NASA

Technical Memorandum 80585

Trends in Materials' Outgassing Technology

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(NASA-TM-80585) TRENDS IN MATERIALS' OUTGASSING TECHNOLOGY (NASA) 27 p HC A03/MF A01 CSCL 07D

N80-16117

Unclas

G3/25 11667

NOVEMBER 1979

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

TM 80585

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November 1979

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TRENDS IN MATERIALS' OUTGASSING TECHNOLOGY

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ABSTRACT

A large amount of chemical analysis data involving identification of outgassing products from spacecraft, experiment modules, and support equipment has been accumulated at the Goddard Space Flight Center over the past nine years. In order to gain some insights into significant trends in the occurrence of outgassing problems and to assist in the implementation of meaningful materials selection policies, this data has been reduced to a computer compatible format and subjected to a variety of relevant program operations.

Chemical identification of outgassing products has been made over the years by a number of analysts using steadily improving techniques of infra-red and mass spectrometric analysis. Data for a computer file was prepared from those analytical reports and includes for each sample such items as identification of the item being tested and the project with which it is associated, the vacuum facility used, the amount of sample, and the date of test, as well as the reported names of up to six of the most abundant species found in the residue.

From these data a list of the most troublesome outgassing species has been compiled and several useful and interesting materials correlations have been developed. For example, it has been shown that the relative frequency of occurrence of excessive outgassing events declined steadily from 1970 to 1975 in response to the implementation

of materials engineering practices dictating the use of low outgassing materials. Since then, however, little over-all improvement has occurred and the rate of appearance of excessive amounts of aliphatic hydrocarbons has actually increased. As a second example, a dramatic reduction in outgassing was observed for ISEE-C solar panels because of a change from RTV 511 to the low outgassing cell adhesive, RTV 566. Another correlation was made between the use of wiring containing a specific antioxidant and high outgassing rates from cable bakeouts. Besides these examples, a number of other correlations, trends, and interesting events were identified.

TRENDS IN MATERIALS' OUTGASSING TECHNOLOGY

INTRODUCTION

Outgassing and condensation of organic contaminants has long been recognized as a problem in aerospace technology. Detrimental effects include attenuation of optical signals in instrument systems, alterations of alpha/epsilon ratios of thermal control surfaces, corona discharge effects, and various detector malfunctions.

Goddard has long maintained a system of surveillance of outgassing levels in its thermal vacuum test facilities. This system involves operation of a liquid nitrogen-cooled cold finger to trap outgassed species in each vacuum facility during hardware testing. At the conclusion of each test, the condensed organic residues are washed from the cold finger and transported to the analytical organic chemistry laboratory for quantification and identification. These analyses are performed using advanced instrumental methods including infra-red spectrophotometry and mass spectrometry. The results of these analyses are routinely used to indicate the acceptability of flight hardware or to flag down problem materials and track down outgassing sources.

In addition to this surveillance activity, an extensive materials' outgassing evaluation program has been conducted through the years by the Materials Control and Applications Branch. Through this effort, polymeric materials are subjected to a standard test condition (24 hours at 125°C in vacuum with a room temperature (25°C) collector plate) resulting in determination of total weight loss and total collected volatile condensable material (CVCM). This test has been accepted as ASTM-E-595-77, and thousands of materials have been evaluated. This information has been used as a basis for recommending materials for space flight use in order that the incidence of problems related to outgassing might be reduced. All spacecraft projects are required to include in their design requirements, a materials review which contains an evaluation of outgassing potential. The effectiveness of this materials engineering effort can be shown both by the degree of success of our flight programs and by reductions in the occurrence of time and money-consuming problems during the test and integration phase of spacecraft preparation.

An effort has now been made to develop more information concerning the effectiveness of our programs by computerizing all of the analytical chemistry data accumulated over the last nine years of outgassing residue analysis. Pertinent data describing the test item, test facility, and the amount and composition of each sample were entered in the data bank. Computer operations were then developed and employed in order to generate data which might show significant events and trends in the occurrence of outgassing problems through the years. By finding specific changes in the frequency of occurrence of individual outgassed species and correlating them with known materials' usage practices, the impact of previous materials' decisions can be estimated. Also, an assist in making logical materials selection and establishing meaningful policies for future spacecraft projects may be obtained.

CHEMICAL ANALYSIS DATA

The scope of the analytical data used to form this study has been restricted somewhat in the hope of keeping it compatible and consistent. Analytical results of cold finger residues from thermal vacuum facilities at Goddard and some of its contractors have been included as well as wipe samples from various flight hardware which either had contamination problems or potential problems. However, analytical data from known materials, suspected sources, micro-CVCM tests, and contamination problems not related to outgassing have been excluded. The total number of analytical reports used was 1163 and covered the time period from 1970 through 1978.

Procedures for obtaining good analytical samples of thermal vacuum outgassing products have been developed and remained essentially unchanged throughout this time period. The cold finger is a small cylindrical device (Figure 1) installed in the thermal vacuum facility and cooled with liquid nitrogen during part or all of a thermal vacuum operation in order to condense any volatile species present. This scavenger process results in accumulation of sufficient sample for analysis. The cold finger is warmed to room temperature during the back filling phase which should result in maximum retention of condensables while avoiding condensation of water vapor from the air. The residue is then washed from the cold finger with spectrograde 2-propanol and the solution sent to the chemistry laboratory for analysis.

The cleanliness profile of spacecraft surfaces can be determined by taking analytical wipe samples. This is done by using precleaned cotton swabs dampened with high purity alcohol and wiping an area from 25 to 50 square inches. In order to obtain sufficiently clean cotton swabs, it is necessary

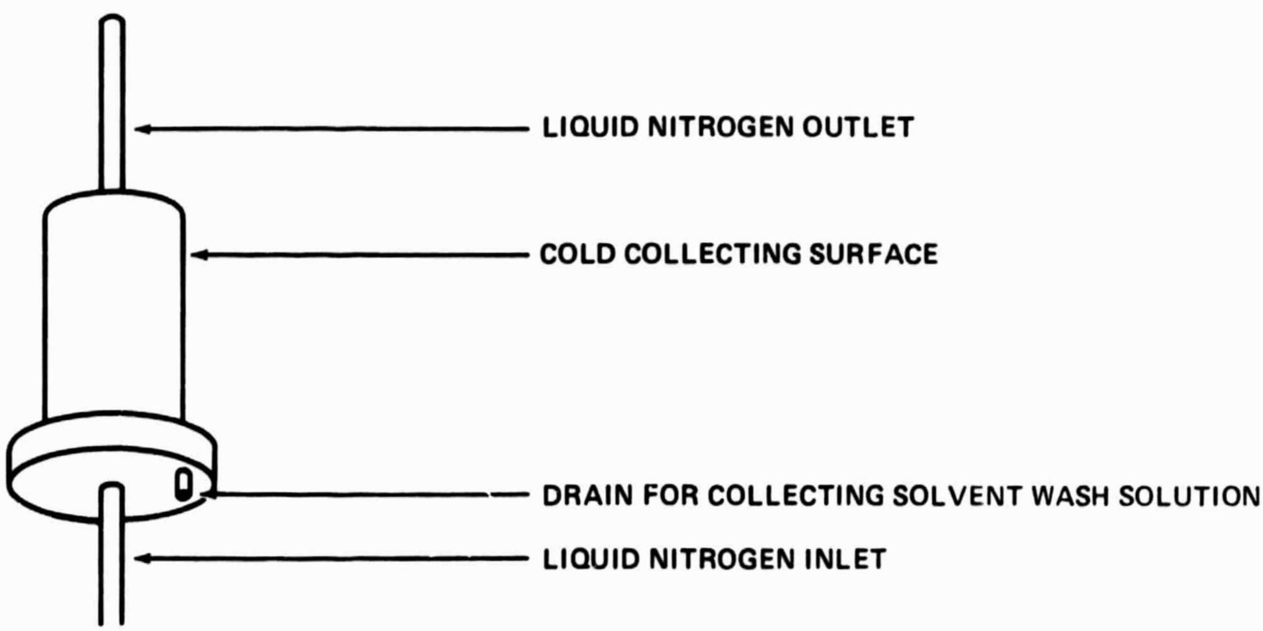

Figure 1. Diagram of Chamber Cold Finger.

to extract them in a Soxhlet extractor for 24 hours with chloroform followed by 24 hours with absolute ethanol. This process removes all traces of wood resins, cotton seed oil, and adhesive which would interfere with the analysis. It is also important to make certain that the surfaces which are wiped are not affected by the alcohol solvent i.e., surfaces such as metallic surfaces, Kapton, Teflon, anodized aluminum, etc.

Although there have been a number of significant advances in analytical technique and capability through the years, the basic procedure for a chemical analysis is somewhat set. The first step in a cold finger analysis is the gentle removal of the isopropyl alcohol by warming on a steam bath. After the weight of the residue has been determined, it is ready for infra-red analysis. Wipe samples are prepared for analysis by extraction of the residue from the swab with hot alcohol, squeezing and rinsing with more alcohol, and evaporation of the solvent on the steam bath.

The infra-red spectrum of one of these samples is most efficiently obtained using the technique called "casting a film". The sample is dissolved in a few drops of chloroform and applied to a polished potassium bromide (KBr) disc. Evaporation of the solvent leaves a thin film of the sample. This technique may be used successfully because most of these samples are oils or semisolids with low volatility under ambient conditions. The fingerprint absorption spectrum is then obtained by scanning from 2½ to 20 microns with a research grade IR spectrophotometer. Interpretation of IR data provides good identification of some homogeneous samples, the prominent constituents of simple mixtures, and at least the more significant functional groups in complex mixtures.

More specific identifications can usually be obtained using advanced mass spectrometric techniques. With this method the sample is ionized by electron bombardment in the mass spectrometer and the mass fragmentation pattern of the resultant positive ions is recorded. This pattern is very specific for each chemical species and results in unique chemical identification of each compound. Moreover, by the use of the combination gas chromatograph/mass spectrometer (GC/MS) a complex mixture may be separated and identification obtained for each of its components. Cold finger condensables are especially amenable to this technique since the very properties which allow mobility in a vacuum system also make the material suitable for chromatographic separation. If the GC/MS data does not account for all the features shown by the infra-red scan, then a batch-type mass spectrum is obtained using the direct insertion probe. Some of the materials which require this treatment are organic acids, amines, and higher molecular weight compounds.

A COMPUTER FORMAT FOR THE ANALYTICAL DATA

A computer format was developed to allow formation of a data bank containing the maximum amount of self-consistent information from chemical analysis reports from log books spanning a nine year period. These reports represent the work of different chemists using an evolving analytical capability and advancement in instrumentation. In addition, there have been some variations in thermal vacuum facilities operating procedures and policies. In spite of these possible sources of inconsistencies and the fact that the reports were never intended to be suitable for computerization, the data format shown below was established. Eighty-entry Fortran coding cards were used – one for each analytical report – with the following assignments:

	Column Numbers
Analysis report number	1-5
Analysis date	6-11
Job order number	12-14
Project name	15-19
Test item name	20-29
Type of test	30-31
Facility identification	32-34
Type of sample	35-36
Sample weight	37-39
Type of analysis	40
Materials identified	41-45, 46-50, 51-55, 56-60, 61-65, 66-70
Were there more?	71

Abbreviations were used where required in order to fit this format. The "Type of test" refers to the hardware testing program being monitored while the "Type of sample" refers to the method of sample collection, i.e., cold finger, wipe sample, etc. Facility identifications are the chamber numbers for Goddard units and arbitrarily assigned numbers for contractor facilities (see code list in appendix). Sample weights are applicable only to cold finger samples and are listed in milligrams. The "Types of analysis" includes infra-red spectrophotometry, direct insertion mass spectrometry, and gas chromatography/mass spectrometry and combinations of these techniques which are number coded as shown in the appendix. Finally, the identifications of materials found are coded by abbreviations and include 102 types of entries which are also listed in the appendix.

Computer operations on this data bank were designed to list data, sorting according to different categories such as test item, project, primary material, or frequency of occurrence of a material using various control parameters. Attempts were then made to illustrate interesting and informative materials' correlations, trends in types of occurrences, and technology areas in which either improvement has been made or in which further study must be concentrated.

RESULTS AND DISCUSSION

In order to attempt to identify the kinds of materials which are responsible for most of the observed outgassing problems at Goddard and significant trends in their rate of occurrence, a program for data sorting was written with the following parameters:

- Count the number of times each material occurred as either primary or secondary material.
- List the count in quarter year increments.
- Limit data to include only samples with ten or more milligrams of material.

IDENTIFICATION OF MATERIALS

From this listing, which disregards all samples where the amount of outgassing was less than 10 milligrams and includes only the predominant two species identified in each sample, a table of the most often reported problem materials was derived (Table 1). It should be pointed out that many of these names used for identification are for generic classes and include large numbers of materials such as aliphatic hydrocarbons, methyl silicones, and esters, while others are for specific individual compounds such as di(2–ethyl hexyl) phthalate (DEHP), dibutyl phthalate (DBP), hydroxy methoxy benzophenones (HMBZP), and 2, 6 ditertiary butyl p–cresol (BHT). Thus, it has been shown that the most often found individual compound is DEHP.

Table 1
Principal Materials Identified in the More Significant Outgassing Residues
(Samples ⩾ 10 mg – April, 1970 Through January 1979)

Material Code	Number of Occurrences
1. ALHYD	185
2. MESIL	129
3. DEHP	114
4. ESTER	100
5. DBP	27
6. PHEST	24
7. ARMHY	23
8. MPHSI	19
9. URETH	18
10. HMBZP	17
11. BHT	16
12. DC704	15
13. RTV56	12
14. ORGAC	9
15. TCEPH	8
16. DEHAZ	6
17. TPP	6
18. DTAMQ	5
19. PCB	5
20. DEHAD	4

TRENDS IN OCCURRENCE OF GENERIC CLASSES

In Table 2 these individual materials have all been incorporated into their generic classes and the number of occurrences and their percentages calculated. This listing shows that esters (36%), aliphatic hydrocarbons (23%), and methyl silicones (16%) account for 75% of the outgassing problems observed during the last nine years of thermal vacuum testing at Goddard. An attempt was made to show possible trends in the rates of occurrence of these classes of compounds by plotting the number of times they were found in samples over ten milligrams as a function of calendar year. It was found immediately that there was a large difference in the number of reports issued from one year to the next and this resulted in discontinuities in all frequency curves. This was corrected by calculating a normalizing factor for each year (Table 3) in order to weight results according to the total amount of analytical activity that year. Using these factors and the quarterly count data from the computer sorting, rate curves were plotted for the three major classes of contaminants, namely, esters, aliphatic hydrocarbons, and methyl silicones (Figure 2). From the curves it can be seen that real progress in reducing the instances of serious outgassing was made between 1970 and 1975. This time period correlates well with the initiation and acceptance of materials engineering practices dictating the incorporation of low outgassing materials into flight hardware. However, from 1975 to the present,

Table 2
Principal Materials by Generic Categories

Category	Number of Occurrences	Percentage
1. All Esters	289	36
2. Aliphatic hydrocarbons	185	23
3. Methyl silicones	129	16
4. Aromatic silicones	46	5.7
5. Antioxidants	38	4.7
6. Aromatic hydrocarbons	23	2.8
7. Polyurethane derivatives	18	2.2
8. Organic acids	9	1.1
9. Other materials	73	9

Table 3
Calculation of Annual Frequency Norma'ization Factors

Year	Total Number of Reports	Fraction of Average	Normalizing Factor
1970	29	129/29	4.4
1971	59	129/59	2.2
1972	164	129/164	0.79
1973	190	129/190	0.68
1974	115	129/115	1.12
1975	61	129/61	2.1
1976	184	129/184	0.70
1977	215	129/215	0.60
1978	102	129/102	1.3
TOTAL	9/ 1163		
AVERAGE	129		

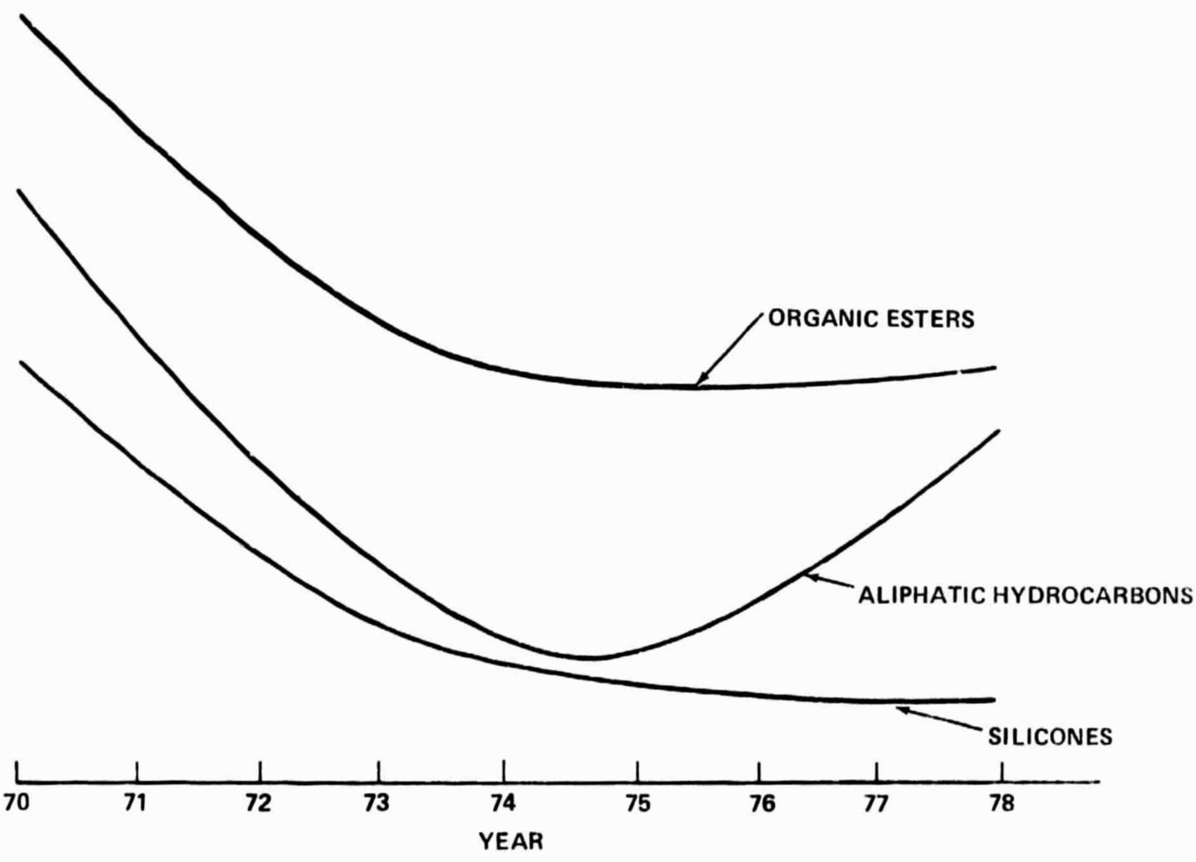

Figure 2. Normalized Frequency of Occurrence of Excessive Outgassing by Chemical Class.

little additional improvement can be shown and, in fact, the occurrence of serious outgassing due to aliphatic hydrocarbons has risen significantly. These facts indicate that increased research into possible sources and differentiation of outgassed aliphatic hydrocarbon species should be initiated and that schemes for more effective materials control and cleanliness procedures should be sought.

OUTGASSING FROM SOLAR PANELS

A dramatic correlation between materials selection and outgassing has been shown in the case of solar panel bakeouts. Historically, these have been one of the largest sources of condensable outgassing material and have resulted in excessive expenditures of time and money to perform repetitive thermal vacuum bakeouts in order to reduce the outgassing rates to acceptable levels. High outgassing solar cell adhesives used over the years were Sylgard 182 and 184, RTV 511, and RTV 560/RTV 580. Table 4 shows the number of thermal vacuum tests performed on solar panels at Goddard for various projects and the number of these with cold finger residues over 10 milligrams. The dramatic improvement for ISEE-C, indicating only one bad outgassing event out of eleven (9%) test as compared to 91% bad for all previous projects, is a direct result of changing from RTV 511 to RTV 566 solar cell

Table 4
Occurrence of Serious Outgassing Due to Bakeout of Solar Panels

Project	Test Year	Number Over 10 mg	Total Tests
RAE-B	1970	4	5
IMP-I	1970	8	8
SSS-A	1970-71	2	2
OAO	1970-72	10	10
IMP-J	1973	7	9
IUE	1974-75	2	2
ISEE-A	1976-77	6	7
ISEE-C	1977	1	11

adhesive. Incidently, the one occurrence was not due to the cell adhesive but was shown to be caused by an improperly prepared polyurethane material used elsewhere on the panel.

OUTGASSING FROM THERMAL BLANKETS

A similar improvement in outgassing performance has been shown for thermal blankets (Table 5). In 1972–1974 eight out of nine thermal blanket bakeouts resulted in excessive outgassing, whereas, in 1977–1979, only three of seventeen were excessive. In this case, however, no clear–cut materials' correlation could be shown and the improvement can probably be explained by the institution of better cleanliness procedures during fabrication and handling.

ANTIOXIDANT FROM WIRE INSULATION

The appearance of a unique material in many cold finger residues since 1976 has caused an enlightening investigation. This material, known as hydroxy, methoxy benzophenones, has occurred in bakeouts of certain electronics packages and a large number of cable bakeouts. Eighteen of twenty two samples where it was found were in the excessive range, i.e., over 10 milligrams. A little research has proven that this substituted benzophenone is the antioxidant in Raychem "Spec 44" wiring

Table 5
Occurrences of Serious Outgassing Due to Bakeout of Thermal Blankets

Project	Test Year	Number Over 10 mg	Total Tests
SAS–B	1972	5	5
ERTS	1972–73	2	3
ATS–F	1974	1	1
AEM–A	1977–78	1	3
IUE	1977	1	4
MMS	1978	1	4
SMM	1978–79	0	6

insulation. Our latest outgassing test data of Spec 44, done in 1976, showed this material to be acceptable. An investigation is currently being made to see if this problem might have come about from a change in antioxidant by the manufacturer around 1976. This appears to be the most likely explanation since the material was never seen in cold finger samples before that time!

MISCELLANEOUS MATERIALS' OUTGASSING

Other attempts at materials' correlation have not been so clear-cut. For instance, tracking of the rate of occurrence of four interesting specific compounds is shown in Figure 3. The appearance of the volatile antioxidant BHT (2, 6 ditertiary butyl p-cresol) has declined somewhat in recent years, perhaps as a result of better materials screening practices, but has not yet been eliminated. This material is commonly used in synthetic rubbers and plastics but its specific sources in aerospace hardware are still uncertain. The compound triphenyl phosphate, which is a fire-retardant plasticizer, appeared in 1972–1973 and then not again until 1977. Studies of the hardware and projects associated with this material were inconclusive with the only correlation being that it appeared mostly in samples which also contained significant amounts of aliphatic esters such as azelates and adipates. The frequency of appearance of another fire-retardant, tris (2-chloroethyl) phosphate, seems to have been more well behaved. Its occurrence, which was associated with polyurethane foams, increased through 1976 and since then has virtually disappeared from collected outgassing product samples. Even more dramatic, but again not well explained, is the case of di(2-ethyl hexyl) azelate, a plasticizer used for its low temperature effectiveness. The rate of appearance of this compound increased radically in 1976 and 1977 and then, for no obvious reason, dropped to almost nothing after 1977.

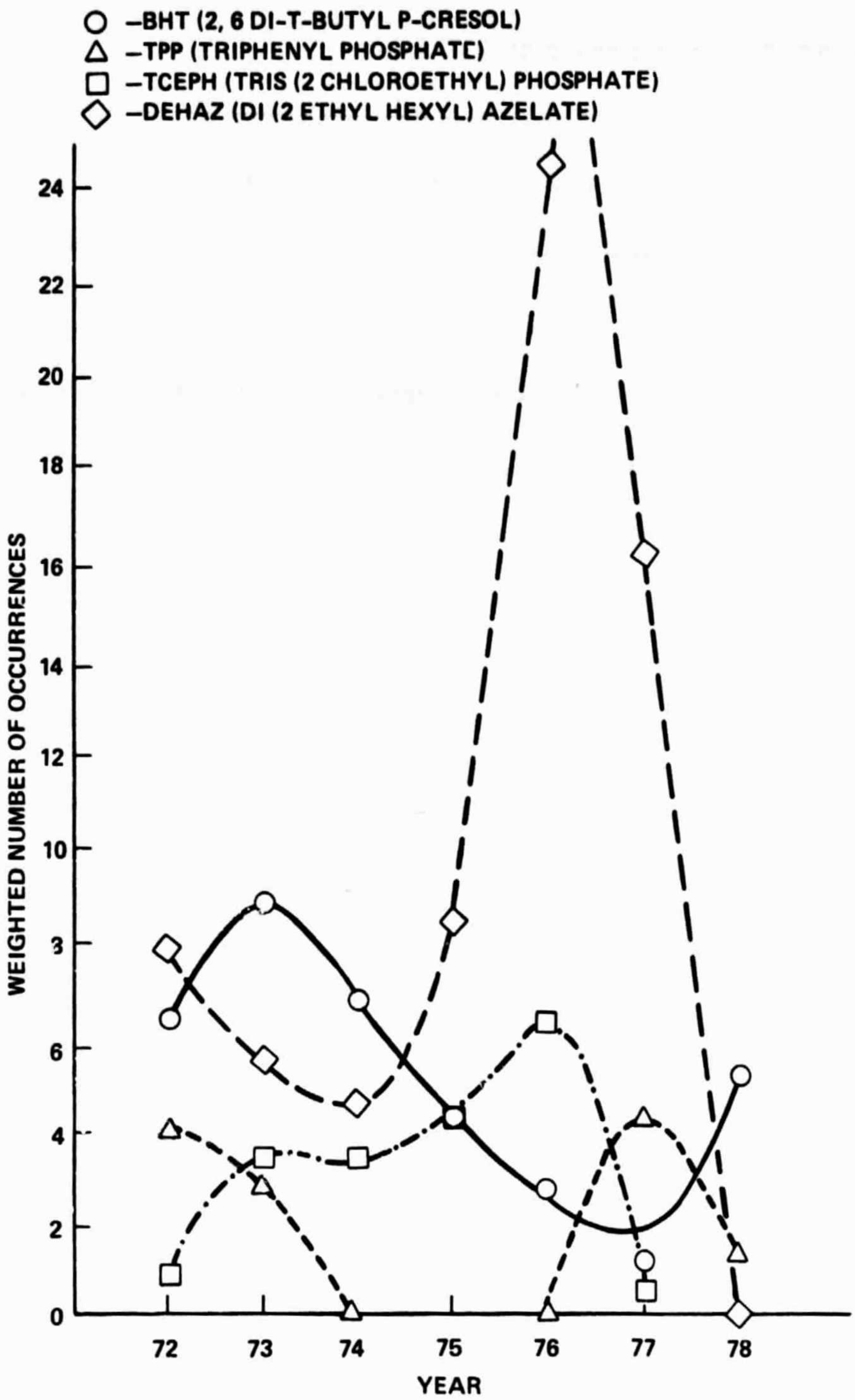

Figure 3. Normalized Rates of Occurrence of Some Unique Compounds.

THERMAL VACUUM TESTS OF WHOLE SPACECRAFT

Although there are not enough data from equivalent tests to provide any statistical trends, the outgassing results from whole spacecraft are never–the–less of considerable interest and demonstrate some important materials' correlations. Some of the results which reasonably can be compared are presented in Table 6.

From facility 238, a dramatic reduction in amount of outgassed residue was observed between the early 70's and the AEM–A(HCMM) tests which were run in 1978 and resulted in only one milligram of collected residue. For the IMP–H in 1971, the large amount of outgassed residue (20 mg) was shown to consist of methyl silicones from the solar cell adhesive. In 1973, excessive outgassing from the RAE–B(32 mg) was attributed to plasticized vinyl (probably wire insulation material) and

Table 6
Outgassing From Thermal Vacuum Tests of Whole Spacecraft

Facility	Year	Spacecraft	Amount of Residue	Primary Products
238	1971	IMP–H	20 mg	Methyl silicones
238	1973	RAE–B	32 mg	DEHP/RTV–560
238	1978	AEM–A	1 mg	ALHYD
238	1978	AEM–A	1 mg	ALHYD
290	1975	CTS	38 mg	DBDAC (Anti–oxidant)
290	1975	CTS	2 mg	ALHYD
290	1975	NRL	9 mg	RTV–560
290	1975	NRL	6 mg	RTV–560
290	1977	ISEE–A	4 mg	ALHYD
290	1977	IUE	4 mg	ALHYD
290	1977	IUE	9 mg	ALHYD
290	1977	IUE	3 mg	ALHYD
290	1977	IUE	1 mg	ALHYD
290	1977	IUE	1 mg	ALHYD
290	1979	SMM	12 mg	ALHYD/DEHP

to the solar cell adhesive system RTV-560/580. Both of these outgassing sources have now been excluded from all flight hardware materials lists.

Tests conducted in the Solar Environment Simulator (SES), facility 290, provide less dramatic results because the collected cold finger residues are always smaller due to unfavorable geometry (the facility is gigantic compared to the cold finger area) and to the fact that there is a tremendous pumping capability, i.e., high through-put per unit volume. However, there have been some notable occurrences such as in the case of the CTS in 1975. The first thermal vacuum test resulted in 38 mg of collected condensable residue which was shown by mass spectrometry to consist of a single chemical species with the ponderous chemical name of ditertiary butyl dimethylamino paracresol. This material, also known as "Ethyl Antioxidant 703", is comparatively volatile and was completely absent from the subsequent cold finger sample where the amount of residue was only two milligrams.

Most of the other spacecraft tested in this facility have produced only moderate amounts of outgassing products. It has been demonstrated, especially in the case of the IUE, that continued thermal vacuum operation can be an effective final clean-up technique. Thus, the last two cold finger amounts were about one milligram which is the amount expected when the chamber is operated with no payload at all.

CONCLUSIONS

Computerization of chemical analysis data has been used successfully to identify several important trends in the occurrence of outgassing problems in aerospace programs. The frequency of occurrence totals show that di(2-ethyl hexyl)phthalate (DEHP) is the most often found individual species in outgassing samples and that esters are the leading generic class of compounds. The effectiveness of this data bank has been demonstrated by the good correlations between materials and their outgassing products for solar panel bakeouts and cable bakeouts. However, trends in frequency of occurrence of many compounds have been demonstrated where no correlation to materials could be established. In the case of the class of compounds called aliphatic hydrocarbons, it was shown that the number of instances of significant outgassing of these products is increasing. If this trend is to be reversed, more knowledge concerning the sources and chemistry of the compounds included in this classification will have to be derived by intensified research in this area.

ACKNOWLEDGMENTS

The computer format and programming were developed by Richard S. Marriott and analytical reports from nine years were converted to a computer code and entered on cards by James Hays. Without their competent and cooperative efforts this work would have been impossible.

Appendix – Code Numbers and Abbreviations

I. Type of Analysis

	Number
Infra-red only (IR)	1
Mass Spectrometer – direct probe (MS)	2
Gas Chromatography/Mass Spectrometry (GC/MS)	3
IR + MS	4
IR + GC/MS	5
IR + MS + GC/MS	6
MS + GC/MS	7

II. Facility Identification

	Number
Goddard Thermal Vacuum Chambers	236-245
Solar Environmental Simulator (GSFC)	290
University College London (UCL)	300
RCA-Hightstown, N. J.	301
MSDS (England)	302
Jet Propulsion Laboratory (JPL), CA	303
Honeywell Radiation, Lexington, MA	304
Ford Aerospace, CA	305
ITT, Fort Wayne, IN	306
Fairchild, MD	307
Lewis Research Center, OH	308
General Electric, Valley Forge, PA	309
Gulton Ind., CA	310
Santa Barbra Research Center, CA	311
Cape Kennedy	312
RFI Clean Room (GSFC)	313
Wallops Island Flight Center, VA	314
Lockheed Missles & Space, CA	315
Sperry Flight Systems, AZ	316

III. Materials Identified

Abbreviation	Material
1. ABIAC	Abietic acid
2. ACESD	Acetate esters
3. ACETA	Acetate polymers
4. ADEST	Adipate esters
5. ALAMI	Aliphatic amines
6. ALEST	Aliphatic esters

III. Materials Identified (Continued)

Abbreviation	Material
7. ALHYD	Aliphatic hydrocarbons
8. ALKEN	Alkenes
9. AMIDES	Amides
10. AMINES	Amines
11. AMMON	Ammonia
12. ANTOX	Aromatic antioxidant
13. ARMAM	Aromatic amines
14. ARMHY	Aromatic hydrocarbons
15. ARMPH	Aromatic phosphates
16. AZEST	Azelate esters
17. BENES	Benzoic acid esters
18. BHT	2, 6 Ditertiary butyl p-cresol
19. BOP	Butyl octyl phthalate
20. BPBG	Butyl phthalyl butyl glycolate
21. BUPAL	Butyl palmitate
22. BUSTR	Butyl stearate
23. BVE	Butyl vinyl ether
24. CAPRO	Caprolactam
25. CARBO	Carboxyl compounds
26. CHLAR	Chlorinated aromatics
27. CHLOR	Chlorinated compounds
28. CRBNL	Carbonyl compounds
29. CRESO	Cresols
30. CYAMD	Cyanoamide compounds
31. DBA	Dibutyl adipate
32. DBAZ	Dibutyl azelate
33. DBDAC	2, 6 Di(t-butyl) 3-dimethyl amino-p-cresol
34. DBP	Dibutyl phthalate
35. DC93	Dow Corning 93-046 silicone
36. DC200	DC 200 methyl silicone fluid
37. DC704	DC 704 diffusion pump fluid
38. DDP	Didecyl phthalates
39. DEHAD	Di(2-ethyl hexyl) adipate
40. DEHAZ	Di(2-ethyl hexyl) azelate
41. DEHP	Di(2-ethyl hexyl) phthalate
42. DEHS	Di(2-ethyl hexyl) sebacate
43. DEP	Diethyl phthalate
44. DMPH	Dimethyl phthalate
45. DPE	Diphenyl esters
46. DTAMQ	2, 5 Ditertiary amyl quinone
47. DTBPH	Ditertiary butyl phenol
48. ESTER	Esters
49. EPOXY	Epoxies

III. Materials Identified (Continued)

Abbreviation	Material
50. ETHES	Ethyl esters
51. ETHOX	Ethoxylated compounds
52. ETPAL	Ethyl palmitate
53. FLOHY	Fluorinated hydrocarbons
54. FLSIL	Fluorosilicones
55. GLYCE	Glycerine
56. HCLBZ	Hexachlorobenzene
57. HMBZP	Hydroxy methoxy benzophenones
58. HMCOM	Hydroxylated methoxylated compounds
59. INDOX	Inorganic oxides
60. ISPRM	Isopropyl myristate
61. KAPT	Kapton (polyimide)
62. KEL-F	Kel-F (polytrifluorochloroethylene)
63. KETON	Ketones
64. LAUAC	Lauric acid
65. LOCKA	Locktite A
66. MEEST	Methyl esters
67. MESIL	Methyl silicones
68. METDP	Methylene diphenol
69. MPHSI	Methyl phenyl silicones or phenyl silicones
70. MYRAC	Myristic acid
71. NBOCT	n-Butyl 1-octanol
72. NICOT	Nicotine
73. NITRI	Nitriles
74. NPHNA	N-Phenyl naphthyl amine
75. ORGAC	Organic acids or fatty acids
76. ORGPH	Organic phosphates
77. PALAC	Palmitic acid
78. PCB	Polychlorinated biphenyls
79. PESHT	Polyethylene shrink tubing (derivative)
80. PHANH	Phthalic anhydride
81. PHENO	Phenol compounds
82. PHEST	Phthalate esters
83. PHOSP	Phosphates
84. POLET	Polyethoxy compounds
85. POLGL	Polypropylene glycols
86. POLHY	Polyhydroxy compounds
87. PSTYR	Polystyrene
88. RTV51	Methyl phenyl silicones (from RTV-511 or RTV-510)
89. RTV56	Methyl phenyl silicones (from RTV-560 or RTV-566)
90. SANT5	Santovac 5 diffusion pump fluid
91. SOAPS	Organic soaps or ionized carboxyls
92. STRAC	Stearic acid

III. Materials Identified (Continued)

Abbreviation	Material
93. SULFU	Sulfur compounds
94. TBE	2-t-Butoxy etnanol
95. TCEPH	Tris (2-chloroethyl) phosphate
96. TCP	Tricresyl phosphate
97. TEHPH	Tris (2-ethyl hexyl) phosphate
98. TMPI	1.1.3 Trimethyl phenyl indane
99. TPP	Triphenyl phosphate
100. TRIS	Tris (2, 3 dibromopropyl) phosphate
101. URETH	Polyurethane derivatives
102. VNLAC	Polyvinyl acetate

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1. Report No. 80585	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TRENDS IN MATERIALS' OUTGASSING TECHNOLOGY		5. Report Date November 1979
		6. Performing Organization Code 313
7. Author(s) Joe A. Colony		8. Performing Organization Report No.
9. Performing Organization Name and Address Materials Control and Applications Branch		10. Work Unit No.
		11. Contract or Grant No.
		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address GODDARD SPACE FLIGHT CENTER Greenbelt, Maryland 20771		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A large amount of chemical analysis data involving identification of outgassing products from spacecraft, experiment modules, and support equipment has been accumulated at the Goddard Space Flight Center over the past nine years. In order to gain some insights into significant trends in the occurrence of outgassing problems and to assist in the implementation of meaningful materials selection policies, this data has been reduced to a computer compatible format and subjected to a variety of relevant program operations. From these data a list of the most troublesome outgassing species has been compiled and several useful and interesting materials correlations have been developed. For example, it has been shown that the relative frequency of occurrence of excessive outgassing events declined steadily from 1970 to 1975 in response to the implementation of materials engineering practices dictating the use of low outgassing materials. Since then, however, little over-all improvement has occurred and the rate of appearance of excessive amounts of aliphatic hydrocarbons has actually increased. A number of other trends, correlations, and interesting events were demonstrated.

17. Key Words (Selected by Author(s)) Spacecraft Contaminants, Outgassing, Chemical Analysis, Materials	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*

*For sale by the National Technical Information Service, Springfield, Virginia 22151.

GSFC 25-44 (10/77)