynamics of floating zones are considered.


Abstract: The mathematical formulation of the problem of calculating the axi-symmetric equilibrium shapes of an incompressible fluid mass, held by surface tension forces between two parallel coaxial discs, and rotating about its axis, is considered.


Abstract: Review of some zero-gravity experiments concerning floating liquid zones is presented.
E. APPLICATIONS


Abstract: Wetting of the solid phase by the liquid during sintering is an important phenomenon in liquid phase sintering, and gravity has influence on both capillary phenomenon and density segregation.


Abstract: A renewed interest in the dynamic behavior of liquid drops and bubbles has resulted from their importance in the space processing of molten materials. Anticipated configurations and problems for crystal growth and solidification in zero gravity are discussed in light of the current state of knowledge of drop and bubble dynamics.
Section III. E.


Abstract: Study of potential application of low-gravity electrohydrodynamic effects and associated unique fluid handling capabilities to space processing.


Abstract: Crystal perfection in space as a function of fluid and mass transports.


Abstract: Studies on equilibrium figures of an isolated dielectric, non-conducting liquid drop, surrounded by another fluid, are considered as a method of manipulation and control of a weightless melt.
SECTION IV. SOLIDIFICATION PROCESSES

A. SOLIDIFICATION STUDIES ................................................. 65
   1. GENERAL ................................................................. 65
   2. EXPERIMENTATION ................................................... 68
   3. STUDIES OF SOLIDIFICATION PHENOMENA .................... 73

B. IMMISCIBLES ................................................................. 77

C. COMPOSITES/EUTECTICS .................................................. 81

D. CRYSTAL GROWTH ............................................................. 88
   1. GENERAL ................................................................. 88
   2. SOLUTION GROWTH ................................................... 93
   3. MELT GROWTH .......................................................... 94
   4. VAPOR GROWTH ....................................................... 97
   5. ANALYSIS ............................................................... 98
A. SOLIDIFICATION STUDIES

1. GENERAL


Abstract: Preparation of stable superconducting cables comprising a filamentary phase of one superconducting in a matrix of another, achieved by directional solidification under zero gravity.


Abstract: The processes or improved methods of processing exploiting weightlessness: elimination of melt phase density separation and thermal convection; moldless solidification; surface tension and electromagnetic forming. General requirements for space environment facilities.


Section IV. A. 1.


Abstract. Influence of magnetic fields and near zero gravity conditions on the behavior of dense liquid near the solidification point.


Abstract: Drop tower experiment of metal melting and resolidifying in three second free fall, measuring temperature-time histories of 0.05 cm Ni and 1090 steel droplets. Results of metalurgical analysis.


Abstract: Summarization of Solidification phenomena applications advantages of space processing.

Section IV. A. 1.


Abstract: Correlation of Apollo and Skylab Metallurgical experiment data.


Abstract: Final report on preparation of free-fall experiment devices and definition of experiment procedures.


Abstract: Crystal quality of Ge crystals of Skylab experiment M559.


Abstract: Many alloys with special physical properties (magnetic, electrical, etc.) are suited for preparation and improvement in space.

(18) Heye, W., Klemm, M., "Melting of a PbAgBaO - Powder Alloy under 0-G Environment (Rocket Flight), Deformed to Wires", Zellerfeld, Germany, Second European Symposium on Material Sciences in Space, Frascati, Italy, April, 1976.
2. EXPERIMENTATION


(2) "Apollo Experiment Definition Study", TRW Systems Group, Downey, Cal., NASA Contract NAS8-27085, Contractor No. TRW 18677-6008-R0-00, Nov, 1971.


Section IV. A. 2.


Abstract: Ground based simulation Skylab samples.


Section IV. A. 2.


Abstract: Evaluation of specimens SL-1.6, SL-2.8, SL-2.4, SL-1.10, and SL-1.11; comparison with ground processed specimens; sphericity, density, microporosity.


Abstract: Specimen Analysis of Skylab M553 Metals.


Abstract: Preliminary Results of M553 Sphere Forming Experiment.
Section IV. A. 2.


Abstract: Review of the eight Skylab experiments dealing with metal processing in space.


Abstract: M552 - Brazing in Space using an exothermic technique. Presentation of preliminary results.


Abstract: Preliminary results of study of the behavior of porous material when melted and resolidified in space.


Abstract: Metallurgical analyses of six Skylab M553 samples to study containerless solidification and the effects of weightlessness on solidification processes.


Section IV.A.2.


Abstract: Study of Solidification of magnetic materials.


Abstract: Study of Solidification Interface.


Abstract: Study of superconducting properties.


Abstract: Review of four metallurgical studies on ASTP.


Section IV. A. 3.

3. STUDIES OF SOLIDIFICATION PHENOMENA


Abstract: Major activities initiated in support of space manufacturing, aimed primarily at defining the role of gravity in solidification processes.


Abstract: Theoretical analysis of zero gravity effects on solidification. Fine single crystal candidates for space manufacturing: silicon, germanium, KTN, BANANAS (barium, sodium niobate), and CuCl.


Abstract: Combinations of Al, Ag, Zn, and Sn with carbon or boron-carbide powders subjected to liquid phase sintering in vacuum to determine effects of dissimilar densities and surface tensions. Wetting, absorption, and defect migration.


Section IV. A. 3.


Abstract: The equation of normal freezing for ideal ternary liquid solutions solidified into ideal solid solutions of the pseudobinary type is given. Sample calculations for the Ga-Al-As system are given.


Abstract: The differential equation of normal evaporation is solved for special cases, applied to a Ni-Al alloy and several binary iron alloys. Accuracy of prediction is checked against experimental data Fe-Ni, Ni-Cr, and vacuum purification of benzllium.


Abstract: Study of evaporative melt segregation and freezing segregation, development of normal evaporation equations, and correlation with experimental data reported in the literature.

Section IV. A. 3.


Abstract: Evaporation equations for predicting the compositional changes with time and temperature have been developed and correlated with actual experimental data.


Abstract: Design of apparatus and choice of optimum conditions for the growth of crystals in bulk or as exptaxial films requires a knowledge of a range of properties of solutions.

Section IV. A. 3.

Abstract: Influence of zero gravity on the concentration and temperature distribution around a growing dendrite in a binary alloy.
B. IMMISCIBLES

(1) Hammei, R. L., Kirkpatrick, M. E., Reger, J. L., "Reduced

Abstract: The effects of low gravity on immiscibility limits of two phase liquid melts, base solidification processes, experiment performance limits, requirements, interface criteria.


Abstract: Procedures and results of Apollo 14 composite casting demonstration, MSFC drop tower tests, and KC-135/M512 Facility tests.


Section IV. B.

Abstract: Seven metallic systems processed in low gravity tests: drop tower at Marshall Space Flight Center, M-512 aboard KC-135 aircraft and the M518 aboard Skylab exhibit more uniform dispersion and microstructure than the gravity samples.


Abstract: Electrical properties of zero gravity processed Ga-Bi samples differ significantly from properties of individual components and ground control samples, and possibly form a new class of electronic material.


Abstract: Preliminary results of M557 data analysis.


Abstract: Review of past activities in immiscible systems studies, current research at Battelle, and explore potentially useful immiscible systems which might benefit from 0-g processing.
Section IV. B.


Abstract: Report on TV102 Skylab results.


Abstract: Development of new materials manufacturing processes for space processing in the area of binary alloys which exhibit solid state immiscibility. The initial material system studied was gold-silicon.


Abstract: Potential applications for systems with liquid phase miscibility gaps were explored. Possibilities included superconductors, electrical contact materials, superplastics, catalysts, magnetic materials. The role of space processing in their production was also analyzed.

Section IV. B.


Abstract: Review of available experimental data on immiscible alloy solidification experiments which have been carried out in terrestrial and space environments.


C. COMPOSITES/EUTECTICS


Abstract: Investigation of electrophoretic deposition with whisker alignment. Secondary reinforcement of boron-epoxy system, copper-alumina whisker composites, and silicon carbide or alumina whisker reinforced epoxy composites.


Abstract: Proposes specific casting experiments and assesses modifications to basic process.


Abstract: Description of program for identification and selection of materials and methods for spherical forming and composite casting experiments of the AAP Workshop.
Section IV. C.


Abstract: Guidelines for hardware weight, volume, power, sample heating and solidification methods, etc. Candidate materials screening and selection was verified by ground based experiment. Engineering drawings included.


Abstract: Experimental program is proposed, specifying: materials, batch size, and mold shape; design, vehicle arrangement, and support requirements; controls, astronaut assistance and expected results.


Section IV. C.


Abstract: Results of liquid phase sintering (experiments 1 and 2) and dispersion of dense particles on a metal matrix rising shaking modes or forces in the system. Qualitative and quantitative interpretation of results.


Abstract: Evaluation of dispersion for mixtures of paraffin and sodium acetate; paraffin, sodium acetate and argon; and paraffin, sodium acetate, and 100 micrometer diameter tungsten spheres. Photographic and microstructure examinations, emsity, droplet size and distribution were measured.
Section IV. C.


Abstract: Final Report. Dispersions of particles, fibers, and gases in liquid metal matrices were maintained during translunar and transearth melting and solidification. Evaluation was made by comparison with ground-processed control samples.


Abstract: A program of sub-orbital and orbital experiments for 1972-1978 to identify materials, processes and experimental equipment for metal-base fiber and particle composites, controlled density metal foams, and eutectic alloys.
Section IV. C.


Abstract: Reexamination of Apollo 14 composite casting to explain unusual results: phase change and surface tension convection, Marangoni flow, bubble and droplet migration.

(27) "Directionally Solidified Composites: Known Also as In Situ Composites or Directionally Solidified Eutectics", NMA/B ad hoc Committee on Directional Solidification, Final Report NMA/B-301, April, 1973.


Section IV. C.


Abstract: Preliminary Results of Skylab Experiment M561.


Abstract: Preliminary science results of Skylab experiment M566.


Abstract: Preliminary science results of Skylab experiment M564.


Abstract: Discussion of techniques of solidification. Combination of experimental and analytical thermal studies for optimization of the solidification process.


Abstract: Suggest process to minimize concentration changes.
Section IV. C.


Abstract: Study objective was definition of materials and processes for the testing of aluminum case fiber and particle composites, and metal foams under extended low-g conditions, in particular for the SPAR program.


Abstract: Suggested improvements to alloy experiments in space.

(45) Lohberg, K., "Results of Studies on Wetting Behavior", Technische Universitat Berlin, Berlin, Germany, Second European Symposium on Material Sciences in Space, Frascati, Italy, April, 1976.
Section IV.C.

D. CRYSTAL GROWTH

1. GENERAL


Abstract: Analytical and mathematical studies of floating zone and Czochralski single crystal growth techniques to determine the role of convection.


Abstract: Principles and techniques of crystal growth. Outline of projected solution growth experiments.


Abstract: Glass solvent method of growing high temperature oxidic crystals. Zero gravity processing should reduce convection produced vacancies and dislocations as well as prevent rapid settling of the solutes.
Section IV. D. 1.


Abstract: Emphasizing electronic crystals grown from solution, and developing a solution type process to demonstrate the growth of potassium sodium niobate crystals from potassium sodium silicate glass solution.


Abstract: Operational unit for growing crystals in zero gravity, specifically gallium arsenide.


Abstract: Tin melted in a furnace on a centrifuge was cooled during rotation to grow single crystals. Visual analyses were made with a scanning electron microscope.


Section IV. D. 1.

Abstract: Space Processing of sophisticated compound single crystals for electronics in 1980's (ceramic oxides and compound semi-conductors) with maximum perfection, purity, and size is suggested.


Abstract: Study of crystal growth mechanisms which may be affected by the space environment, technical and scientific advantages without regard to economic advantage, recommendations of several Shuttle experiments.


Abstract: Theoretical and experimental work on near-zero gravity effects on crystal and metallic whisker growth during Skylab and Apollo experiments. Indium-bismuth compounds, bismuth single crystals, gallium arsenide films and single crystals and cadmium whiskers.


Abstract: Design of a ribbon puller. Attempt to grow a conventional float zone crystal in an external static magnetic field.

Section IV. D. 1.

Abstract: Growth of electronic ceramic single crystals from solutions including fused or glass solvents and aqueous solutions, growth and characterization of triglycine sulphate.


Abstract: Description of results of the six Skylab crystal growth experiments.


Section IV. D. 1.


Abstract: Preliminary results of SPAR I experiment 74-37.


Abstract: Report on preparation of experiment to be performed at variable accelerations above 1g.


Abstract: Methods of growth and effects of Microgravity are discussed.


Section IV.D.1.


Abstract: Review of experiment results for ASTP experiments: MA060 (Melt Growth), MS085 (Vapor Growth), MA-028 (Solution Growth).


2. SOLUTION GROWTH


Abstract: Silver, copper, gold and their alloys investigation to develop background information to support space flight experiment and generate ground based data for comparison.


Section IV. D. 2.


Abstract: Report on preliminary results of science demonstration TV-106, silver crystals grown by electrochemical deposition of silver ion from solution by copper.


Abstract: Investigation of the effects of convection of crystal properties. Crystal growth from solution is discussed, in particular the Rochelle salt crystals grown on Skylab IV.

3. MELT GROWTH


Abstract: Value of perfect single crystals, factors limiting perfection, and a crystal pulling apparatus are discussed.


Abstract: Brief outline of normal gravity single crystal growth from melts. Review effects of interface shape, high-g, gamma-ray, and electromagnetic body forces. Proposed experiment to study growth kinetics in equivalent gravity fields.


Abstract: Preliminary results of Skylab experiment M560.


Abstract: Preliminary results of Skylab experiment M562.


Abstract: Preliminary results of Skylab experiment M563.

Section IV. D. 3.


Abstract: Results obtained prove the advantageous conditions provided in outer space. Ideal diffusion controlled steady-state conditions were achieved during the growth of Te-doped InSb crystals on Skylab.


Abstract: Summary of final results of Skylab experiment M562.


Abstract: Preliminary results of ASTP experiment MA-060.


Abstract: New concept derived to explain off-facet striations in InSb Skylab samples. Concept considers decrease of liquidus temperature in the initial transient region.


Abstract: Growth rate oscillations and pulsations may be triggered in the thermal transient region.

4. VAPOR GROWTH


Abstract: Preliminary results of Skylab experiment M556. Analysis based on comparison of GeSe and GeTe crystals and mass transport rate data obtained on earth and in space indicate crystals of improved quality could be grown in space by the vapor transport technique.

Section IV. D. 4.

Abstract: Post flight preliminary report of ASTC experiment MA-085.


Abstract: Description of the European tentative proposals for the first Spacelab flight.


5. ANALYSIS


Abstract: Brief discussion of modern techniques to detect ultratrace impurities and dislocation-type imperfections influencing electronic properties of gallium arsenide.

Section IV. D. 5.


Abstract: Three nondestructive methods of electrical characterization of semiconductor single crystals are discussed.


Abstract: Two crystal growth processes under consideration for Spacelab experiments were studied. Computer calculations were performed on transport processes in floating zone melting and crystal growth from solution under low-gravity conditions.


Abstract: A selected bibliography on known electrical characterization techniques for semiconductors.
SECTION V. CONTAINERLESS PROCESSING

A. GENERAL STUDIES................................................................. 100

B. POSITION/CONTROL TECHNIQUES........................................... 101
   1. GENERAL................................................................. 101
   2. ACOUSTIC FIELDS.................................................. 101
   3. ELECTROMAGNETIC FIELDS.......................................... 103

C. HEATING/COOLING TECHNIQUES............................................. 105
   1. GENERAL................................................................. 105
   2. INDUCTION HEATING.................................................. 105
   3. ELECTRON BEAM.................................................... 105
   4. SOLAR ENERGY....................................................... 107
   5. LASER................................................................. 107
   6. WELDING STUDIES................................................... 107

D. APPLICATION STUDIES.......................................................... 109
   1. GENERAL................................................................. 109
   2. SINGLE CRYSTAL PROCESS........................................... 110
A. GENERAL STUDIES


Abstract: Qualitative evaluation of two levitation coil designs.


Abstract: Super alloy castings with rare earth oxides, metal emulsions casting, ultrapure materials preparation, and solidification with extreme subcooling.


Abstract: Melt solidification, crystal growth from melt, microstructure formation.


Abstract: Introduction to containerless processing, techniques for positioning and manipulation in zero-g, and possible applications.
B. POSITION/CONTROL TECHNIQUES

1. GENERAL


Abstract: Description and application of electro-mechanical transfer, positioning and retrieving devices for an orbiting manufacturing facility.

2. ACOUSTIC FIELDS


Abstract: Patent application. Acoustic transducers establish a standing wave pattern in a rectangular furnace chamber to position an object under low gravity conditions.

Section V. B. 2.


Abstract: Design of a resonator to position molten materials in an extreme temperature gradient and a servo loop to maintain position as temperature varies.


Abstract: Description of a new non-contact positioning device for space processing. Containerless melting and solidification can be performed and a freely suspended liquid can be shaped to the contour of the sound field.


Abstract: By readily levitating, positioning, and manipulating materials placed in it, the acoustic resonator can serve a variety of space processing operations, such as drawing crystals, degassing and stirring of melts, and casting.


Abstract: Description of newly developed furnace utilizing acoustic positioning techniques.
Section V. B. 3.

3. **ELECTROMAGNETIC FIELDS**


Abstract: Derivation of levitation forces exerted by spatially non-uniform arc magnetic fields on nonmagnetic conducting spheres as the negative gradient of a potential function.


Abstract: Long circular cylinder supported by a.c. field produced by two conductors parallel to the cylinder axis. Boundaries for the stable float region were determined for 2 cm diameter aluminum bar with wires 2, 4 and 6 cm apart with ac frequency at 50,400 and 2,000 Hz.


Abstract: Brief review of high magnetic pressure application, particularly metal forming by pulsed 100 kilogauss magnetic fields and levitation of superconducting rings by 10 kG static magnetic fields.
Section V. B. 3.


Abstract: Discussion of machine for trapped hot plasma stability and confinement studies in vacuum, emphasizing superconducting aspects and coil performance.


Abstract: Four coil optimization, four vs. six coil comparison; four coil position servocontrol and breadboard; position sensing servosystem; two color pyrometer, and specimen rotation mode analysis.


105
C. HEATING/COOLING TECHNIQUES

1. GENERAL


Abstract: Assessment of available heat sources for zero-gravity processing: weight, bulk, power, reliability, safety, and cost.

2. INDUCTION HEATING


Abstract: Translated from Russian. Crucible-less electromagnetic levitation and heating.

3. ELECTRON BEAM


Abstract: (In Hungarian) Equipment design features and performance. Results of use with alloy steels and aluminum alloys in zero and normal gravity.


Abstract: Electrochemical and electron beam techniques in material processing. Some key words: Boron, electrophoresis, etching, silicon.
Section V. C. 3.


Abstract: Description of battery operated laboratory and second generation flight models.


Abstract: A 60 lb., 2-kw, 20 kv electron beam device is discussed.


Abstract: Translated from Russian. Comparison of results of laboratory and Soyuz 6 operations of maneuverable thin sheet metal cutter/welder.

Section V. C. 4.

4. SOLAR ENERGY


Abstract: Orbital or lunar high temperature processing opportunities and problems with refractory metals (tungsten, tantalum, iridium).


Abstract: (In Russian) Description of equipment used for solar energy welding, soldering and heat treating. Parabolic 2 meter reflector produced 20 kcal/sq. cm./min. Test data for tubular steel and titanium alloy.

5. LASER


6. WELDING STUDIES


Abstract: Electron beam welding and cutting, low pressure plasma arc welding and cutting, and arc welding with fused electrode were investigated in weightlessness. Translated into English.
Section V. C. 6.


Abstract: Effects of porosity on weld joint performance, sources of porosity, weld thermal effects, residual stresses and distortions, and manufacturing process system control.


Abstract: Plasma Arc, electron-beam, and consumable electrode arc welding. Translated into English.


D. APPLICATION STUDIES

1. GENERAL


Abstract: Specific processing needs to 18 representative materials/combinations likely to be processed advantageously in weightlessness of space flight using electromagnetic positioning and heating.


Abstract: Work concerns further definition of a containerless processing facilities for the Space Laboratory and Space Shuttle. Four material process examples were studies as representative with severe requirements for the facility in areas such as power, heat dissipation, etc.


Abstract: Specific heats, heats of fusion, and surface emissionities.
Section V. D. 2.

2. SINGLE CRYSTAL PROCESS


Abstract: Translated into English. Based on 67 single crystals of molybdenum.


Abstract: Directional solidification of a containerless melt that was suspended at the end of a seed crystal was employed to produce crystals of InSb during Skylab missions (SL3 and SL4).
SECTION VI. GLASS AND CERAMIC MATERIAL PROCESSING

A. GENERAL STUDIES................................................................. 111

B. METHODS OF PREPARATION................................................ 115
   1. GENERAL............................................................... 115
   2. SLIP CASTING...................................................... 115
   2. LASER SPIN MELTING............................................. 115
A. GENERAL STUDIES


Abstract: Superheating and cooling without normal nucleation sites (i.e. container walls) may permit glass production from normally crystalline materials such as Al₂O₃, HfO₂, ZrO₂, etc.


Abstract: Super alloy castings with rare earth oxides, metal emulsions casting, ultrapure materials preparation, and solidification with extreme subcooling.


Abstract: Crucible free melting, glasses sensitive to thermal convection, lenses and mirror blanks with fire polished surfaces direct from melt, dispersion filters, nucleation control through solid power dispersion.


Abstract: Superheating and cooling without normal nucleation sites (i.e. container walls) may permit glass production for normally crystalline materials such as Al₂O₃, HfO₂, ZrO₂, etc.

Section VI. A.


Abstract: Maintenance of two-phase immiscibility is essential to opacity.


Abstract: Preliminary study of processing equipment for new glass production in zero gravity. Induction and laser melting are preferred. Calculation of power for melting and calculation of cooling rates.


Abstract: Free-fall cooled spherules of previously unreported glassy-state composition were produced from laser melted spinning ceramic-oxide rods.


Abstract: The absence of a mold in space processing offers no heterogeneous nucleation sites. New glasses with interesting combinations of optical properties e.g. index of refraction and dispersion, then might be produced.
Section VI. A.


Abstract: Summary discussions of state of the art technology in glass and ceramic preparation, applicability to space processing, potential applications.


Abstract: Study to determine effects of processing glass-ceramic materials in low-gravity environment.


Abstract: The work involves the premise that diffusion studies of the glass forming ion can be examined in zero-gravity environments and diffusion data obtained from these experiments will be unique because of earth based experimental problems.

Section VI. A.


Abstract: Chalcogenide glasses are considered as potential candidate materials for use as laser windows and infrared fiber optics. This project is being conducted to investigate space processing of chalcogenide glasses.


Abstract: A programme for pre-studies of space processing based on German experiment proposals in the field of glasses and ceramics has been recommended.
B. METHODS OF PREPARATION

1. GENERAL


Abstract: Forming from vapors, foamed ceramics, fibers, bulk placement and molding, impregnation, reaction sintering, high-energy-rate forming, electrophoretic forming, and machining and grinding.


2. SLIP CASTING


Abstract: To consolidate ceramic, cermet, and metal powders to high density; slurry process, chemistry of deflocculation, particle size distributions, rheology, binders, mixing, molding and the casting process.

3. LASER SPIN-MELTING

Section VI. B. 3.


SECTION VII. ELECTROPHORETIC, CHEMICAL AND BIOCHEMICAL PROCESSES

A. GENERAL SEPARATION STUDIES .................................................. 117

B. ELECTROPHORETIC METHODS ..................................................... 119
   1. GENERAL STUDIES .......................................................... 119
   2. PARTICLE ELECTROPHORESIS .......................................... 123
   3. ELECTROMAGNETOPHORESIS ............................................ 123
   4. CONTINUOUS FREE FLOW ELECTROPHORESIS ......................... 123
   5. GEL ELECTROPHORESIS .................................................. 124
   6. IMMUNOELECTROPHORESIS ............................................. 125
   7. DISC ELECTROPHORESIS ................................................ 126
   8. PAPER ELECTROPHORESIS .............................................. 126
   9. CONTROL METHODS ........................................................ 127
  10. ELECTROPHORETIC EQUIPMENT ........................................... 127
  11. APPLICATIONS .............................................................. 128
  12. DIELECTROPHORESIS ..................................................... 130
  13. CHROMATOGRAPHY .......................................................... 131
  14. ISOTACHOPHORESIS ......................................................... 132

C. GENERAL CHEMICAL PROCESS STUDIES ...................................... 133

D. GENERAL BIOCHEMICAL PROCESS STUDIES .................................. 134
A. GENERAL SEPARATION STUDIES


Abstract: Study of heat exchange, mechanical, dielectrophoresis, surface tension, and rotation methods of separation.


Abstract: Centrifugation and electrophoresis, freeze drying and ultraviolet sterilization.


Abstract: Orbital facility with solar powered electrical generator and particle accelerator emphasizing production of plutonium or U-235.


Abstract: Re-examination of separation technique for possible use in space processing.

Section VII. A.

Abstract: Separation methods to be used during experiments in space biology are reviewed.
B. ELECTROPHORETIC METHODS

1. GENERAL STUDIES


Section VII. B.


Abstract: Experiment to demonstrate principle and possible problems. Color photographs of separation.


Abstract: Free fluid electrophoresis to separate particulate species by surface charge, size or shape. Dye separation was photographed, biological separation was simulated using polystyrene latex.

Section VII. B.


Section VII. B.


Abstract: Value of space electrophoresis is enhanced by isoelectric focusing and isotochophoresis to increase resolution.


Abstract: The study is concerned with the effectiveness of electrophoresis in space compared with similar separation done on the ground and the consideration of what biological materials or biomedical problems will benefit from electrophoresis in space.


Abstract: Current state of the art of electrophoresis, emphasis on the role of gravity and the possible use of istachophoresis.


Abstract: Engineering and operational tests of zone electrophoresis apparatus in low-gravity.

123
Section VII.B.


Abstract: Paper reports recent study of the technical and scientific problems inherent in the design, construction, and operation of a containerless floating zone electrophoresis facility suitable for Spacelab flight.


2. PARTICLE ELECTROPHORESIS


3. ELECTROMAGNETOPHORESIS


4. CONTINUOUS FREE FLOW ELECTROPHORESIS

Section VII.B.


(4) Hannig, K., Wirth, H., "Detailed Results of ASTP Experiment MA-014 (Continuous Flow Electrophoresis)", Max-Planck, Institut fur Biochemie, Munchen, Germany, Second European Symposium on Material Sciences in Space, Frascati, Italy, April 1976.

(5) Ostrach, S., "Convection in Continuous - Flow Electrophoresis", Case Western Reserve University, Cleveland, Ohio, Second European Symposium on Material Sciences in Space, Frascati, Italy, April 1976.

Abstract: Various types of convection possible in electrophoresis devices are indicated and criteria are presented from which estimates can be made of the importance of convection in separation.


Abstract: Thicker separation chamber operations can be performed in low-g than 1-g permitting improved resolution or shorter separation time per unit of sample.

5. GEL ELECTROPHORESIS

Section VII. B. 6.

6. IMMUNOELECTROPHORESIS

(1) Russel, W. J., "Some Influences of Antigen Concentration and Nonreacting Additives on Mobility and Diffusion in Immunolectrophoresis", Journal of Immunology, Vol. 95, School of Aerospace Medicine, USAF, Brooks AFB, TX SAM-TR-66-219 (68N87844), Feb., 1966.


Abstract: Commercially available and synthetic wide range and short range ampholytes used in the isoelectric focusing of proteins can be analyzed by ion exchange chromatography.


Abstract: Vertical liquid columns with density gradients to simulate zero gravity, and upward electrophoresis in vertical columns are hampered by convection and sedimentation problems which can be eliminated by a zero gravity environment.
Section VII. B. 6.


Abstract: Work associated with pre-flight and post-flight analyses of ASTP experiment MA011.


Abstract: A promising experiment in this direction would be to perform suspend cell cultures to study the mechanism of T- and B-cell cooperation under better defined conditions.

7. DISC ELECTROPHORESIS


8. PAPER ELECTROPHORESIS

Section VII. B. 8.


9. CONTROL METHODS


Abstract: Gamma amino propyl trihydroxysilane provides low potential coating (-3.86 mv.) as surface of shear between mobile and stationary layers to control electrokinetic effects.


Abstract: Measurement technique developed to evaluate the effects of hydrophilic coatings on electroosmotic flow.

10. ELECTROPHORETIC EQUIPMENT

(1) Shaw, R. K., "Preparative Electrophoresis Equipment for Laboratory Use", Suffield Experiment Station, Ralston, Alberta, SUFFIELD-TP-204, (65N21717), April, 1964.


Section VII. B. 10.

Abstract: Critical review of electrophoresis, study of new techniques for enhancing resolution and stability, and construction and testing of a high resolution cell.


Abstract: Three major tasks of this contract are Task I - Design Criteria Optimization - Math Modeling; Task II - Design, Build, and Test a flowing electrophoretic Separator System, and Task III - Experimental operations of the system.

11. APPLICATIONS

(1) Freetz, W., "Separation, Isolation, and Investigation of Mixed Ligand Complex of Platinum Elements with the Help of High Voltage Electrophoresis", Technische University, Berlin, Germany, (70N77103), 1963.
Section VII. B. 11.


Section VII. B. 11.


Abstract: Due to convection and sedimentation, separation at 1g is less than ideal, but it is expected that at 0 gravity electrophoresis will prove to be a uniquely powerful cell separation tool.


Abstract: Electrophoretic techniques are limited in achieving its fullest potential by gravity effects. A zero-gravity facility on Shuttle will provide new impetus to both our cell biology research and its applications to diverse problems in medicine.


Abstract: Review of MA011 and MA014 ASTP electrophoresis experiments.

12. DIELECTROPHORESIS


Section VII. B. 12.


Abstract: Transient and steady state nucleate boiling for heating surface horizontal up, vertical and horizontal down orientations, observing conduction and convection regimes.


Abstract: Small and full scale electrode systems experiments indicate full scale performance predictibility from small scale breakdown tests. Aluminum and stainless steel electrodes with Teflon supports were compatible with oxygen and hydrogen.


Abstract: English translation.

13. CHROMATOGRAPHY

(1) Verly, W., "Preparation and Purification of Toritiated Geranyllinooliol", Liege University, Belgium, (66N13590), 1965.
Section VII.B.13.


14. ISOTACHOPHORESIS


C. GENERAL CHEMICAL PROCESS STUDIES


Abstract: Effects of reduced gravity and weightlessness on fluidized bed polymerization reaction.


Abstract: Method of manufacturing homogeneous foamed materials in weightless environment from constituents having different physical properties.

D. GENERAL BIOCHEMICAL PROCESS STUDIES


(5) Kober, C. L., "Chemical and Biochemical Space Manufacturing", MMA, Denver, Colorado, (71N26013), April, 1970, 10 pgs.


Abstract: Some key words: Biological effects, dialysis, fermentation, metabolic wastes, microorganisms; buoyancy, reduced gravity; liquid-gas mixtures; space shuttle.
Section VII. D.

APPENDIX A

SUBJECT INDEX
## SUBJECT INDEX

<table>
<thead>
<tr>
<th>Subject</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Fields, Containerless Processing</td>
<td>V.B.2</td>
</tr>
<tr>
<td>Biochemical Processes, General</td>
<td>VII.D</td>
</tr>
<tr>
<td>Casting of Glasses and Ceramics</td>
<td>VI.B.2</td>
</tr>
<tr>
<td>Ceramics</td>
<td>VI.A.</td>
</tr>
<tr>
<td>Chemical Processes, General</td>
<td>VII.C</td>
</tr>
<tr>
<td>Composite Casting</td>
<td>IV.C</td>
</tr>
<tr>
<td>Containerless Processing</td>
<td>V.</td>
</tr>
<tr>
<td>Containerless Processing, Acoustic Fields</td>
<td>V.B.2</td>
</tr>
<tr>
<td>Containerless Processing, Applications</td>
<td>V.D.</td>
</tr>
<tr>
<td>Containerless Processing, Electromagnetic Fields</td>
<td>V.B.3</td>
</tr>
<tr>
<td>Containerless Processing, Furnaces</td>
<td>V.C.1</td>
</tr>
<tr>
<td>Containerless Processing, Hardware</td>
<td>V.B.1</td>
</tr>
<tr>
<td>Containerless Processing, Heating and Cooling Techniques</td>
<td>V.C.</td>
</tr>
<tr>
<td>Containerless Processing, Position Control</td>
<td>V.B.</td>
</tr>
<tr>
<td>Containerless Processing, Single Crystal Growth</td>
<td>V.D.2</td>
</tr>
<tr>
<td>Convection</td>
<td>III.C</td>
</tr>
<tr>
<td>Convection, Effect on Crystal Growth</td>
<td>III.C.4</td>
</tr>
<tr>
<td>Convection, Marangoni</td>
<td>III.C.3</td>
</tr>
<tr>
<td>Convection, Thermo Diffusion</td>
<td>III.C.2</td>
</tr>
<tr>
<td>Subject</td>
<td>Section</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Crystal Growth</td>
<td>IV.D</td>
</tr>
<tr>
<td>Crystal Growth, Analysis</td>
<td>IV.D.5</td>
</tr>
<tr>
<td>Crystal Growth, Containerless Processing</td>
<td>V.D.2</td>
</tr>
<tr>
<td>Crystal Growth, Effect of Convection</td>
<td>III.C.4</td>
</tr>
<tr>
<td>Design/Pav : Interface</td>
<td>II.E</td>
</tr>
<tr>
<td>Dielectrophoresis</td>
<td>VII.B.12</td>
</tr>
<tr>
<td>Electromagnetic Fields, Containerless Processing</td>
<td>V.B.3</td>
</tr>
<tr>
<td>Electrophoresis, General Studies</td>
<td>VII.B.1</td>
</tr>
<tr>
<td>Electrophoretic Deposition</td>
<td>VII.B.9</td>
</tr>
<tr>
<td>Electrophoretic Methods</td>
<td>VII.B</td>
</tr>
<tr>
<td>Electron Beam, Heating in Containerless Processing</td>
<td>V.C.3</td>
</tr>
<tr>
<td>Facilities, Space Manufacturing</td>
<td>I.B.</td>
</tr>
<tr>
<td>Fluid Mechanics and Heat Transfer</td>
<td>III.</td>
</tr>
<tr>
<td>Fluid Mechanics and Heat Transfer, Applications</td>
<td>III.E</td>
</tr>
<tr>
<td>Fluid Motion</td>
<td>III.A</td>
</tr>
<tr>
<td>Furnaces for Containerless Processing</td>
<td>V.C.1</td>
</tr>
<tr>
<td>Glass and Ceramic Material Processing</td>
<td>VI.</td>
</tr>
<tr>
<td>Glass and Ceramic, Method of Preparation</td>
<td>VI.B.</td>
</tr>
<tr>
<td>Heating and Cooling Techniques, Containerless Processing</td>
<td>V.C.</td>
</tr>
<tr>
<td>Heat Transfer</td>
<td>III.B</td>
</tr>
<tr>
<td><strong>Subject</strong></td>
<td><strong>Section</strong></td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Immunoelectrophoresis</td>
<td>VII.B.6</td>
</tr>
<tr>
<td>Induction Heating in Containerless Processing</td>
<td>V.C.2</td>
</tr>
<tr>
<td>Interface Design/Payload</td>
<td>II.E.</td>
</tr>
<tr>
<td>Laser Spin Melting</td>
<td></td>
</tr>
<tr>
<td>Laser Heating in Containerless Processing</td>
<td>V.C.5</td>
</tr>
<tr>
<td>Liquid Floating Zone</td>
<td>III.D</td>
</tr>
<tr>
<td>Manufacturing (See Space Manufacturing)</td>
<td></td>
</tr>
<tr>
<td>Marangoni Convection</td>
<td>III.C.3</td>
</tr>
<tr>
<td>Melt Growth, Crystal Growth</td>
<td>IV.D.3</td>
</tr>
<tr>
<td>Planning, Skylab</td>
<td>II.B.</td>
</tr>
<tr>
<td>Planning, Space Shuttle</td>
<td>II.D.</td>
</tr>
<tr>
<td>Position Control, Containerless Processing</td>
<td>V.B.</td>
</tr>
<tr>
<td>Separation Studies, General</td>
<td>VII.A.</td>
</tr>
<tr>
<td>Single Crystal Growth</td>
<td>IV.D.</td>
</tr>
<tr>
<td></td>
<td>V.D.2</td>
</tr>
<tr>
<td>Skylab Program Planning</td>
<td>II.B.</td>
</tr>
<tr>
<td>Slip Casting</td>
<td>VI.B.2</td>
</tr>
<tr>
<td>Solar Heating in Containerless Processing</td>
<td>V.C.4</td>
</tr>
<tr>
<td>Solidification Processes, General Studies</td>
<td>IV.A.1</td>
</tr>
<tr>
<td>Solution Growth, Crystal Growth</td>
<td>IV.D.2</td>
</tr>
<tr>
<td>Sounding Rocket Planning</td>
<td>II.C.</td>
</tr>
<tr>
<td>Space Manufacturing, General</td>
<td>I.</td>
</tr>
</tbody>
</table>

139
<table>
<thead>
<tr>
<th>Subject</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Manufacturing, Facilities</td>
<td>I.B.</td>
</tr>
<tr>
<td>Space Manufacturing, General Applications</td>
<td>I.C.</td>
</tr>
<tr>
<td>Space Manufacturing, Management and Planning</td>
<td>IV.</td>
</tr>
<tr>
<td>Space Manufacturing, Survey Papers</td>
<td>I.A.</td>
</tr>
<tr>
<td>Space Shuttle, Design/Payload Interface</td>
<td>II.E.</td>
</tr>
<tr>
<td>Space Shuttle, Planning and Utilization</td>
<td>II.D.</td>
</tr>
<tr>
<td>Survey Papers, Space Manufacturing</td>
<td>I.A.</td>
</tr>
<tr>
<td>Thermodiffusion</td>
<td>III.C.2</td>
</tr>
<tr>
<td>Vapor Growth, Crystal Growth</td>
<td>IV.D.4</td>
</tr>
<tr>
<td>Welding Studies</td>
<td>V.C.6</td>
</tr>
</tbody>
</table>
APPENDIX B

CONTRACT INDEX
Contract Index

By Subject

I. General Space Manufacturing and Planning

A. Survey Papers
   Contracts: 8-26979 General Dynamics, Convair

B. Facilities
   Contracts: 8-20582 Astro-Space Labs, Inc.
             8-20707 Astro-Space Labs, Inc.
             8-21279 Martin Marietta Corp.
             8-26122 Westinghouse
             8-27718 Hewlett-Packard
             8-28055 Massachusetts Institute of Technology
             8-28059 Weiner Associates
             8-28271 Westinghouse
             8-28729 Lockheed Missiles and Space Company
             8-29769 Antcor Inc.
             8-28960 Lockheed Missile and Space Company
             8-29860 Georgia Institute of Technology
             8-30036 Astro-Space Labs, Inc.
             8-30268 Lockheed Missile and Space Company
             8-30289 Westinghouse
             8-30166 Astro-Space Labs, Inc.
             8-30528 Astro-Space Labs, Inc.
             8-30741 Bendix Corporation

C. General Application Papers
   Contracts: 8-29748 Battelle Memorial Institute
             8-25202 Carnegie-Mellon University
             8-28615 General Dynamics, Convair
             8-28179 General Electric Company, Space Science Div.
             8-29874 Arthur D. Little, Inc.
             8-29669 United Aircraft Corp., Pratt and Whitney
             8-29881 Auburn University
             8-27942 General Electric
             8-31533 McDonnell Douglas Astronautics Co.
             8-21279 Martin Marietta Corp.
             8-28938 TRW System Group
             8-24633 General Electric Corp.
             8-24979 General Electric Corp.
             8-27734 Universities Space Research Association

II. Space Manufacturing Management and Planning

A. General Planning
Contracts: 8-21012 Electro-Optical Systems, Inc.
8-20146 General Dynamics, Convair
8-25179 Georgia Institute of Technology
8-28644 Boeing
8-27015 Lockheed Missiles and Space Co.

F. General Heat Transfer Studies
Contracts: 8-21143 University of Alabama - Tuscaloosa
8-25577 Lockheed Missiles and Space Co.

C. Convection Studies
Contracts: 8-25577 Lockheed Missiles and Space Co.
8-27015 Lockheed Missiles and Space Co.
8-29710 Lockheed Missiles and Space Co.
8-28732 Massachusetts Institute of Technology

C. Liquid Floating Zone
Contracts: 8-29877 Arthur D. Little, Inc.
8-27015 Lockheed Missiles and Space Co.

E. Application Studies
Contracts: 8-30250 Colorado State University
IV. Solidification Processes

A. Solidification Studies

Contracts: 8-24592 Cornell Aeronautical Laboratory
8-27891 Grumman Aerospace Corp.
8-28308 Texas Instruments
8-28056 Grumman Aerospace Corp.
8-28604 Grumman Aerospace Corp.
8-28664 Boeing Aerospace Company, Huntsville
8-28723 Arthur D. Little, Inc.
8-28724 United Aircraft Corp., Pratt and Whitney
8-28725 Battelle Memorial Institute
8-28728 Grumman Aerospace Corp.
8-28729 Lockheed Missiles and Space Co.
8-28732 Massachusetts Institute of Technology
8-28733 University of Wisconsin
8-28734 University of Connecticut
8-28734 Georgia Institute of Technology
8-28749 Battelle Memorial Institute
8-28730 Westinghouse Electric Corp.
8-29145 Arthur D. Little, Inc.
8-29626 Battelle Memorial Institute
8-29650 University of Alabama, Huntsville
8-29662 Grumman Aerospace Corp.
8-29851 Texas A&M University
8-29854 University of California, Los Angeles
8-29877 Arthur D. Little, Inc.
8-29951 Brown Engineering Company
8-31350 Massachusetts Institute of Technology
8-31384 Battelle - Northwest
8-21123 Lockheed Missiles and Space Co.
8-30561 Athens College
8-31529 Grumman Aerospace Corp.

B. Immiscibles

Contracts: 8-27085 TRW Systems Group
8-28267 TRW Systems Group
8-28309 TRW Systems Group
8-29748 Battelle Memorial Institute
8-27809 University of Alabama
8-29725 Washington State University

C. Composite Casting Studies

Contracts: 8-21402 Arthur D. Little, Inc.
8-25709 Arthur D. Little, Inc.
8-26402 University of California, Los Angeles
C. Composite Casting Studies (Cont'd)

Contracts:  
8-26991 University of Alabama, Huntsville  
8-27106 Cornell Aeronautical Laboratory  
8-27806 General Dynamics, Convair  
8-28189 Massachusetts Institute of Technology  
8-28735 Georgia Institute of Technology  
8-29620 General Dynamics, Convair  
8-29799 Grumman Aerospace Corp.  
8-27085 TRW Systems Group  
8-28724 United Aircraft Corp.  
8-29629 Battelle Memorial Institute  
8-29854 University of California at Los Angeles  
8-31534 Marvaland, Inc.

D. Crystal Growth

Contracts:  
8-29847 University of Southern California  
8-30576 Massachusetts Institute of Technology  
8-28306 Massachusetts Institute of Technology  
8-24683 General Electric Corp.  
8-24509 Westinghouse Electric Corp.  
1-11869 Southern Methodist University  
8-27807 Texas Instruments, Inc.  
8-28305 University of Southern California  
8-31530 Grumman Aerospace Corp.  
8-26122 Westinghouse  
8-28098 University of Alabama at Huntsville  
8-29077 Eagle-Pitcher, Inc.  
8-29875 Battelle Memorial Institute  
8-28189 Massachusetts Institute of Technology  
8-28304 University of Alabama at Huntsville  
8-26146 Rensselaer Polytechnic Institute  
8-30578 Rensselaer Polytechnic Institute  
8-29494 University of Alabama at Huntsville  
8-30171 PEC Research Associates  
8-29542 University of Alabama at Huntsville  
8-29650 University of Alabama at Huntsville  
8-30744 University of Alabama at Huntsville  
8-26122 Westinghouse Research Laboratories  
8-24612 University of Alabama at Huntsville  
8-25120 University of Alabama at Huntsville  
8-26158 Westinghouse Research Laboratories  
8-28112 University of Alabama, Huntsville  
8-28114 General Electric Company, Space Div.  
8-26793 University of Alabama, Huntsville  
8-28725 Battelle Memorial Institute  
8-30537 Massachusetts Institute of Technology
V. Containerless Processing

A. General Studies
8-30250 Colorado State University
8-28729 Lockheed Missiles and Space Co.

B. Position Control Techniques
Contracts: 8-28762 Interand Corp.
8-29030 Interand Corp.
8-30471 Intersonics, Inc.
8-27228 General Electric Company, Space Science Div.
8-29680 General Electric Company, Space Sciences Lab.

C. Heating and Cooling Techniques
Contracts: 8-29860 Georgia Institute of Technology
8-30268 Lockheed Missiles and Space Co.
8-25364 Massachusetts Institute of Technology
8-24365 Massachusetts Institute of Technology
8-21347 Lockheed Missiles and Space Co.
8-28059 Weiner Associates, Inc.
8-29769 Artcor Corp.
8-30289 Westinghouse Research Laboratories

D. Application Studies
Contracts: 8-26157 General Electric Company
8-29879 General Electric Company
8-29860 General Electric Company

VI. Glass and Ceramic Material Processing

A. General Studies
Contracts: 8-28014 North American Rockwell
8-28991 Rockwell International Corp.
8-30627 ITT Research Institute
8-30656 Vanderbilt University
8-29850 ITT Research Institute
8-29626 Battelle Memorial Institute

B. Methods of Preparation Studies
Contracts: 8-29850 ITT Research Institute

VII. Electrophoretic, Chemical and Biochemical Processes

A. General Separation Studies
Contracts: 8-29609 Lockheed Missiles and Space Co.
8-29629 Battelle Memorial Institute
8-30252 Howard University
B. Electrophoretic Methods
Contracts: 8-28654 Lehigh University
8-29878 General Electric Co., Space Sciences Lab.
8-24683 General Electric Company
8-28474 Beckman Instruments, Inc.
8-29566 University of Arizona
8-29629 Battelle Memorial Institute
8-29745 State University of New York, Buffalo
8-29778 Georgetown University
8-29823 Wayne State University
8-30887 University of Oregon
8-30253 University of Utah
8-296551 Fairchild Hiller, Inc.
8-28365 General Electric Company
8-30591 Abbott Labs
8-29874 Arthur D. Little
8-20229 University of Michigan
8-20553 Dynatech Corp.

C. General Chemical Process Studies

D. General Biochemical Process Studies
Contracts: 8-26552 Fairchild Hiller Corporation
8-27797 General Electric Company, Space
8-28085 Battelle Memorial Institute
8-28411 Massachusetts Institute of Technology
APPENDIX C

AUTHOR INDEX
AUTHOR INDEX

ABDALLA, K. L. III.A.26 ARNETT, G. M. IV.D.5(2) BENEDIKT, E. T. III.A.14
ADAMS, E. F. VI.B.2(1) ASOIANETS, G. V. V.C.3(6) BENEFIELD, J. W. III.B.23
ALBERTI VII.B.12(6) AUBIN, W. M. IV.A.1(9) BENZ, K. IV.J.1(19)(28)
ADEMÖRGEN. M. VII.B.12(6) IV.A.2(14) BERGE, K. D. II.A.12II.D.19
AERNOUDT, E. IV.A.2(25) BAILEY, R. V. III.B.7) BERGE, L. H. V.B.1(1)
AHLBORN, H. IV.A.1(17) BARLOW, G. H. VII.B.1(29) BERGHEZAN, A. IV.C.43
ALADEV, I. T. III.B.18) BANNISTER, T. C. I.A.3(4) IV.C.6) VERKOWITZ-MATTUCK, J.
ALDRICH, B. R. I.B.2(7) I.C.3(12) IV.C.6)
ANG, C. IV.A.2(28(35) IV.C.42) BELOUET, C. III.E.6) BIRD, J. O.
ANDRADE, J. D. VII.B.9(2) I.C.3(7) VII.B.1(25)(28)(29) BIER, M. VII.B.6(8)
ANDREWS, J. B. V.C.6(2) III.A.25) VII.B.11(11) VII.B.14(1)
BECK, R. I.A.4(4) BIGAZZI, P. E. VII.B.1(29) VII.B.6(3)
BEYERLE, F. J. IV.D.2(5)(6) IV.C.2(5)
<table>
<thead>
<tr>
<th>Author</th>
<th>Section</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhat, B. N.</td>
<td>IV.C</td>
<td>39</td>
</tr>
<tr>
<td>Blutt, J. R.</td>
<td>VII.B</td>
<td>12(4)</td>
</tr>
<tr>
<td>Bloom, H. L.</td>
<td>I.C.1(4)(6)</td>
<td>V.D.1(3)</td>
</tr>
<tr>
<td>Boese, A.</td>
<td>I.C.2(4)</td>
<td></td>
</tr>
<tr>
<td>Boulay, J. L.</td>
<td>III.B</td>
<td>16</td>
</tr>
<tr>
<td>Boundy, R. A.</td>
<td>I.C.3</td>
<td>13</td>
</tr>
<tr>
<td>Bourgeois, S. V.</td>
<td>III.A</td>
<td>29(32)(35)(36)(37)</td>
</tr>
<tr>
<td></td>
<td>IV.C</td>
<td>26</td>
</tr>
<tr>
<td>Bowers, D. J.</td>
<td>VI.B</td>
<td>1(1)</td>
</tr>
<tr>
<td>Bowman, T. E.</td>
<td>III.A</td>
<td>18</td>
</tr>
<tr>
<td>Boyd, R.</td>
<td>I.C.2(1)</td>
<td></td>
</tr>
<tr>
<td>Brandt, R. C.</td>
<td>VI.A</td>
<td>6</td>
</tr>
<tr>
<td>Brashears, M. R.</td>
<td>I.B.1(7)</td>
<td>III.A(29)(32)</td>
</tr>
<tr>
<td></td>
<td>IV.A.2(15)</td>
<td>V.A.(5)</td>
</tr>
<tr>
<td>Braski, D. H.</td>
<td>III.C.2(5)(6)(7)</td>
<td></td>
</tr>
<tr>
<td>Brazinsky, I.</td>
<td>III.A</td>
<td>1</td>
</tr>
<tr>
<td>Cary, T.</td>
<td>I.I.A</td>
<td>8</td>
</tr>
<tr>
<td>Castle, J. G.</td>
<td>IV.D.1(14)</td>
<td>IV.D.5(8)(10)</td>
</tr>
<tr>
<td>Caston, I.</td>
<td>III.C.4</td>
<td>1</td>
</tr>
<tr>
<td>Causse, J. P.</td>
<td>II.D</td>
<td>18</td>
</tr>
<tr>
<td>Chanin, L. M.</td>
<td>VII.B</td>
<td>1(18)</td>
</tr>
<tr>
<td>Hang, C. E.</td>
<td>III.C.2(6)</td>
<td></td>
</tr>
<tr>
<td>Chernousko, F. L.</td>
<td>III.A</td>
<td>16(17)</td>
</tr>
<tr>
<td>Chi, J. W. H.</td>
<td>I.B</td>
<td>2(8)</td>
</tr>
<tr>
<td>Chu, T. L.</td>
<td>IV.D.1(13)</td>
<td>IV.D.1(17)</td>
</tr>
<tr>
<td>Chung, A. M.</td>
<td>I.C.1</td>
<td>2</td>
</tr>
<tr>
<td>IV.D.1(12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clanet, F.</td>
<td>VII.B</td>
<td>13(5)</td>
</tr>
<tr>
<td>Brashears, J. R.</td>
<td>III.C.4</td>
<td>6</td>
</tr>
<tr>
<td>Clark, D. A.</td>
<td>VII.B</td>
<td>5(11)</td>
</tr>
<tr>
<td>Clark, M. F.</td>
<td>V.B</td>
<td>3(6)</td>
</tr>
<tr>
<td>Author</td>
<td>Index</td>
<td>Page References</td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Clayton, D. A.</td>
<td></td>
<td>III. A. (22)</td>
</tr>
<tr>
<td>Desforges, C. D.</td>
<td></td>
<td>IV. B. (17)</td>
</tr>
<tr>
<td>Ehricke, K. A.</td>
<td></td>
<td>II. D. (5)</td>
</tr>
<tr>
<td>Colledge, R.</td>
<td></td>
<td>III. C.2(3)</td>
</tr>
<tr>
<td>Dodge, F. T.</td>
<td></td>
<td>III. B. (35)</td>
</tr>
<tr>
<td>Euus</td>
<td></td>
<td>II. B. (3)</td>
</tr>
<tr>
<td>Cook, J. L.</td>
<td></td>
<td>IV. C. (14)</td>
</tr>
<tr>
<td>Dooling, D., Jr.</td>
<td></td>
<td>I.A.1(17)</td>
</tr>
<tr>
<td>Ellemann, D. D.</td>
<td></td>
<td>V. B.2(4)(6)(8)</td>
</tr>
<tr>
<td>Cornish, D. N.</td>
<td></td>
<td>V. B.3(5)</td>
</tr>
<tr>
<td>Doty, J. P.</td>
<td></td>
<td>IV. D.2(3)</td>
</tr>
<tr>
<td>Ewell, D.</td>
<td></td>
<td>IV. A.3(16)</td>
</tr>
<tr>
<td>Crandall, W. B.</td>
<td></td>
<td>VI. A. (9)</td>
</tr>
<tr>
<td>Douglas, F. C.</td>
<td></td>
<td>IV. C. (21)(37)</td>
</tr>
<tr>
<td>Ensanian, M.</td>
<td></td>
<td>VII. C. (3)</td>
</tr>
<tr>
<td>Coller, P. E.</td>
<td></td>
<td>II. D. (11)</td>
</tr>
<tr>
<td>Doce, K.</td>
<td></td>
<td>VII. B. (19)</td>
</tr>
<tr>
<td>Eber, E.</td>
<td></td>
<td>I.C.3(14)</td>
</tr>
<tr>
<td>Darbo, W.</td>
<td></td>
<td>III. A. (34)</td>
</tr>
<tr>
<td>Downey, J. W.</td>
<td></td>
<td>V. A. (2)</td>
</tr>
<tr>
<td>Eyer, A.</td>
<td></td>
<td>I.B.2(9)</td>
</tr>
<tr>
<td>Dariva, I.</td>
<td></td>
<td>III. D. (9)</td>
</tr>
<tr>
<td>Downs, W. R.</td>
<td></td>
<td>V. C.5 (1)</td>
</tr>
<tr>
<td>Everaets, F. M.</td>
<td></td>
<td>VII. B.1(8)</td>
</tr>
<tr>
<td>Davis, J. H.</td>
<td></td>
<td>IV. D.1(11)(14)</td>
</tr>
<tr>
<td>Dragoo, A. L.</td>
<td></td>
<td>III. C.3(3)</td>
</tr>
<tr>
<td>Eberna, W.</td>
<td></td>
<td>I.C.2(1)</td>
</tr>
<tr>
<td>Debler, W. R.</td>
<td></td>
<td>III. C.3(2)</td>
</tr>
<tr>
<td>Duga, J.</td>
<td></td>
<td>IV. B. (15)</td>
</tr>
<tr>
<td>Fabiniak, R.</td>
<td></td>
<td>IV. A.1 (2)</td>
</tr>
<tr>
<td>Deeg, E. W.</td>
<td></td>
<td>VI. A. (3)</td>
</tr>
<tr>
<td>Duncan, C. S.</td>
<td></td>
<td>I.B.2(2)(8)</td>
</tr>
<tr>
<td>Fabiniak, T. J.</td>
<td></td>
<td>IV. A.1(2)</td>
</tr>
<tr>
<td>Delancey, G. B.</td>
<td></td>
<td>II. B. (13)</td>
</tr>
<tr>
<td>Dunga</td>
<td></td>
<td>IV. D.1(8)</td>
</tr>
<tr>
<td>Facemire, B. R.</td>
<td></td>
<td>IV. A.3(3)</td>
</tr>
<tr>
<td>Dennis, M. D.</td>
<td></td>
<td>IV. D.2(1)</td>
</tr>
<tr>
<td>Dverniankov, V. S.</td>
<td></td>
<td>IV. C. (17)</td>
</tr>
<tr>
<td>Edwards, D. K.</td>
<td></td>
<td>IV. D.3(3)</td>
</tr>
<tr>
<td>Deruyttere, A.</td>
<td></td>
<td>III. B. (12)</td>
</tr>
<tr>
<td>Faessler, A.</td>
<td></td>
<td>III. C.1(3)</td>
</tr>
<tr>
<td>Author</td>
<td>Index</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Fahimian, F. J.</td>
<td>VII.C.1(2)</td>
<td></td>
</tr>
<tr>
<td>Farn, C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farrell, M.</td>
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<tr>
<td>Feldmanis, C. J.</td>
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</tr>
<tr>
<td>Fleck, J. N.</td>
<td>IV.C.(3)</td>
<td></td>
</tr>
<tr>
<td>Fleming, M. G.</td>
<td>IV.D 1(2)</td>
<td></td>
</tr>
<tr>
<td>Föx, M.</td>
<td>V.4(1)</td>
<td></td>
</tr>
<tr>
<td>Forbes, R. E.</td>
<td>III.B.19</td>
<td></td>
</tr>
<tr>
<td>Foster, J. F.</td>
<td>VII.D.(6)</td>
<td></td>
</tr>
<tr>
<td>Fink, W. B.</td>
<td>VII.B.12(1)</td>
<td></td>
</tr>
<tr>
<td>Foxle, A. A.</td>
<td>III.D.(4)</td>
<td></td>
</tr>
<tr>
<td>Frahm, J. L.</td>
<td>VII.B.8(2)</td>
<td></td>
</tr>
<tr>
<td>Franke, B.</td>
<td>I.A.1(16)</td>
<td></td>
</tr>
<tr>
<td>Frantsevich, I. N.</td>
<td>V.C.4(2)</td>
<td></td>
</tr>
<tr>
<td>Fredrikson, H.</td>
<td>IV.A.3(17)</td>
<td></td>
</tr>
<tr>
<td>Frost, R. T.</td>
<td>IV.A.1(4)</td>
<td></td>
</tr>
<tr>
<td>Fuller, L. D.</td>
<td>IV.D.3(1)</td>
<td></td>
</tr>
<tr>
<td>Furr, H. P.</td>
<td>V.E.(4)</td>
<td></td>
</tr>
<tr>
<td>Gehart, D.</td>
<td>III.B.(4)</td>
<td></td>
</tr>
<tr>
<td>Gelles, S. H.</td>
<td>V.V.(11)(15)(16)</td>
<td></td>
</tr>
<tr>
<td>George, F. D.</td>
<td>IV.C.(24)</td>
<td></td>
</tr>
<tr>
<td>Geschwind, G. I.</td>
<td>IV.A.1(9)</td>
<td></td>
</tr>
<tr>
<td>Gibson, E. G.</td>
<td>III.A.(33)</td>
<td></td>
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<tr>
<td>Golovin, G. F.</td>
<td>V.C.2(1)</td>
<td></td>
</tr>
<tr>
<td>Godd, R. J.</td>
<td>III.A.(5)(13)</td>
<td></td>
</tr>
<tr>
<td>Gondt, P.</td>
<td>IV.-.4(44)</td>
<td></td>
</tr>
<tr>
<td>Gorham, D. J.</td>
<td>I.A.1(13)</td>
<td></td>
</tr>
<tr>
<td>Greer, F.</td>
<td>I.C.2(1)</td>
<td></td>
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<tr>
<td>Green, M.</td>
<td>III.C.(1)</td>
<td></td>
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<tr>
<td>Green, M. D.</td>
<td>II.B.(8)</td>
<td></td>
</tr>
<tr>
<td>Greenwell, E. N.</td>
<td>III.A.2(34)</td>
<td></td>
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<td>Greg, G.</td>
<td></td>
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<tr>
<td>Griesenauer, N. D.</td>
<td>IV.A.3(6)</td>
<td></td>
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<tr>
<td>Griesenauer, N. D.</td>
<td>IV.D.2(4)</td>
<td></td>
</tr>
<tr>
<td>Griffin, R. N.</td>
<td>I.C.3(3)</td>
<td></td>
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<td>Grin, C.</td>
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<td>Grodzka, P. G.</td>
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<tr>
<td>Author</td>
<td>Volume</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------</td>
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</tr>
<tr>
<td>GRODZKA, P. G.</td>
<td>IV.A.1</td>
<td>(3)</td>
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<tr>
<td></td>
<td>IV.A.3</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>IV.C.</td>
<td>(26)</td>
</tr>
<tr>
<td></td>
<td>IV.D.1</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>IV.D.2</td>
<td>(7)</td>
</tr>
<tr>
<td></td>
<td>VII.A.</td>
<td>(5)</td>
</tr>
<tr>
<td>GRUS, K.</td>
<td>III.C.</td>
<td>(6)</td>
</tr>
<tr>
<td>GUILI, R. T.</td>
<td>I.A.</td>
<td>(3)</td>
</tr>
<tr>
<td>GUSTA, K.</td>
<td>IV.A.3</td>
<td>(5)</td>
</tr>
<tr>
<td></td>
<td>IV.B.</td>
<td>(14)</td>
</tr>
<tr>
<td>GUREVICH, I. G.</td>
<td>III.B</td>
<td>(10)</td>
</tr>
<tr>
<td>HAESSNER, F.</td>
<td>IV.A.3</td>
<td>(14)</td>
</tr>
<tr>
<td>HAGGERTY, J. S.</td>
<td>III.D.</td>
<td>(4)</td>
</tr>
<tr>
<td>HALBACH, C. R.</td>
<td>I.B.</td>
<td>(2)</td>
</tr>
<tr>
<td>HAMMEL, R. L.</td>
<td>II.D.</td>
<td>(6)</td>
</tr>
<tr>
<td></td>
<td>II.E.</td>
<td>(15)</td>
</tr>
<tr>
<td></td>
<td>IV.B.</td>
<td>(1)</td>
</tr>
<tr>
<td>HANKINS, B. K.</td>
<td>VII.B.</td>
<td>(9)</td>
</tr>
<tr>
<td>HANNIG, K.</td>
<td>VII.B.</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>VII.B.1</td>
<td>(12)</td>
</tr>
<tr>
<td></td>
<td>VII.D.</td>
<td>(9)</td>
</tr>
<tr>
<td>HAPPE, R. A.</td>
<td>VI.A.</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>(4)(5)(7)</td>
<td>(8)(10)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author</th>
<th>Volume</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>HART, R. K.</td>
<td>I.B.</td>
<td>(6)</td>
</tr>
<tr>
<td>HASSAN, C. B.</td>
<td>V.C.</td>
<td>(4)(5)</td>
</tr>
<tr>
<td>HASEMEYER, E. A.</td>
<td>IV.C.</td>
<td>(3)</td>
</tr>
<tr>
<td>HATCH, A. J.</td>
<td>V.B.</td>
<td>(2)</td>
</tr>
<tr>
<td>HATTERICK, R. G.</td>
<td>II.E.</td>
<td>(13)</td>
</tr>
<tr>
<td>HAUGHNEY, L. C.</td>
<td>II.D.</td>
<td>(14)</td>
</tr>
<tr>
<td>HAYNES, J. M.</td>
<td>III.A.</td>
<td>(39)</td>
</tr>
<tr>
<td>HEBERLIG, J. C.</td>
<td>II.E.</td>
<td>(6)</td>
</tr>
<tr>
<td>HERMAN, C. J.</td>
<td>IV.D.</td>
<td>(12)</td>
</tr>
<tr>
<td>HEDDEN, R. O.</td>
<td>III.B.</td>
<td>(25)</td>
</tr>
<tr>
<td>HEEMSTER, R. J.</td>
<td>VII.B.</td>
<td>(5)</td>
</tr>
<tr>
<td>HEDGEPETH, L. M.</td>
<td>III.B.</td>
<td>(6)</td>
</tr>
<tr>
<td>HEMMINGER, W.</td>
<td>IV.A.</td>
<td>(3)</td>
</tr>
<tr>
<td>HENRICI, J.</td>
<td>II.D.</td>
<td>(8)</td>
</tr>
<tr>
<td></td>
<td>I.C.</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>IV.D.1</td>
<td>(6)(7)</td>
</tr>
<tr>
<td></td>
<td>IV.D.1</td>
<td>(16)</td>
</tr>
<tr>
<td>HENRY, H. R.</td>
<td>III.B.</td>
<td>(22)</td>
</tr>
<tr>
<td>HERRANZ, J. M.</td>
<td>III.D.</td>
<td>(8)</td>
</tr>
<tr>
<td>HEYE, W.</td>
<td>IV.A.</td>
<td>(18)</td>
</tr>
<tr>
<td></td>
<td>IV.A.2</td>
<td>(31)</td>
</tr>
<tr>
<td>HIBBS, A. R.</td>
<td>I.C.</td>
<td>(13)</td>
</tr>
<tr>
<td>HOEZ, M.</td>
<td>V.C.</td>
<td>(4)</td>
</tr>
<tr>
<td>HICKLEY, D. N.</td>
<td>VII.B.</td>
<td>(28)</td>
</tr>
<tr>
<td>HOPPES, R. V.</td>
<td>II.A.</td>
<td>(1)</td>
</tr>
<tr>
<td>HORYLEV, R. J.</td>
<td>IV.B.</td>
<td>(14)</td>
</tr>
<tr>
<td>HUBBARD, J. L.</td>
<td>IV.A.2</td>
<td>(11)</td>
</tr>
<tr>
<td></td>
<td>IV.C.</td>
<td>(33)</td>
</tr>
<tr>
<td>HUDSON, V.</td>
<td>VII.A.</td>
<td>(1)</td>
</tr>
<tr>
<td>HUEBNER, V. R.</td>
<td>VII.B.2</td>
<td>(1)(2)</td>
</tr>
<tr>
<td>HURWITZ, M.</td>
<td>VII.B.1</td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td>VII.B.2</td>
<td>(12)</td>
</tr>
<tr>
<td>ITO, R.</td>
<td>III.C.</td>
<td>(2)</td>
</tr>
<tr>
<td>JABLONOWSKI, E. J.</td>
<td>IV.C.</td>
<td>(3)</td>
</tr>
<tr>
<td>JANN, W. K.</td>
<td>VII.B.1</td>
<td>(23)</td>
</tr>
<tr>
<td>Author</td>
<td>Index</td>
<td>Page Numbers</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>--------------</td>
</tr>
<tr>
<td>Jain, V. K.</td>
<td>Keck, P. H.</td>
<td>III.D(1)</td>
</tr>
<tr>
<td>Johnson, A. A.</td>
<td>Khomov, A.</td>
<td>III.B(33)</td>
</tr>
<tr>
<td>Johnson, P. C.</td>
<td>Kirko, I. M.</td>
<td>VII.B.12(6)</td>
</tr>
<tr>
<td>Johnston, M. H.</td>
<td>Klett, M. G.</td>
<td>IV.A.2(31)</td>
</tr>
<tr>
<td>Jones, T. B.</td>
<td>Klett, M. G.</td>
<td>III.A(35)</td>
</tr>
<tr>
<td>Juntz, R. S.</td>
<td>Knoll, R. H.</td>
<td>III.A(3)</td>
</tr>
<tr>
<td>IV.D.1(25)</td>
<td></td>
<td>VII.B.6(7)</td>
</tr>
<tr>
<td>Kattamis, T. Z.</td>
<td>I.C.3(4)</td>
<td>II.A(6)</td>
</tr>
<tr>
<td>V.A.2(5)(16)(40)</td>
<td></td>
<td>VII.D(5)</td>
</tr>
<tr>
<td>I.C.3(9)</td>
<td></td>
<td>III.C.2(5)(7)(8)</td>
</tr>
<tr>
<td>IV.C(25)</td>
<td>Kawada, T.</td>
<td></td>
</tr>
<tr>
<td>IV.C(32)(34)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

152
<table>
<thead>
<tr>
<th>Author</th>
<th>Index</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambdin, F.</td>
<td>IV.C. 14</td>
<td></td>
</tr>
<tr>
<td>Langbein, D.</td>
<td>III.B. 36</td>
<td></td>
</tr>
<tr>
<td>Lands, J. F.</td>
<td>III.C. 1(4)</td>
<td></td>
</tr>
<tr>
<td>Larkin, B. K.</td>
<td>III.B. 13</td>
<td></td>
</tr>
<tr>
<td>Larson, D. C.</td>
<td>IV.A. 1(9)</td>
<td></td>
</tr>
<tr>
<td>Lavine, M. C.</td>
<td>IV.D. 3(12)</td>
<td></td>
</tr>
<tr>
<td>Leffever, R. A.</td>
<td>III.C. 3(2)</td>
<td></td>
</tr>
<tr>
<td>IV.D. 1(24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV.D. 5(9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levy, M.</td>
<td>II.A. 1(11)</td>
<td></td>
</tr>
<tr>
<td>Lewis, G.</td>
<td>II.C. 4(30)</td>
<td></td>
</tr>
<tr>
<td>Lierke, E. G.</td>
<td>V.B. 2(9)</td>
<td></td>
</tr>
<tr>
<td>Li, C.</td>
<td>IV.A. 2(21)</td>
<td></td>
</tr>
<tr>
<td>IV.A. 3(7)(8)(9)(10)(13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV.D. 1(21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lih openly, D.</td>
<td>VII.B. 6(9)</td>
<td></td>
</tr>
<tr>
<td>Libermann, H. M.</td>
<td>VII.B. 1(11)</td>
<td></td>
</tr>
<tr>
<td>Libby, W. F.</td>
<td>I.C. 3(2)</td>
<td></td>
</tr>
<tr>
<td>III.C. 2(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lichtenstein, M.</td>
<td>IV.D. 3(7)(12)</td>
<td></td>
</tr>
<tr>
<td>Lindberg, R. G.</td>
<td>VII.B. 1(27)</td>
<td></td>
</tr>
<tr>
<td>Lin, M.</td>
<td>IV.D. 3(8)</td>
<td></td>
</tr>
<tr>
<td>Littles, J. W.</td>
<td>III.B. 24</td>
<td></td>
</tr>
<tr>
<td>Lingren, W. E.</td>
<td>VII.B. 8(1)</td>
<td></td>
</tr>
<tr>
<td>Liubin, L. I.</td>
<td>III.A. 10(21)</td>
<td></td>
</tr>
<tr>
<td>III.B. 14(26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locker, J. R.</td>
<td>II.C. 8</td>
<td></td>
</tr>
<tr>
<td>VII.B. 4(6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lohberg, K.</td>
<td>IV.C. 45</td>
<td></td>
</tr>
<tr>
<td>Lovoy, C. V.</td>
<td>IV.C. 35</td>
<td></td>
</tr>
<tr>
<td>Lu, H. Y.</td>
<td>VII.B. 13(2)</td>
<td></td>
</tr>
<tr>
<td>VII.C. 17(7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lukas, H. L.</td>
<td>IV.A. 3(14)</td>
<td></td>
</tr>
<tr>
<td>Massaglia, A.</td>
<td>VII.B. 12(3)</td>
<td></td>
</tr>
<tr>
<td>Mazelski, R.</td>
<td>I.B. 2(4)</td>
<td></td>
</tr>
<tr>
<td>Mazerkian, J.</td>
<td>I.C. 3(13)</td>
<td></td>
</tr>
<tr>
<td>Subuchi, K.</td>
<td>I.C. 7(17)</td>
<td></td>
</tr>
<tr>
<td>IV.A. 2(3)(7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V.C. 6(2)(3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massinelli, A.</td>
<td>VII.B. 12(3)</td>
<td></td>
</tr>
<tr>
<td>VILLEBEIN, D.</td>
<td>I.B. 1(24)</td>
<td></td>
</tr>
<tr>
<td>Lundholm, J. G.</td>
<td>II.B. 1(1)</td>
<td></td>
</tr>
<tr>
<td>Lundquist, C. A.</td>
<td>I.A. 3(2)</td>
<td></td>
</tr>
<tr>
<td>IV.A. 2(23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV.D. 1(20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Markgrafe, J. L.</td>
<td>III.B. 21</td>
<td></td>
</tr>
<tr>
<td>V.D. 1(5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Markworth, A. J.</td>
<td>IV.B. 15</td>
<td></td>
</tr>
<tr>
<td>Marshall, D. L.</td>
<td>VII.B. 1(26)</td>
<td></td>
</tr>
<tr>
<td>VII.B. 10(7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marshall W. R.</td>
<td>II.E. 2</td>
<td></td>
</tr>
<tr>
<td>Martin, L. L.</td>
<td>VII.B. 1(10)</td>
<td></td>
</tr>
<tr>
<td>Martin, R. C.</td>
<td>II.C. 1</td>
<td></td>
</tr>
<tr>
<td>Maserjian, J.</td>
<td>I.C. 3(13)</td>
<td></td>
</tr>
</tbody>
</table>

153
<table>
<thead>
<tr>
<th>Author Name</th>
<th>Section</th>
<th>Weight</th>
<th>Index Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>MECKLENBURG, K. R.</td>
<td>III.B. (8)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MEIER, H. U.</td>
<td>VII.B.1 (17)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MELCHER, J. R.</td>
<td>VII.B.12 (2)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MERKULOV. I.</td>
<td>I.B.1 (8)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MERTE, H., JR.</td>
<td>III.B. (24)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MESSMANN, G.</td>
<td>VII.B.12 (5)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>METTLER, R. F.</td>
<td>I.A.9 (1)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MICALE, F. J.</td>
<td>VII.B.1 (16)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MIKHAILOV, V. D.</td>
<td>VII.B.12 (5) (6)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MILLER, J. F.</td>
<td>IV.D.2 (4)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MILLER, R. I.</td>
<td>III.A. (29)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MITCHELL, R. C.</td>
<td>VII.A. (1)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MITIN, R. V.</td>
<td>VII.B.1 (20)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MIYAGAWA, I.</td>
<td>IV.D.2 (2) (8)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MIZUSHINA, T.</td>
<td>III.C.2 (4)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MONROE, R. E.</td>
<td>IV.A.2 (12) (17) (19)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MONTGOMERY, B. O.</td>
<td>I.A.1 (30)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MOOKHERJI, T.</td>
<td>III.E. (3)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MORGENTHALER, G. W.</td>
<td>II.E. (8)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MUKHERJEE, J. L.</td>
<td>IV.A.3 (4) (5)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MULHOLLAND, D. R.</td>
<td>II.D. (13)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>MULLER, G.</td>
<td>IV.D.1 (27)</td>
<td>154</td>
<td></td>
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<tr>
<td>MURAKI, T.</td>
<td>III.C.1 (7)</td>
<td>154</td>
<td></td>
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<tr>
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<td>III.B. (7)</td>
<td>154</td>
<td></td>
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<td>III.C. (3)</td>
<td>154</td>
<td></td>
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<td>154</td>
<td></td>
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<td>I.B.1 (9)</td>
<td>154</td>
<td></td>
</tr>
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<td>I.A.1 (1)</td>
<td>154</td>
<td></td>
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<td>154</td>
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<td>154</td>
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<td>154</td>
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<td>154</td>
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<td>V.A. (4)</td>
<td>154</td>
<td></td>
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<tr>
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<td>II.D. (17)</td>
<td>154</td>
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<td>154</td>
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<td>154</td>
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<td>IV.D.1 (30)</td>
<td>154</td>
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<td>VII.B.1 (12)</td>
<td>154</td>
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<td>NITSCH, R.</td>
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<td>154</td>
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<td>NIX, G. F.</td>
<td>V.B.3 (3)</td>
<td>154</td>
<td></td>
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<tr>
<td>NOONE, M. J.</td>
<td>II.C. (8)</td>
<td>154</td>
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<tr>
<td>NOONE, M. J.</td>
<td>IV.D.1 (15)</td>
<td>154</td>
<td></td>
</tr>
</tbody>
</table>
AUTHOR INDEX (CONT'D)

O'DONNELL, F. R.
III.C.2(5)

Oker, E.
VII.B.12(3)

OSTRACH, S.
III.C.1(22)
VII.B.4(5)

OTTON, E. W.
III.A(15)(19)

OTTO, G. H.
III.A(28)
III.B(37)
IV.B(7)(8)(9)(19)(20)(21)

OKRESS, E. C.
V.B.3(10)

OYOSHI, A.
VII.B.13(4)

OYOSHI, E.
VII.B.13(4)

PADDY, J. F.
III.A(38)

PADOVANI, F. W.
IV.D.1(15)

PAK, H. Y.
III.B(20)

PAPAZIAN, J. M.
IV.A.1(10)
IV.A.3(15)
IV.D.1(25)

PAPELL, S. S.
III.B.1

PARKS, P. G.
IB.B.1(1)(3)(11)

PARKER, R. L.
I.A.2(13)(14)(17)

PARKER, H. S.
III.C.4(3)

PASICHNYI, V. V.
V.C.4(4)

PASSAGLIA, E.
IV.A.2(33)

PATON, B.
I.A.2(12)
I.C.2(6)
V.C.3(1)
V.C.3(6)
V.C.6(1)

PATTEE, H. E.
IV.A.2(6)(12)(19)

PATTEN, J. W.
IV.A.2(34)

PAULE, R. C.
III.C.3(3)
VI.B.1(3)

PAULIS, P. N.
VII.B.1(21)

PAYTON, P.
I.C.3(2)

PERKAREV, A. I.
V.D.2(1)

PETERS, E. T.
IV.A.2(19)

PETROV, B. H.
II.A(13)

PFANN, W. G.
V.B.3(1)

PIGGOTT, L. S.
V.G.3(3)

POLK
III.D(1)

POLLOCK, J. T. A.
IV.A.1(1)

POND, R. B.
IV.C(41)

POVITSKII, A. S.
III.A(10)(21)
III.B(26)

POORMAN, R. M.
V.C.6(5)

PREETZ, W.
VII.B.11(1)

QUANTOCK, C.
II.A(8)

RANDOLPH, B. W.
III.A(4)

RASQUIN, J. E.
V.C.1(1)

RAUCH, H. W.
IV.C(1)

RAYMOND, L.
IV.C(42)

REED, R. E.
III.C.3(4)

REGER, J. L.
IV.B(1)(2)(3)(4)(10)
IV.C(4)(18)

155
<table>
<thead>
<tr>
<th>Author</th>
<th>Volume, Issue</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>RENDON, L.</td>
<td>VII.B.7(1)</td>
<td></td>
</tr>
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<td>IV.D.2(3)</td>
<td></td>
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<td>II.D(13)</td>
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<td>III.A. (20)</td>
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<td>REID, R. C., JR.</td>
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<td>I.B.1(8)</td>
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<td>ROBINSON, A. L.</td>
<td>IV.D.5(7)</td>
<td></td>
</tr>
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<td>RODOT, H.</td>
<td>IV.D.1(29)</td>
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<td>ROSE, J. T.</td>
<td>II.D. (1)</td>
<td></td>
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<td>ROTHMAN, R. L.</td>
<td>IV.A.2(6)</td>
<td></td>
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<tr>
<td>ROY, U.</td>
<td>IV.D.1(4)</td>
<td></td>
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<tr>
<td>RUBENSTEIN, M.</td>
<td>IV.D.1(8)</td>
<td></td>
</tr>
<tr>
<td>RUBIN, B. A.</td>
<td>I.C.3(3)</td>
<td></td>
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<tr>
<td>RUESGA, J. M.</td>
<td>III.D. (9)</td>
<td></td>
</tr>
<tr>
<td>RUSSEL, W. J.</td>
<td>VII.B.6(1)</td>
<td></td>
</tr>
<tr>
<td>RUTECKI, D. J.</td>
<td>V.B.3(10)</td>
<td></td>
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<td>RUSSAR, M. A.</td>
<td>VI.A. (12)(14)</td>
<td></td>
</tr>
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<td>SAFFREN, M. M.</td>
<td>V.B.2(4)(6)(8)</td>
<td></td>
</tr>
<tr>
<td>SACONE, I.</td>
<td>VII.B.11(8)</td>
<td></td>
</tr>
<tr>
<td>SAKOILENKO, I.</td>
<td>I.B.1(8)</td>
<td></td>
</tr>
<tr>
<td>SAMRA, K.</td>
<td>IV.D.3(8)</td>
<td></td>
</tr>
<tr>
<td>SATTERLEE, H. M.</td>
<td>III.A. (20)</td>
<td></td>
</tr>
<tr>
<td>SCARFF, D. D.</td>
<td>I.C.1(4)</td>
<td></td>
</tr>
<tr>
<td>SCHAFER, C. F.</td>
<td>III.A. (40)</td>
<td></td>
</tr>
<tr>
<td>SCHLICTA, P. J.</td>
<td>IV.D.1(2)</td>
<td></td>
</tr>
<tr>
<td>SCRIVER, L. E.</td>
<td>III.C.3(1)</td>
<td></td>
</tr>
<tr>
<td>SHAPLAND, D.</td>
<td>II.E. (17)(19)</td>
<td></td>
</tr>
<tr>
<td>SHAPIRO, N.</td>
<td>VII.B.2(1)</td>
<td></td>
</tr>
<tr>
<td>SHAPIRO, W. G.</td>
<td>I.A.1(6)</td>
<td></td>
</tr>
<tr>
<td>SHER, L. D.</td>
<td>VII.B.11(2)</td>
<td></td>
</tr>
<tr>
<td>SHERLEIKIN, V. V.</td>
<td>III.A. (5)(9)</td>
<td></td>
</tr>
<tr>
<td>SICKA, R.</td>
<td>IV.C. (2)</td>
<td></td>
</tr>
<tr>
<td>SIEBERT, G.</td>
<td>I.A.4(6)</td>
<td></td>
</tr>
<tr>
<td>SIEGEL, R.</td>
<td>III.B.(11)</td>
<td></td>
</tr>
</tbody>
</table>
AUTHOR INDEX (CONT'D)

UTECH, H. P.
IV.D.1(1)

WALTER, H. U.
IV.A.1(10)
IV.D.1(14)
IV.D.3(6)(15)(16)
V.D.2(2)

WILLIAMS, J. R.
II.A.(2)
IV.A.2(24)

WILLIAMSON, K. D.
III.B.(32)

WALTZ, D. M.
I.C.2(5)

WINKLER, C. E.
II.B.(5)

WANG, T. G.
V.B.1(4)
W.B.2(6)(8)

WINTER, E.R.F.
III.B.(20)

WECHSLER, A. E.
IV.A.2(1)
IV.C.(6)

WISE, T. D.
V.A.(4)

WEISS, S.
III.A.(1)
IV.D.1(26)(28)

WIT, A. F.
III.A.2(23)(31)

VELKOFF, H. R.
III.A.(2)

WOLF, L. W.
III.C.3(2)

VEEN, G. E.
VII.B.10(4)

VERLEY, W.
VII.B.13(1)

VERNON, A.C.
I.A.1(7)

WHYMARK, R. R.
V.B.2(1)(2)(3)(5)(7)

WITT, A. F.
III.A.(8)
III.E.(1)
IV.A.1(14)

WOLFER, F. W.
IV.A.1(12)

WOOD, C. C.
III.A.(8)

IV.D.'(15)

II.E.(1)

IV.D.3(9)

IV.A.1(1)

WIESBROOK, G.
V.B.3(10)

VON BRAUN, W.
I.A.1(10)

V.D.1(3)

WAHL, B. W.
I.A.2(1)

WUEST, W.
III.C.(7)

III.C.1(2)

III.C.3(5)

WILCOX, W. R.
I.A.1(9)(11)(12)(15)(19)

II.C.(2)

VII.C.(5)

WILCOX, W. R.
III.C.1(2)

WUENSCHER, H. F.
III.C.3(5)

IV.A.3(15)

VII.C.(5)

IV.D.3(8)

WUEST, W.
III.C.(7)

IV.D.5(9)
AUTHOR INDEX (CONT'D)

YAFFEE, M. L. II.A. (15)
YAN, C. S. I.C.1(2) IV.D.1(12)
YATES, I. C. IV.A.3(11) IV.B. (6) IV.C. (13)(19)
YEE, J. F. IV.D.3(8)
YEH, H. M. III.C.2(6)
YOST, V. H. I.A.1(20) IV.A.3(11)
YUE, A. S. IV.C. (9)(36)(39)
YUE, B. K. IV.C. (39)
YUE, J. T. IV.A.1(12)(15) IV.D.3(9)
ZARA, E. A. III.B. (6)
ZENKOVSKAIA, S. M. III.C.1(1)(2)
ZENKEVICH, V. B. III.A. (11)
ZIMMERMAN, H. I.B.2(9, II.E. (20)

159
APPENDIX D

CORPORATE INDEX
**CORPORATE INDEX**

<table>
<thead>
<tr>
<th>CONTRACTOR</th>
<th>CONTRACT NO.</th>
<th>PRINCIPAL INVESTIGATOR</th>
<th>PRINCIPAL AUTHOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Univ. of Alabama</td>
<td>NAS8-24612</td>
<td>J. H. Davis</td>
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<td>J. G. Castle</td>
<td>J. H. Davis et al</td>
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<td>NAS8-21143</td>
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<td>H. R. Henry et al</td>
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<td>Tuscaloosa, AL</td>
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<td>M. Bier</td>
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<td>Astro-Space Labs., Inc., Huntsville, AL</td>
<td>NAS8-20582</td>
<td></td>
<td>R. C. Mapes</td>
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<tr>
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<td>NAS8-20707</td>
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<td>NAS8-30036</td>
<td>R. F. Pickard</td>
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<tr>
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160
## CORPORATE INDEX (CONT'D)

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163
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164
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165
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166
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167
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ADDENDUM

CONTINUED BIBLIOGRAPHY TO JANUARY 1978.
CONTINUED BIBLIOGRAPHY OF MATERIALS PROCESSING IN SPACE

A. BOUND VOLUMES


B. GENERAL PAPER ON FLUID AND HEAT FLOW


170
Davidson, M. C., "Narrow Zone Heating by a New Radiation Focusing Technique: Toroidal Ellipsoid Furnace," MSFC 1977


C. ELECTROPHORESIS SEPARATION

Snyder, R. S., "Electrophoresis Demonstration on Apollo 16," NASA TMX 64724, 1972


D. METALLURGY


E. POLYMER CHEMISTRY


F. CRYSTAL GROWTH


NOTE: Additional papers may be found in the reports of specific flight results listed under A. Bound Volumes.

G. SPAR III FINAL REPORT
TO BEbound and published in a single volume, 1978

Papazian, J. M., "Thermal Migration of Bubbles and Their Interactions With Solidification Interfaces"

Lind, M. D., "Epitaxial Growth of Single Crystal Films SPAR III Final Report"

Schafer, C. F., "Results From Experiments 74-18/2, 3, the SPAR III Liquid Mixing Experiment"

Wouch, G., "Containerless Processing of Beryllium Experiment 74-48"

Uhlmann, D. R., Technical Report on Experiment 74/53 flown on SPAR III
SPACE PROCESSING APPLICATIONS BIBLIOGRAPHY

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E. C. McKANNAN
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