

LONG DURATION EXPOSURE FACILITY EXPERIMENT
M0003 DEINTEGRATION OBSERVATION DATA BASE

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ABSTRACT

The four trays (2 leading edge and 2 trailing edge) of the M0003 materials experiment on LDEF contained 1274 samples from 20 subexperiments. The complete sample complement represented a broad range of materials, including thin film optical coatings, paints, polymer sheets and tapes, adhesives, and composites, for use in various spacecraft applications, including thermal control, structures, optics, and solar power. Most subexperiments contained sets of samples exposed on both the leading and trailing edge trays of LDEF. Each individual sample was examined by high resolution optical microscope during the deintegration of the subexperiments from the M0003 trays. Observations of the post-flight condition of the samples made during this examination were recorded in a computer data base. The deintegration observation data base is available to requesters on floppy disk in 4th Dimension for the Macintosh format. Over 3,000 color macrographs and photomicrographs were shot to complement the observation records and to document the condition of the individual samples and of the M0003 trays. The photographs provide a visual comparison of the response of materials in leading and trailing edge LDEF environments. The Aerospace Corporate Archives is distributing photographs of the samples and hard copies of the database records to the general public upon request. Information on obtaining copies of the data base disks and for ordering photographs and records of specific samples or materials are given in this paper.

INTRODUCTION

The Aerospace Corp. M0003 Experiment

Of the 57 experiments flown on the 86 experiment-holding trays arrayed around the LDEF, M0003 was one of the most comprehensive materials experiments. Experiment M0003 resided on four trays, two on the leading edge of LDEF and two on the trailing edge. This experiment, planned and integrated by the Aerospace Corporation Mechanics and Materials Technology Center, was designed to study the effects of the space environment on current and developmental spacecraft materials. The M0003 experiment was a collection of 20 subexperiments from the Aerospace Corporation Laboratories, Air Force and Navy Laboratories, and Department of

Defense (DoD) contractors, fielded under the sponsorship of the Air Force Space Systems Division and the Space Test Program. The 20 subexperiments are described in Table I; the current point of contact for each is given.

M0003 Trays And Samples

The M0003 hardware consisted of four encircling trays, two Experiment Power and Data Systems (EPDS), two Environment Exposure Control Canisters (EECCs), and several Li/SO₂ batteries to satisfy power requirements. The trays were flown in pairs, one pair consisting of a 6-inch deep tray (carrying a data system and a canister) that was connected by wiring harness to a 3-inch deep tray (carrying mostly sample coupons). One tray pair was located on the LDEF leading edge and a similar pair was located on the trailing edge. Aerospace designated the trays as "L3", "L6", "T3", and "T6", according to the tray depth and leading or trailing edge location, before NASA had assigned the trays to an exact location on the LDEF. Subsequently, these trays were named by NASA according to their row and ring location and are more commonly known as "D9", "D8", "D3", and "D4", respectively. The Aerospace tray designations were ensconced in the unique identification code assigned to each subexperimenter sample for the coordination and data base accounting of the M0003 experiment integration and deintegration and these could not easily be changed.

The design of the M0003 trays was modular, allowing samples to be thermally coupled or decoupled from the tray and therefore, the LDEF structure. Each tray had six of the experiment-carrying modules, designated by Roman Numerals I through VI. The 1274 samples were mounted on anodized black aluminum hardware plates on the modules. The materials in the M0003 experiment included a variety of thermal control paints and coatings, polymers, optics, structural materials, and solar power materials. The M0003 sample complement is diagrammed by these material types in Figures 1 through 5. For brevity, not all samples types are shown in these diagrams.

For the 69 month duration of the LDEF exposure at Low Earth orbit, the four trays of samples experienced different environments which varied according to their location on LDEF, but all trays, leading and trailing edge, experienced the same number of thermal cycles, were exposed to roughly the same number of hours of UV exposure and received the same low levels of electron and proton irradiation. Only the leading edge trays, D8 (L6) and D9 (L3), were subjected to a significant atomic oxygen dose; these trays also received a greater number of hypervelocity impacts than did the trailing edge trays (Ref. 1, 2, 3).

Most of the subexperiments in M0003 contained duplicate sets of samples exposed on the leading and the trailing edge trays. A few had duplicate sets exposed for shorter durations in the canisters as well. Some subexperiments also included a set of "flight control" samples that were mounted within the modules and that were not directly exposed to the space environment, but were subject to the thermal vacuum cycling.

Environment Exposure Control Canisters

The canisters on trays D4 (T6) and D8 (L6) were programmed to open in three stages in order to obtain different duration exposures on some materials. Two weeks after the initiate

signal, the canisters opened to expose a large ($\sim 3/4$ area) of samples. The next canister stepped movement occurred approximately 23 weeks after deployment and exposed another row of samples ($1/8$ additional area). The next canister stepped movement was at approximately 33 weeks and exposed the last row of samples ($1/8$ area) by opening to the canister's fullest extension. The canister drawer closed completely at 42 weeks after initiate and remained closed during the remainder of the LDEF mission. Thus, varying exposure times of 9, 19, and 40 weeks were obtained for some samples in addition to the full mission exposure of 69 months for identical samples on the other M0003 trays. The canisters were opened in a clean room at Aerospace roughly five months after LDEF retrieval. LDEF special investigation group (SIG) personnel were present during this event and sampled the canister gases and assisted in helium leak testing of the seals. The canisters were both essentially at atmospheric pressure and some leakage of the front seals was detected.

THE M0003 EXPERIMENT DEINTEGRATION

Following retrieval of the LDEF, the Aerospace Corporation was charged by the Space Test Program, with documentation of the handling and disassembly of the M0003 experimental trays and with providing support to the subexperimenters. The support included full photographic documentation of the trays, modules, and quarter-modules from the earliest stages of retrieval through the complete deintegration of the trays; photographic documentation of the condition of the individual samples; packaging and return of the samples to the subexperimenters; and providing flight data to the subexperimenters. The deintegration tasks were documented in a relational computer data base, 4th Dimension for the Macintosh.

Inspection at Kennedy Space Center

The deintegration tasks began with inspection of the M0003 trays at Kennedy Space Center following the removal of LDEF from the payload bay of the Shuttle Columbia to the SAEF (Spacecraft Assembly and Encapsulation) II clean room facility. Observations were recorded and NASA photographic surveys were made to document the condition of the trays and samples following their reintroduction into the earth environment (air, humidity, gravity, etc.).

Tray Disassembly at The Aerospace Corporation

The four M0003 trays were air-shipped to the Aerospace Corporation and unpacked and disassembled in a class 10,000 clean room. As test samples were removed from the trays, they were individually examined by optical microscopy and photographed, preserving the orientation of the samples as mounted on the LDEF. Many of the samples experienced space-induced damage effects such as crazing, surface roughening, discoloration, erosion, contamination staining, and hypervelocity impact crater formation. Not all samples exhibited discernible changes, however. Observations of the condition of the samples were made by a single examiner who maintained a consistent criteria for the qualitative descriptions of the condition of all the M0003

samples. Each sample was examined and photographed using optical microscopy at magnifications from 3X to 1000X. A Wild-Heerbrug stereomicroscope and a Zeiss Axioplan Pol research microscope were used for the examinations. Microscopy techniques used included bright field, dark field, and Nomarski differential interference contrast. The observations of the condition of the samples were entered in real time into the computer data base. It should be noted that in-depth analysis of the effects of the space exposure on the samples was the prerogative of the subexperimenters and was not the role of the examiner or the deintegration team. The microscopy examination was performed to provide a record of the post-flight condition of all samples in the event that some subexperiments were not reclaimed by the original subexperiments.

All entries in the M0003 database were keyed on a simple database number and unique sample identification code assigned to each sample. How each is used is illustrated in the example in Figure 6. The database number for the sample in this example is #73. Encoded in the sample identification is the sample's location on the trays, the module on which it was mounted, the subexperiment number, the sample location number on the module, and the identification code number given it by the subexperimenter. In the example, L3II-7-65-10, an optical coating specimen, was fielded on L3 (D9), the leading edge 3-in. deep tray, on module II. It was part of subexperiment 7 and was sample #65 on module II on D9. It was designated as "10" by the principal investigator of the subexperiment.

Photographic And Observation Documentation

Over 3,000 macrographs and photomicrographs were made at the Aerospace Corporation to document the effects observed on the M0003 trays and the individual samples. Overall photographs of the trays, modules, and quarter-modules, (front and back) were shot using large format print film in color and in black and white. An example of one such photograph, a view of the D9 (L3) tray before deintegration of the samples, is shown in Figure 7. As the individual samples were dismantled from the modules, the underlying layers of the module hardware were also photo-documented. In addition, photographs of side-by-side leading and trailing edge pieces of hardware were made for visual comparison of the differences in degree of contamination staining, erosion, discoloration, etc. Photomicrographs made during the optical microscopy examination were recorded on high resolution 35 mm color print film. An example of a series of photographs made of an optical sample is shown in Figure 8. This sample, identified by both database number and sample identification code is a ZnS optical thin film coating on a fused silica substrate. Photographs of this type and the accompanying observation records are available for specific samples by request to the Aerospace Corporation Corporate Archives. The observation record for this sample is shown in Figure 9. The ZnS coating buckled during the 69 months of exposure. In addition, ring-like features, discernible at 200 times magnification, were observed on the buckled surface.

OBTAINING DATA AND PHOTOGRAPHS

The M0003 Deintegration Observation Record Database is available to requesters on an 1.4 MB (HD) diskette in Macintosh 4th Dimension™ format. A user instruction text file is provided on the

disk. The text file includes the detailed examination criteria used in compiling the observation records. A copy of the Aerospace form for ordering records and photographs of samples is also included in this file. The database file contains various layouts for examining the contents of the database by location on the M0003 trays, by sample identification code, or by spacecraft application. Searches may be made by material type, damage effects, categories, or text strings. Observation records in the database file include the dimensions of the samples, the subexperimenter-supplied descriptions of their composition or configuration, the observations made at Kennedy Space Center, the observations made during the deintegration process at Aerospace Corporation, and the subexperiment contacts for additional information on the samples.

The photographic portion of the database is not included on the diskette. The Aerospace Corporate Archives maintains a copy of the entire database to coordinate requests for photographs of specific samples. Requests should be addressed to the Aerospace Corporate Archives, P. O. Box 92957, Mail Station M2/326, Los Angeles, CA 90009-2957, phone (310) 336-5319; FAX (310) 336-5912). The requester should be as specific as possible in stating the type of materials desired (e. g., color prints of full trays, black and white photographs of certain modules, color micrographs of a specific samples, data records , etc.). This service will be provided as long as resources allow.

REFERENCES

1. Bourassa, R. J. and Gillis, J. R.: *Data Summary Atomic Oxygen Flux and Fluence Calculation for Long Duration Exposure Facility (LDEF)*, NAS1-18224, Task 12, Boeing Defense and Space Group, Seattle, WA, January 18, 1991.
2. Bourassa, R. J. and Gillis, J. R.: *Solar Exposure of LDEF Experiment Trays*, NASA Contractor Report 189554, Boeing Defense and Space Group, Seattle, WA, February 1992.
3. See, T. H.; Allbrooks, M. A.; Atkinson, D. R.; Simon, C. G.; and Zolensky, M.: *Meteoroid and Debris Impact Features Documented on the Long Duration Exposure Facility, A Preliminary Report*, Publication #84, JSC #24608, 1990.

TABLE I. SUMMARY OF M0003 EXPERIMENTS

Subexperiment number	Scope	Subexperiment Point of Contact	Organization/ Address
-1	Radar camouflage materials and electro-optical signature coatings	Charles Hurley	Univ. of Dayton Research Inst. 300 College Park Dayton, OH 45469-0001
-2	Laser optics	Linda De Hainaut	Phillips Lab/LIDA Kirtland AFB, NM 87117-6008
-3	Structural materials	Charles Miglionico	Phillips Lab/PL/VTSI Kirtland AFB, NM 87117-6008
-4	Solar power components	Terry Trumble	Wright Labs/POOC Wright Patterson AFB, OH 45433-6533
-5	Thermal control materials	Charles Hurley	Univ. of Dayton Research Inst. 300 College Park Dayton, OH 45469-0001
-6	Laser communication components	Randall R. Hodgson	McDonnell Douglas Astronautics Corp. Mail Code 1067267 P. O. Box 516 St. Louis, MO 63166
-7	Laser mirror coatings	Terry M. Donovan	3481 Murdoch Dr. Palo Alto, CA 94306
-8	Composite materials, electronic piece parts, fiber optics	Gary Pippin	Boeing Aerospace Co. Materials Technology Dept., MS 2E-01 P. O. Box 3999 Seattle, WA 98124
-9	Thermal control materials, antenna materials, composite materials, and cold welding	Brian C. Petrie	Lockheed Missiles & Space Co. Dept. 62-92, Bldg. 564 P. O. Box J04 Sunnyvale, CA 94086
-10	Advanced composite materials	Gary L. Steckel	The Aerospace Corp. P. O. Box 92957, M2/242 Los Angeles, CA 90009
-11, -12	Contamination monitoring, Radiation measurements	Eugene N. Borson, F. B. Sinsheimer	The Aerospace Corp. M2/270
-13	Laser hardened materials	Randall R. Hodgson	McDonnell Douglas Astronautics Corp. Mail Code 1067267 P. O. Box 516 St. Louis, MO 63166
-14	Quartz crystal microbalance	Donald A. Wallace	QCM Research 2825 Laguna Canyon Road P. O. Box 277 Laguna Beach, CA 92652
-15	Thermal control materials	Oscar Esquivel	The Aerospace Corp. M2/241
-16	Advanced polymer composites	Gary L. Steckel	The Aerospace Corp. M2/242
-17	Radiation dosimetry	Sam S. Imamoto, J. Bernard Blake	The Aerospace Corp. M2/260
-18	Thermal control paints	Christopher H. Jagers	The Aerospace Corp. M2/271
-19	Electronic Piece Parts	Seymour Feuerstein	The Aerospace Corp. M2/244
-20	Tray Hardware	Michael J. Meshishnek	The Aerospace Corp. M2/271

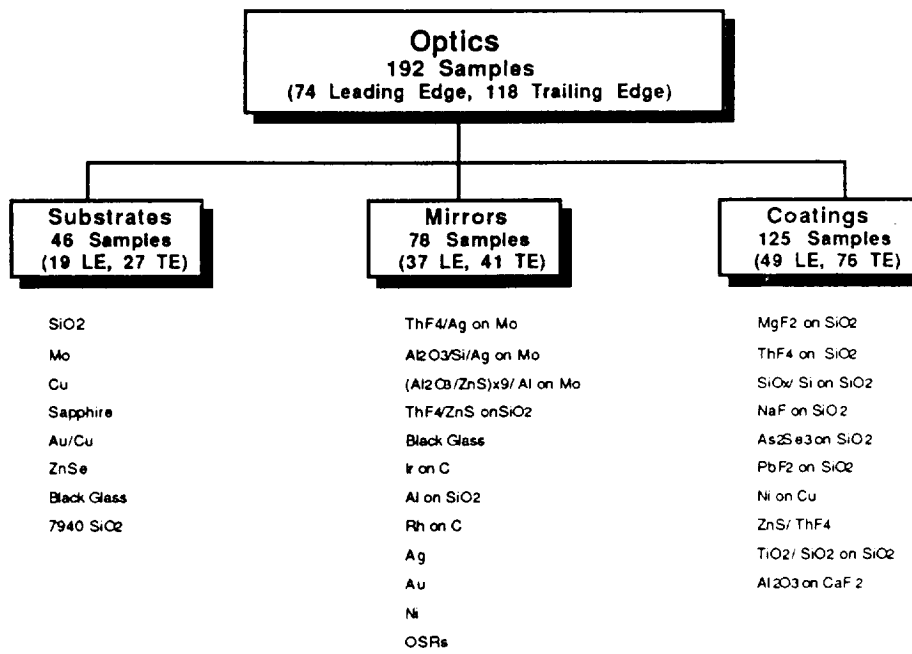


Figure 1. Diagram of Optics samples in database.

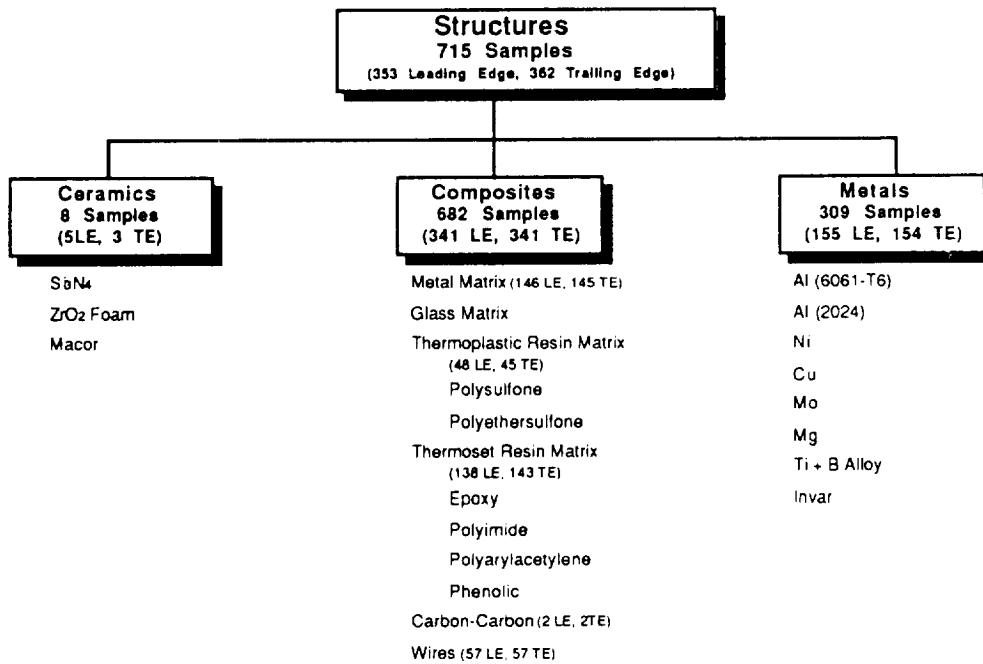


Figure 2. Diagram of Structure samples in database.

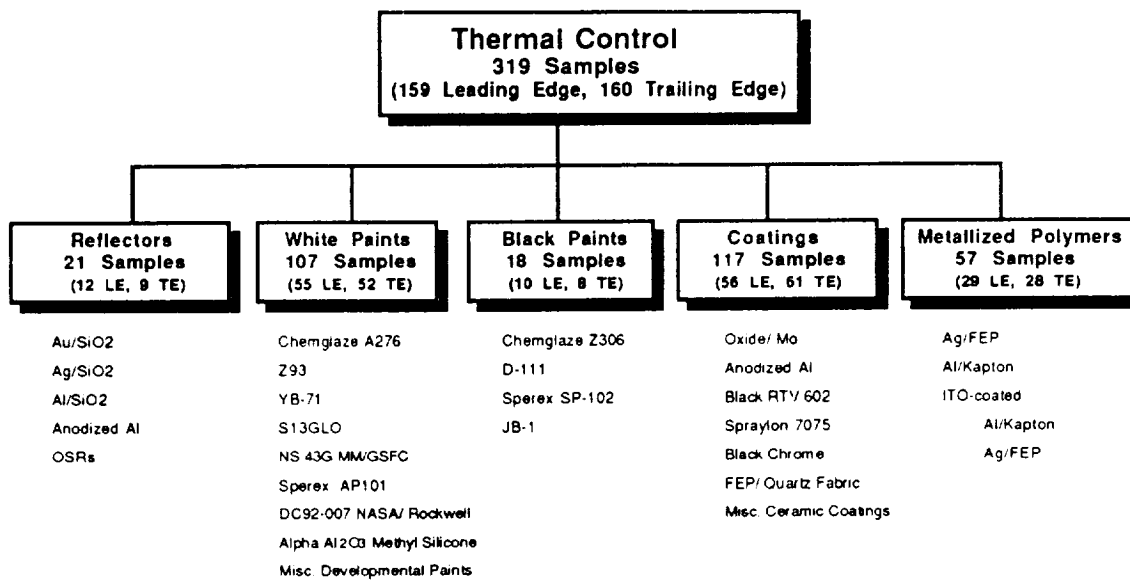


Figure 3. Diagram of Thermal Control samples in database.

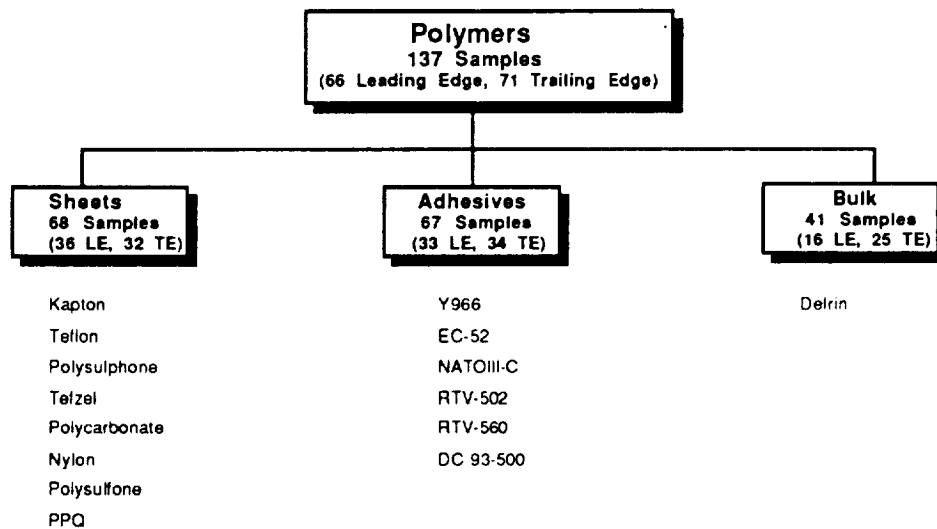


Figure 4. Diagram of Polymer samples in database.

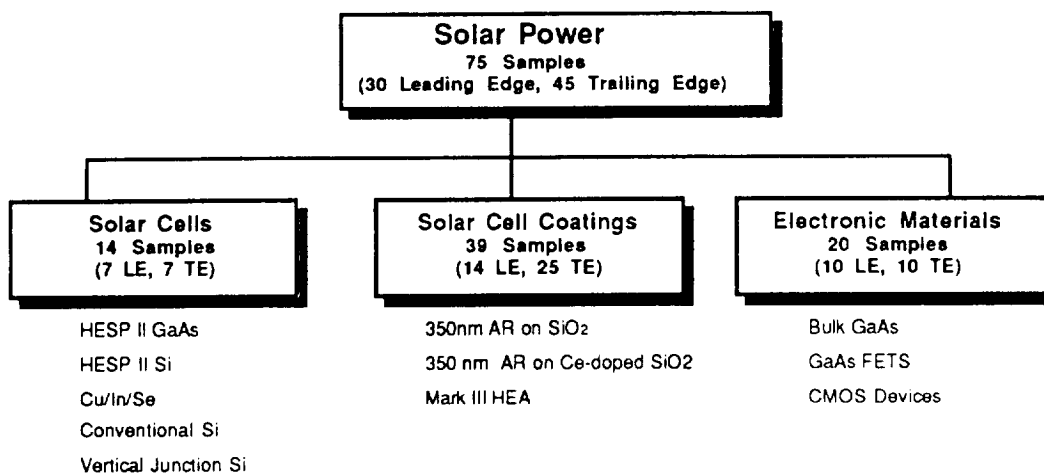


Figure 5. Diagram of Solar Power samples in database.

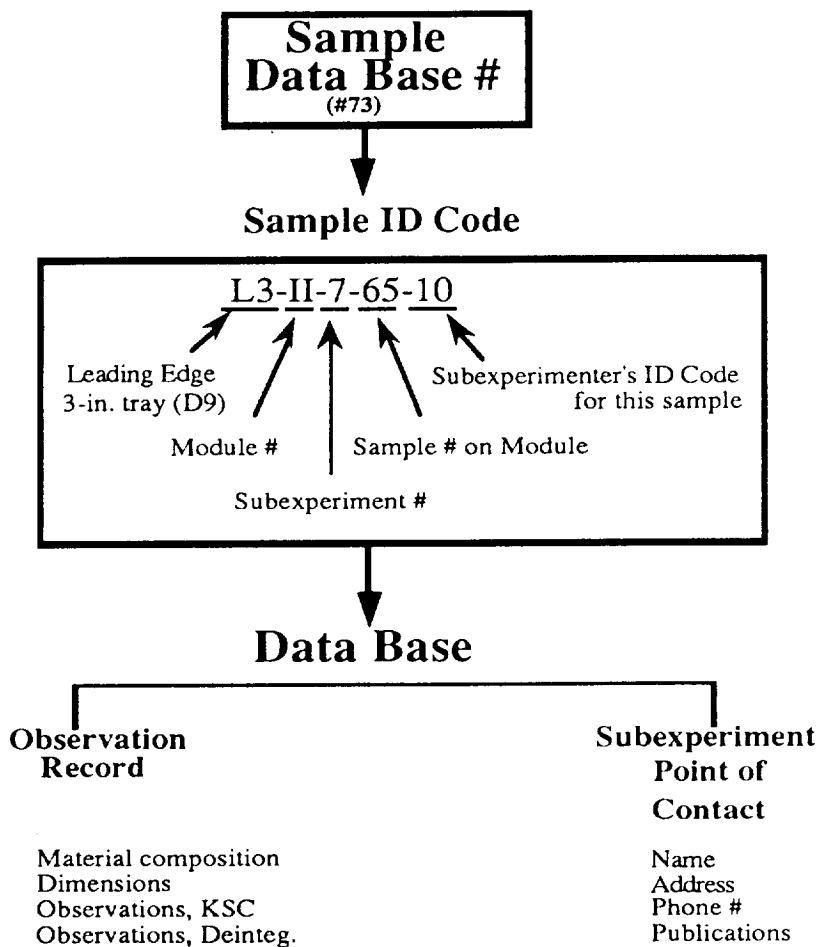


Figure 6. Diagram of M0003 database.

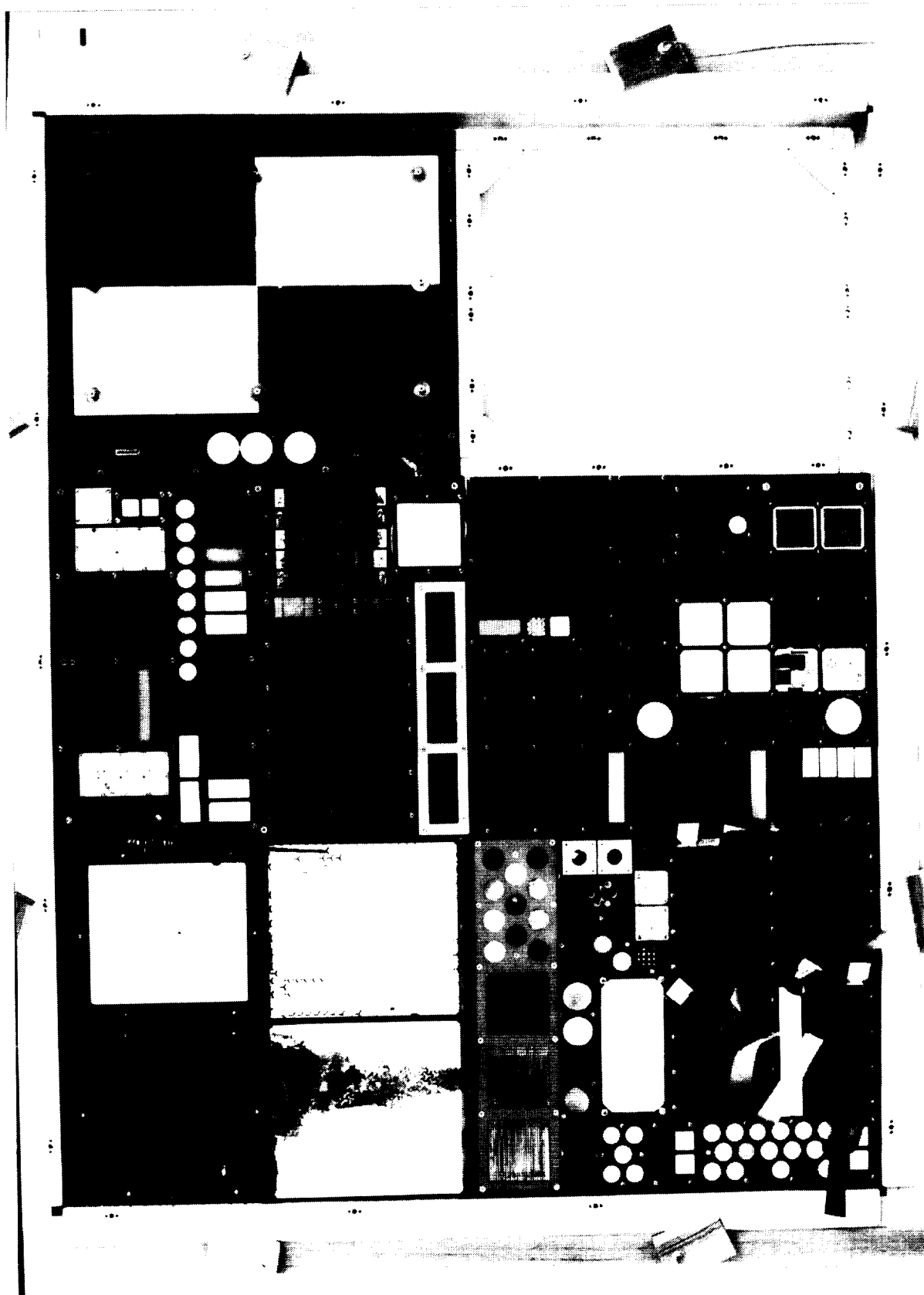


Figure 7. View of the D9 (L3) tray before deintegration of the samples.

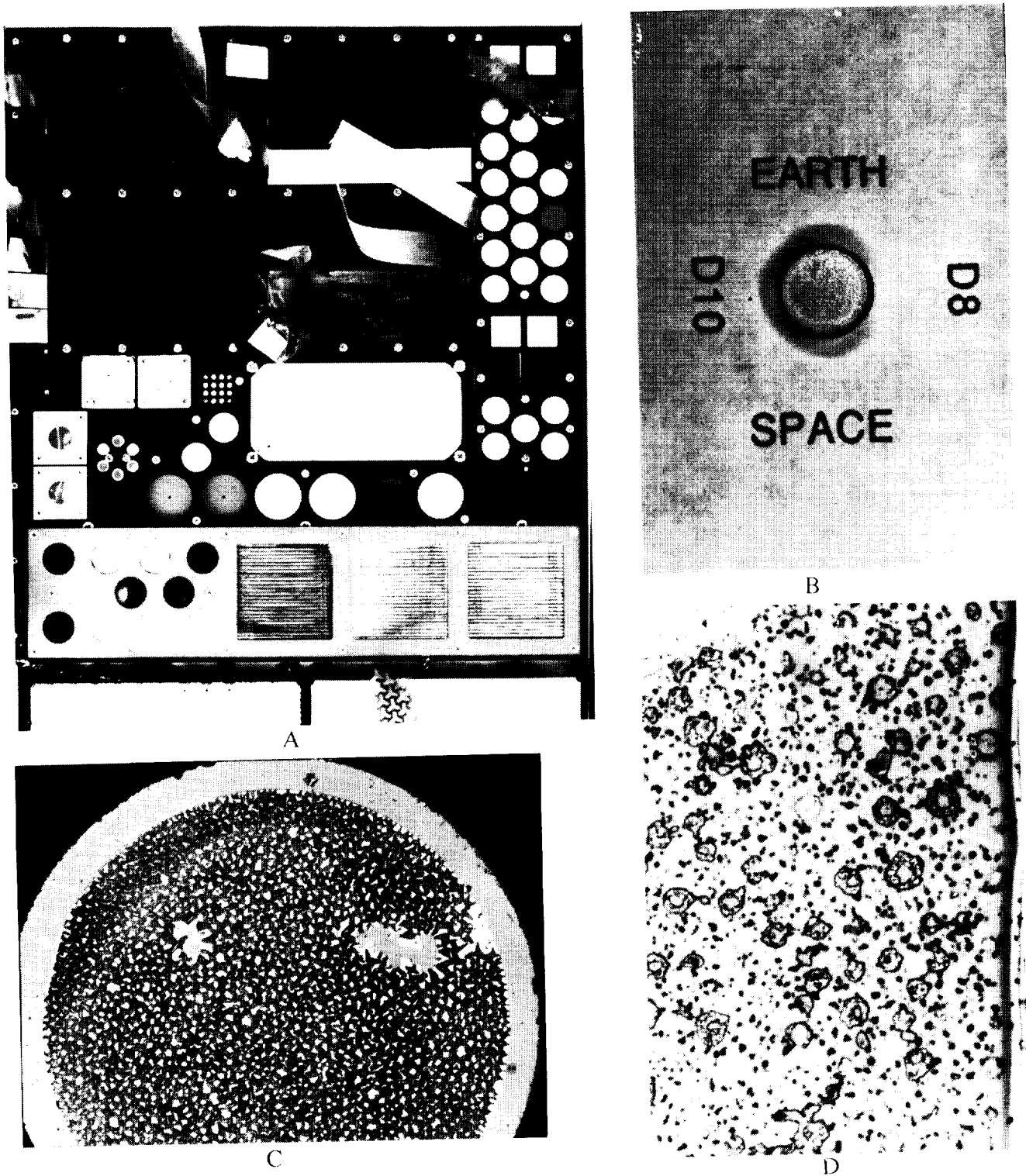


Figure 8. Macrographs and micrographs of sample Database #73.
 View A. Module macrograph - Module II on Tray D9.
 View B. Sample macrograph of DB#73 (L3II-7-65-10, ZnS coating on fused silica, .375 in. dia.).
 View C. Low magnification micrograph of buckled coating on surface of DB#73.
 View D. High magnification micrograph of annular features on buckled coating on DB#73.

LDEF M0003 Sample Observation

Sample ID: L3II-7-65-10	Tray: D9	Module: II	Experiment #: 7
Database #: 73	Description: Coating, ZnS on SiO2 (SiO2 substrate, ZnS coating)		
Width: 0.375	Exposure: 69 months		
Length: -	Post-flight Condition:		
Thickness: 0.100	Buckled (+), delaminated		
Category: Coating, glass			
Subcategory: Coated substrate			
Application: Optics			

Observations at KSC Before Deintegration:

SURFACE CRAKED, FLAKING

Observations at The Aerospace Corporation:

Date: Tuesday, May 15, 1990

The exposed coating appears uniformly buckled; some areas have buckled so severely that the coating has flaked. In the flaked areas, the residual surface (the substrate) is smooth. Another phase appears to have nucleated on the top of the buckled surface. This phase is manifested, in various stages of formation, as crescent-, ring- or circular-shaped features on the surface.

Point of Contact:

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CA 94306
FAX: (____) 000-0000

Publications:

1. T. M. Donovan, J. M. Bennett, and S. Gyetvay, "Space Environmental Effects on Coated Optics," Proceedings of the First Post-Retrieval Symposium, Kissimmee, FL, Jun 2-8, 1991, NASA Conference Publication 3134, Part 3

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Figure 9. Example of hard copy database observation record (DB#73).

COLOR PHOTOGRAPHS



Figure 3. Layered contaminant films from Tray C12.
(Color version of black and white photograph shown on page 1028.)

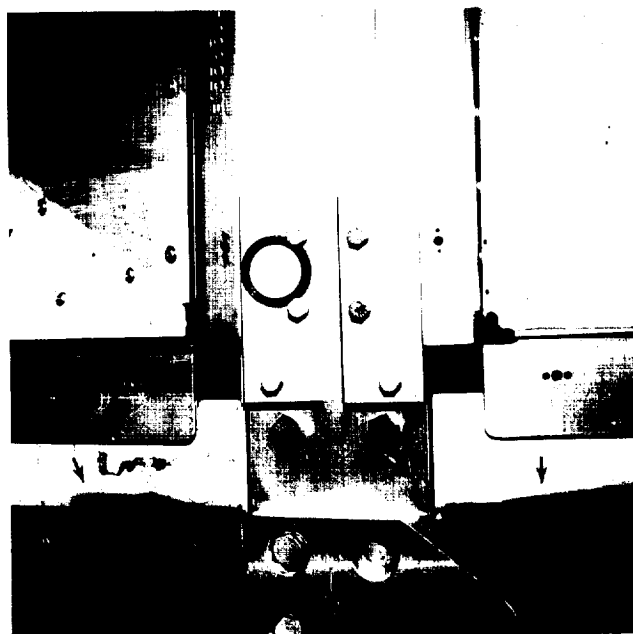


Figure 5. Outgassed material on LDEF structure near vents from interior.
(Color version of black and white photograph shown on page 1029.)

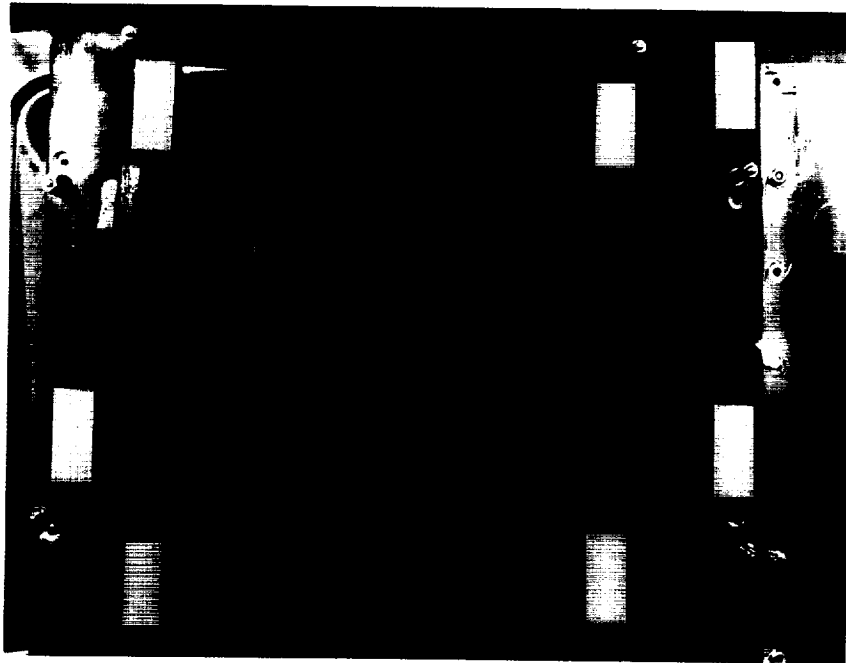
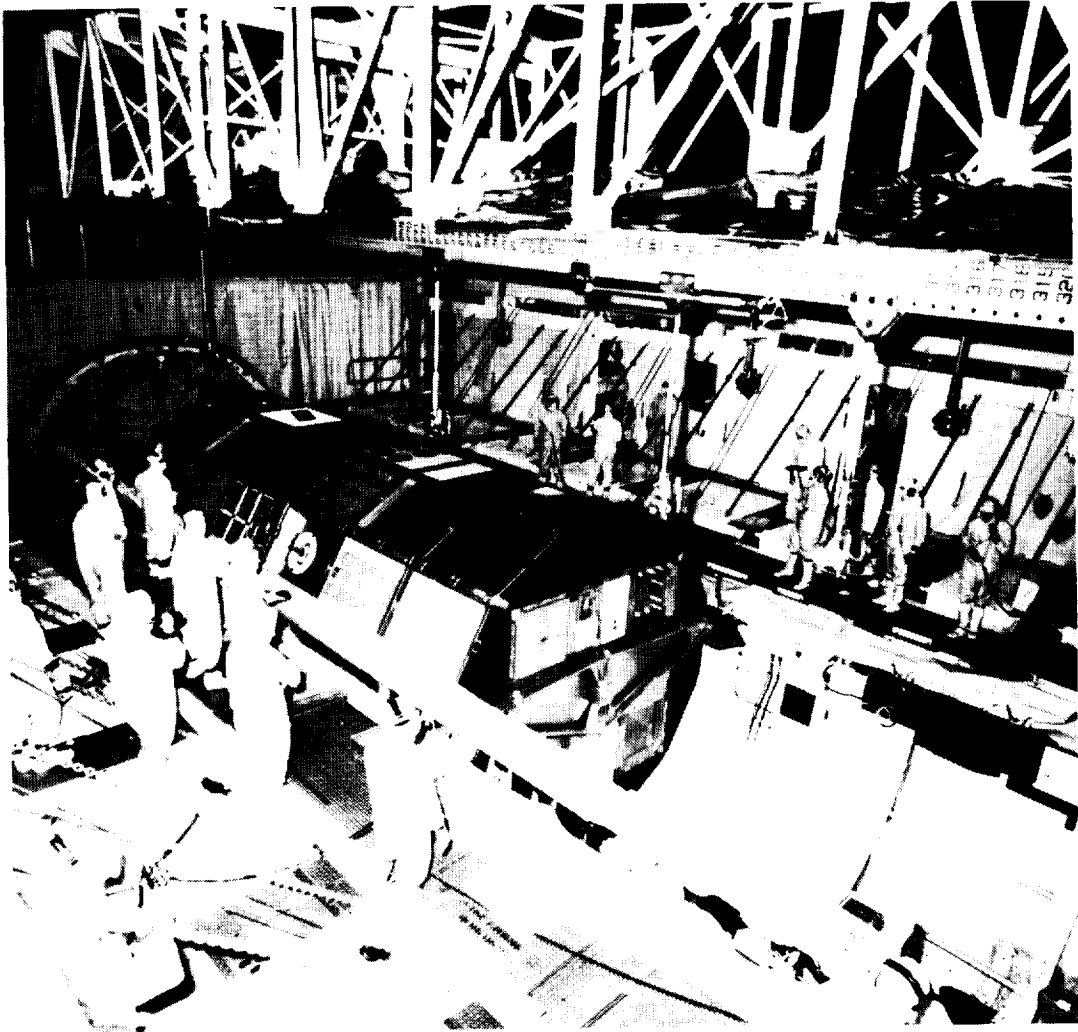


Figure 1. Photograph of black chromium plated solar absorber panel, experiment AO076, tray F9.
(Color version of black and white photograph shown on page 1106.)

AUTHOR INDEX



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

L-90-11206

Author Index

Index Guide

Part 1, pages 1-274; Part 2, pages 275-738

Part 3, pages 739-1254; Part 4, pages 1255-1570

- Adams, J.H., Jr. 247, 1551
Agüero, R.C. 665
Ahearn, J.S. 1285
Albrecht, A. 231
Allbrooks, M.K. 595
Alston, J.A. 1493
Amari, S. 513
Armstrong, T.W. 137, 163, 187, 195, 207, 221
Arthur, R.J. 79
Atkinson, D.R. 277, 595, 619, 1399
Auer, B.M. 1137
Bada, J. 453
Banks, B.A. 431, 1137
Beahm, L.P. 247
Beaujean, R. 239
Becker, L. 453
Benton, E.R., 171, 181
Benton, E.V. 163, 171, 181, 187
Bergman, L.A. 1439
Bernhard, R.P. 541, 551
Berry, J.N. 1425
Best, S. 479
Blake, J.B. 147
Blakkolb, B.K. 1035, 1343
Blue, M.D., 1333
Boberg, P.R. 247
Bobias, S.G. 87
Bohnhoff-Hlavacek, G. 1223
Bonnemason, F. 1401
Borg, J. 347
Borson, E.N. 1033
Bosch, J. 261
Bourassa, R.J. 13
Bourrieau, J. 157
Bowen, H.S. 1035
Bradley, J. 577
Brennan, P.J. 1455
Brinker, D.J. 1291, 1375
Brodzinski, R.L. 79
Brownlee, D.E. 577, 677
Bühler, F. 705
Bunch, T.E. 347, 453
Burns, F. 107
Cagle, J.A. 1511
Callen, W.R. 1403
Carabétian, Ch. 1355
Chaloupka, T. 479
Champetier, R.J. 1399
Chang, A.C. 827
Chapman, S.P. 1425
Chatzitheodoridis, E. 791
Coggi, J.M. 357, 1075, 1235
Christl, L.C. 1169
Colborn, B.L. 137, 163, 187, 195, 207, 221
Cooke, W.J. 667, 693
Coombs, C.R. 277, 595, 619
Crawford, G. 479
Cromer, T.F. 1015
Cromwell, B.K. 1001
Crutcher, E.R. 1023, 1187

Csige, I. 171, 181, 187
Dardano, C.B. 277
Davis, J.M. 1201
de Groh, K.K. 1137
DeHainaut, L.L. 1361
Delaboudinière, J.P. 1355
Derrickson, J.H. 171
Deshpande, S.P. 417
De Vries, C. 431
DeWalt, S.A. 1413
Dezfouly-Arjomandy, B. 231
Divine, N. 665
Domingo, C. 261
Drolshagen, G. 325
Durin, C. 541, 1315
Dursch, H.W. 923, 1041, 1257
Edelman, Joel 1257
Edwards, J.L. 1137
Enge, W. 239
Erlichman, J. 453
Eugster, O. 705
Farrow, A. 849
Felbeck, D.K. 889
Finckenor, M.M. 1125
Fishman, G.J. 111, 125
Fleming, R.H. 453
Foote, J. 513
Ford, D.I. 811
Frank, A.L. 163, 171
Frigo, L.A. 171, 187
Funk, J.G. 1201
Gaylord, T.K. 1403
Gebauer, L. 1137
Geiss, J. 705
George, G.A. 867
George, P.E. 923
Gillis, J.R. 13
Gilmour, J.D. 791
Golden, J.L. 1099
Grammer, H.L. 1015
Green, S.F. 417
Gregory, J.C. 3, 231, 1111, 1169
Griffis, D.P. 677
Grigsby, D.K. 1479
Gursky, H. 1535
Gyetvay, S.R. 357, 1235
Harmon, B.A. 111, 125, 231
Hartmayer, R. 1439
Harvey, G.A. 797
Havey, K. 1389
Hemminger, C.S. 963
Hennessy, C.J. 595
Henke, R.P. 171
Herzog, G. 231
Hickey, J.R. 1291, 1375
Hill, D.J.T. 867
Hill, S.G. 923
Hochedez, J.F. 1355
Hörz, F. 277, 551, 577
Hunter, J.L. 677
Hurley, D.L. 97
Imamoto, S.S. 147
Jaggers, C.H. 1075
Jansen, F. 261
Jenkins, P. 1375
Johnson, R.E. 811
Johnston, A.R. 1439
Jonathal, D. 239
Joswiak, D. 577
Kamenetzy, R.R. 1125, 1151
Kassel, Jr., P.C. 667, 693
Keegan, R. 261

Kemp, W.T. 1399
 Kenemuth, J.R. 1361
 Keough, B. 1041
 Kessler, D.J. 585
 Kinard, W.H. 277
 Kinser, D.L. 529
 Klein, J. 231
 Kosic, T.J. 1035
 Laird, C.E. 111, 125
 Lange, G. 513
 Lauriente, M. 51
 Le, T.D. 977
 Lee, M. 957
 Letton, A. 849
 Lind, D.L. 705
 Lind, M.D. 725
 Linton, R.C. 1151
 Lyon, I.C. 791
 Mack, K.S. 313
 Mackay, N. 417
 Macklin, J. 453
 Mallon, J.J. 963
 Mandeville, J.-C. 303, 347
 Manuelpillai, G. 493
 Masarik, J. 87
 Mason, J.B. 1257
 Matthews, R. 877
 McCreight, C. 1455
 McDonnell, J.A.M. 417
 McKibben, R.B. 1535
 McIntosh, R. 1455
 Mell, R.J. 1061, 1111
 Merrow, J.E. 431
 Meshishnek, M.J. 357, 1075, 1235
 Middleton, R. 231
 Miglionico, C.J. 905
 Miller, E.R. 1061, 1111
 Mirtich, M.J. 431
 Misra, V. 677
 Monarski, T.W. 1425
 Moss, C.E. 87
 Motley, W.R. III 667
 Mulholland, J.D. 667, 693
 Murr, L.E. 905
 Mustico, A. 1389
 Newman, P.J. 417
 Newman, S.C. 1511
 Nielsen, K.F. 725
 Norwood, J.K. 1125
 Oda, K. 171
 O'Donnell, J.H. 867
 Oliver, J.P. 667, 693
 Olmez, I. 107
 O'Sullivan, D. 261
 Padden, R.J. 1425
 Parnell, T.A. 69, 111, 125, 171, 187
 Paschen, K.W. 357
 Pender, C.W. 1001
 Perry, A.T. 1511
 Peters, P.N. 3, 1111, 1169
 Pippin, H.G. 13, 1023, 1041, 1187
 Pomery, P.J. 867
 Radhakrishnan, G. 1269
 Radicati di Brozolo, F. 347, 453
 Raikar, G.N. 1169
 Rasoul, F.A. 867
 Reedy, R.C. 87
 Reeves, J.H. 79
 Ricks, D.A. 677
 Rooney, W. 957
 Rose, M.F. 479
 Roybal, R.E. 905

