REPORT

PROJECT FOR THE ANALYSIS OF TECHNOLOGY TRANSFER

Quarterly Reports Nos. 3 – 4

1 July 1970 – 31 December 1970

Contract NNSR 06-004-063

DENVER RESEARCH INSTITUTE
UNIVERSITY OF DENVER

This report presents the results of six months of research on technology transfer conducted by the Industrial Economics Division of the University of Denver Research Institute (DRI). Material presented in this report was gathered and analyzed as a part of the Project for the Analysis of Technology Transfer (PATT).

PATT was established in November 1967 to provide a better understanding of the technology transfer process by examining nonspace applications of NASA-developed technologies. To facilitate reaching this objective, PATT: (1) Operates a technology transfer data bank which documents information on the characteristics of users of NASA's Tech Brief-Technical Support Package program; (2) documents situations in which NASA-generated technologies have been applied outside the space program; (3) develops suggestions for improving the effectiveness and efficiency of NASA's technology transfer activities; and (4) maintains contact with sources of technology, with channels of technological communication, and with users of technology in order to keep up-to-date with developments affecting technology transfer processes.

This report summarizes progress made from June through December 1970 in achieving these goals and briefly discusses future activities. It builds on data presented in previous PATT reports as well as on results of other DRI technology transfer research.

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1 July 1970 - 31 December 1970

Contract NSR 06-004-063

- Prepared for -

National Aeronautics and Space Administration

- Prepared by -

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REPORT HIGHLIGHTS

- A major program modification in the area of PATT transfer documentation was instituted during the third quarter of 1970. While retaining an emphasis on documenting individual cases of technology transfer activities, the new approach groups particular transfer activities into selected technical fields (e.g., plastics, lubrication, fire safety) and describes those activities in "transfer profile" presentations (Sections I and II).

- During the reporting period, PATT personnel continued to investigate the technical and economic impacts of NASA's Tech Brief-Technical Support Package (TSP) program. In addition to processing 7,738 TSP request letters, PATT interviewers completed approximately 300 telephone interviews with TSP requesters to document the transfer experiences of persons using these publications (Section I).

- A technical and economic impact analysis was completed late in the reporting period of the May 1970 "NASA Conference on Materials For Improved Fire Safety" (Section I).

- Progress was made during December 1970 in formulating a conceptual model of technology transfer processes (Section I).

SECTION I. PATT 1970 RESEARCH ACTIVITIES: JULY - DECEMBER, 1970

PATT research activities conducted from July through December 1970 are reviewed in this section.*

Tech Brief-Technical Support Package Program

During the last six months of 1970, PATT received 7,738 letters which had been sent to NASA by persons requesting Technical Support Packages (TSP's). The number of TSP requests which were made in that time period was approximately equal to the number received during the first six months of the year (see Figure 1). The 15,607 TSP requests coded by PATT personnel in 1970 brought the total number of requests processed from the inception of the project to 47,210.

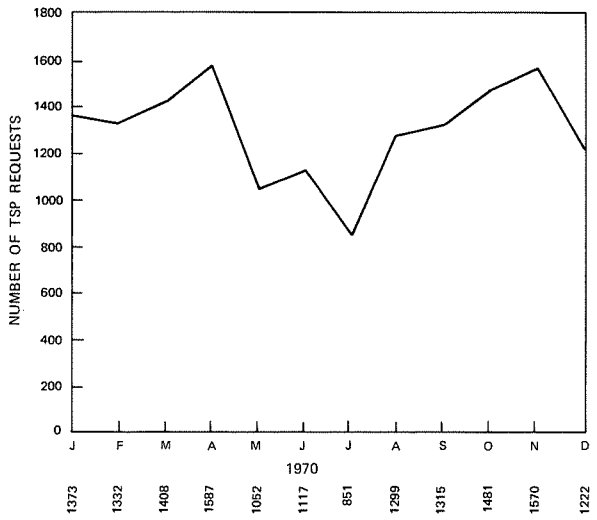


Figure 1. Monthly Requests for Technical Support Packages: January 1970 - December 1970

Data concerning the number of 1970 requests for TSP's generated by the different NASA field centers are shown in Table 1. During the

* A major program modification in the area of transfer documentation was instituted during the third quarter of 1970. That modification, described below in Section II, effected a decision to combine reviews of PATT activities during the final two quarters of the year into this single report.

TABLE 1. REQUESTS FOR TECHNICAL SUPPORT PACKAGES, BY NASA CENTER, JANUARY 1970 - DECEMBER 1970

	1970												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
Ames Research Center	39	74	64	38	36	29	32	65	63	78	68	81	667
Flight Research Center	2	2	7	1	4	0	0	40	15	2	2	0	75
Goddard Space Flight Center	59	76	202	227	124	165	61	74	48	23	61	36	1,156
Headquarters	0	0	40	5	55	165	64	79	18	0	0	0	426
Kennedy Space Center	72	55	11	11	0	0	90	29	73	77	68	0	486
Langley Research Center	92	12	21	16	16	8	7	15	137	203	195	111	833
Lewis Research Center	129	124	225	250	93	51	56	96	39	50	18	120	1,251
Manned Spacecraft Center	124	178	218	261	254	91	68	101	428	273	154	108	2,258
Marshall Space Flight Center	459	530	513	590	382	395	240	671	423	523	521	467	5,714
NASA Pasadena Office (JPL)	67	97	48	111	61	170	150	93	58	73	366	199	1,493
Space Nuclear Propulsion Office	330	184	59	77	27	43	83	36	13	179	117	100	1,248
TOTAL	1,373	1,332	1,408	1,587	1,052	1,117	851	1,299	1,315	1,481	1,570	1,222	15,607

last six months of 1970, TSP's originating at Marshall Space Flight Center generated approximately 37 percent of all requests; these developed at Manned Spacecraft Center, NASA Pasadena Office, and Langley Research Center collectively accounted for another 35 percent. To some extent, this variation in TSP request frequency can be accounted for by the different rate of TSP production among the field centers (see Figure 2), and by the fact that some centers produce a few Tech Briefs having very popular TSP's (see Table 2).

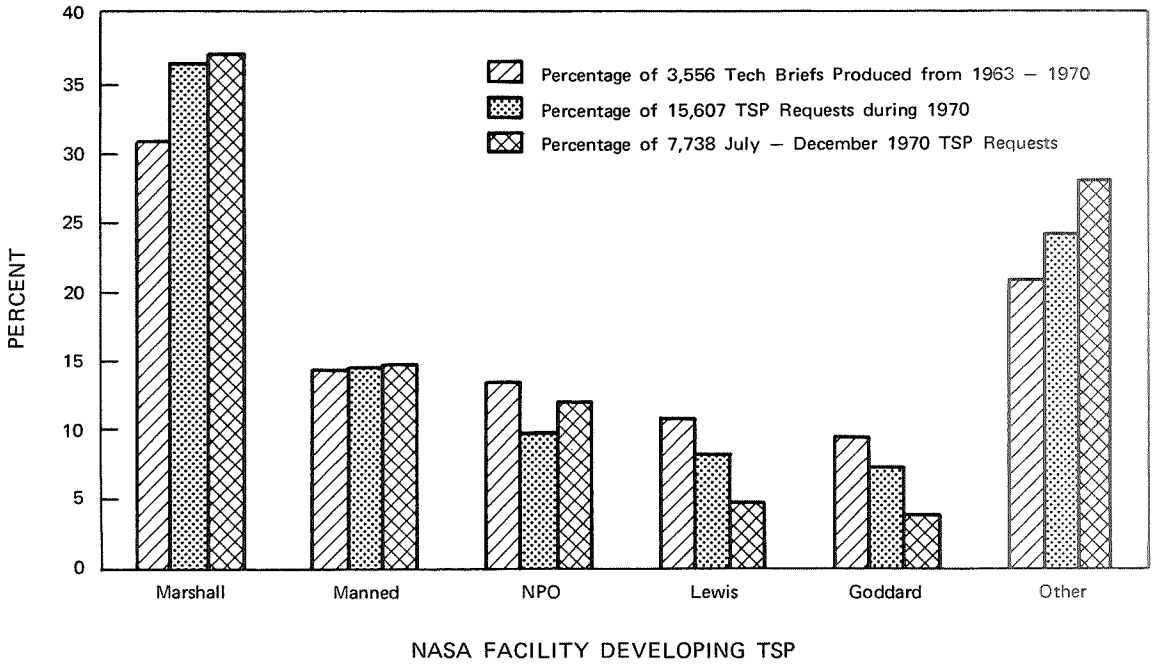


Figure 2. A Comparison of Total Tech Brief Production With Total 1970 TSP Request Frequency, and July-December 1970 TSP Request Frequency by NASA Field Center

TABLE 2. TEN TSP's MOST FREQUENTLY REQUESTED DURING JULY - DECEMBER 1970

TSP Number	Request Frequency	Originating Center	Title
69-10705	309	SNPO	Handbook Explaining the Fundamentals of Nuclear and Atomic Physics
68-10224	258	LERC	Semiconductor AC Static Power Switch
69-10725	224	NPO	Pocket-Sized Tone-Modulated FM Transmitter
70-10520	223	LARC	Nondestructive Spot Tests Allow Rapid Identification of Metals
68-10017	144	GSFC	Regulated DC-to-DC Converter Features Low Power Drain
69-10581	139	MSC	A Method for Precision Anodize Stripping
69-10807	124	MSFC	Investigation of the Development of Cracks in Solder Joints
70-10483	112	MSFC	A Conceptual Current Surge Protector for Incandescent Lamps
69-10607	110	MSFC	Sprayed Shielding of Plastic-Encapsulated Electronic Modules
69-10740	100	MSC	Burn-Rate Testing Apparatus

Transfer Documentation Activities

In this reporting period, approximately 300 telephone interviews were conducted with persons who appeared to have used technologies generated by or for NASA. Since the inception of PATT in November 1967, 1,038 such interviews have been completed; approximately 20 percent of those interviews involved a recontact to determine the user's progress in attempting to adopt technology developed for the space program.

Prior to this report, the results of the telephone interviews were presented as detailed individual case histories in the appendices of quarterly reports. Beginning with this quarterly report, that format no longer will be followed. The results of the interviews will be presented, instead, in summary form only in the appendices of these reports.

Other PATT Activities

Technology Transfer Profiles. In July 1970, the PATT program underwent a major modification in the area of activities associated with documenting nonaerospace uses being made of NASA technology. A new, integrated program was developed, structured in the following manner: (1) select technical areas compatible with the technology transfer example files (files consisting of documented examples of transfer); (2) use clippings and TSP questionnaire responses related to the technical areas in order to generate new transfer examples; (3) identify and examine representative NASA contributions to the technical areas using either the trend line methodology or state-of-the-art descriptions; (4) determine which communication channels have been used to publicize the existence and availability of the contributions; (5) determine, as much as possible, the extent to which selected NASA contributions have transferred to the private sector; and (6) place transferred contributions in the context of appropriate industries, using economic and technical impact data and analysis.

With these criteria established, and in agreement with Technology Utilization Program objectives, the preparation of technology transfer profiles associated with NASA contributions to selected fields of technology was initiated. During the third and fourth quarters of 1970, three profiles were prepared: NASA Contributions to the Plastics Field, Lubrication Field and Contamination Control Field. A more detailed discussion of this activity is presented in Section II of this

report; technology transfer example file summaries developed in conjunction with these profiles are presented in Appendices A, B, and C.

Conference Impact Analysis. In May 1970 the "NASA Conference on Materials for Improved Fire Safety" was held at the Manned Spacecraft Center in Houston, Texas. Approximately 500 industrial representatives and NASA personnel attended the conference to discuss fire safety technology developed originally for use in the space program. During this reporting period, a survey of the conferees was conducted to assess the impact of the technology transfer activities resulting from information presented at the conference. In October, questionnaires were mailed to 182 non-NASA engineers and scientists who attended the conference. The six-month time lag was considered sufficient for participants to make initial decisions concerning their use of the technology presented. Sixty-two percent of the persons contacted returned questionnaires. Telephone interviews then were conducted with respondents who indicated on the questionnaire that they had made substantial progress in their attempts to apply fire safety technology described at the conference. The results of this survey will be presented in a technology transfer profile dealing with NASA contributions to the fire safety field.

A Technology Transfer Model. Initial steps were taken during the fourth quarter of 1970 to develop a model of the technology transfer process for the NASA Office of Industry Affairs and Technology Utilization. The model, generated primarily from the data collected through PATT research activities, should be useful not only in describing and explaining the technology transfer process, but also in identifying areas where NASA efforts to transfer technology might be augmented.

Technology Transfer Example Files. The files are being developed primarily to supplement the technology transfer profiles mentioned above; however, it also is the objective of the PATT program to provide interested persons with ready access to information on NASA-related technology transfer activities. By the end of this reporting period, 346 individual files--involving 634 transfer cases associated with NASA-developed technologies--had been established, 44 of which were created during the last two quarters of 1970. A total of 79 files containing comprehensive summaries for 188 transfer cases had been prepared. Of the 188 cases, 106 were developed in 1970 and 53 were recontacted for more up-to-date information. For a more detailed discussion on the files and the related information retrieval system, see Section III of PATT Quarterly Report #1-1970.

Technology Transfer Library and Bibliography. The holdings in the PATT library increased to approximately 2,028 titles through the reporting period. NASA Headquarters completed its review of the revised bibliography on technology transfer, which contains 60 abstracts of the key literature in the field. Publication of the document, designated NASA CR-1724, is forthcoming.

NASA-Related News Clippings. To augment PATT sources of leads to technology transfer activities, news clippings taken from magazines and newspapers are reviewed regularly. The clippings, which are compiled for NASA by a professional clipping service, include all news items which reference space program activities. The majority of the clippings deal with NASA contracts being awarded, current events (e.g., moon landings) and newly-developed NASA technology.

During 1970, PATT personnel processed 1,913 clippings taken from 521 different magazines and newspapers. In screening the clippings, items that indicated transfer activities were selected for follow-up. Resulting information subsequently was used to provide several new transfer cases for the technology transfer example files.

SECTION II. TECHNOLOGY TRANSFER PROFILES

The Project for the Analysis of Technology Transfer (PATT) was established at the University of Denver Research Institute in November 1967, under contract with the National Aeronautics and Space Administration, to undertake an inquiry in depth into the ways technologies generated for use in the American space program are disseminated and utilized in other sectors of the economy. The following brief description of PATT activities focuses on some of the factors leading up to one recent major change in the strategy used to meet research objectives.

Initial Approach to the Problem

When PATT began, principal attention was devoted to arriving at some specific understanding of the ways technologies generated for use in the American space program are adapted for use in other sectors of the economy. The need for systematically investigating particular instances of technology transfer was justified on two grounds. Previous attempts to explain the transfer process were considered inadequate in terms of their empirical underpinnings: often too few instances of transfer were available to clarify, in any quantitative way, the extent to which different kinds of transfer phenomena occur or fail to occur. In addition, and perhaps more importantly, it appeared desirable to generate information indicating the extent to which private sector attempts to use technologies developed originally for space program purposes are producing tangible benefits for the rest of society.

PATT was organized primarily to identify particular instances of technology transfer associated with the NASA Tech Brief program, since this was the most readily traceable and validated source of transferable technology. A Tech Brief is used to announce the occurrence of a technical innovation growing out of NASA research and development activities. It is a one- or two-page bulletin concisely describing an innovation and explaining its basic concepts and principles. The reader may obtain more information about the innovation, in the form of a Technical Support Package (TSP), by writing to the address given on the Tech Brief. Since the Space Agency kept records of the names and addresses of persons requesting TSP's, an obvious and straightforward link could be established with persons showing an interest in technologies developed for use in the space program.

By June 30, 1970, NASA had issued over 3,500 Tech Briefs. PATT personnel, by the same date, had processed nearly 40,000 requests

for TSP's. Questionnaires had been mailed to approximately two-fifths of those requesters, of whom roughly 9,600 had returned questionnaires. Approximately 750 telephone interviews also had been conducted with questionnaire respondents who indicated making substantial progress in adapting the technologies for their private use. The interviews served the purpose of pinpointing not only what difficulties had been encountered to date in attempts to transfer the technologies, but also of roughly estimating in some cases to what extent financial and other nontechnical benefits had resulted.

Among other things, PATT research by mid-1970 confirmed the following:

- Technology transfer can usefully be described as occurring in four stages. Stage one transfers involve the recognition of opportunity and searches for additional information to determine the relevance of a technology to organizational activities. Stage two transfers include laboratory verifications of materials or techniques. Stage three transfer behavior involves either market testing of prototypes or actual use of new technology in operational activities. Stage four transfers include those situations in which adopters are marketing technical products or processes developed originally either by or for NASA. Regardless of the type of technology involved, over three-fourths of the TSP users contacted six months after they requested the documents could be grouped into stage one.

- Technical innovations developed by or for NASA rarely transfer "intact." In most cases, only certain elements of an original technical configuration survive the transfer process. While a few cases of intact transfer involving the use of TSP's were identified, most often, as transfer activities progressed through the four stages, only certain technical elements of an innovation were retained.

- Many examples of transfer are stage-limited. The largest number of TSP users indicated acquiring the documents primarily to keep up-to-date with developments in their fields of interest; their reason for acquiring the documents literally was satisfied in the first transfer stage. Other TSP users indicated they were in a type of "holding action" situation: they understood the technology, had tested and

favorably evaluated it, and intended to proceed with adaptation activities after financial, political, or other kinds of transfer barriers were overcome by perceived need or benefit.

- Annual cost savings of at least $3 to $4 million are estimated to have accrued to TSP users during the last two years. This estimate is conservative because, among other things, it does not include the unknown benefits associated with the use of Tech Briefs when TSP's were not requested or the monetary gains resulting from sales increases. The cost savings estimate compares with an approximate cost of the program of $2 million annually, indicating that the total monetary benefits to users exceed program costs by a substantial margin.

The examples of technology transfer identified in the first 30 months of PATT activity thus were useful in generating a frame of reference for describing NASA's use of Tech Briefs to initiate technology transfer activities. That frame of reference not only mirrored, but also expanded in some fundamental ways, models of the technology transfer process developed previously by other investigators. Since the Tech Briefs report a wide array of technical innovations, and in view of the fact that a monthly average of more than 1,000 individuals request TSP's, the transfer examples cited in Congressional hearings and elsewhere tended to reflect society-wide attempts to utilize technologies developed originally for space program applications.

Current Research Strategy

PATT research thus generated a considerable number of useful results concerning the operation of the Tech Brief program. It became quite clear late in 1969, however, that other mechanisms used for initiating and facilitating technology transfer also should be examined. For several months, PATT personnel had been reviewing thousands of magazine and newspaper clippings that described a variety of ways people outside of the space program had learned about and were using technologies developed for or by NASA. In addition, late in 1969 PATT began processing approximately 200 transfer example files received from NASA's Technology Utilization Division. Those files, which TUD had compiled over a period of several years, contained a number of transfer examples involving the operation of transfer mechanisms other than Tech Briefs. Contractor commercialization activities, participation

by NASA in-house and contractor personnel in technical conferences, Biomedical Applications Team and Regional Dissemination Center activities, and trade magazine articles describing technology developed for the space program were among the types of transfer mechanisms involved. The fact that such mechanisms operate on a substantial scale in the technology transfer process was, of course, well known before 1970. PATT research, however, did not focus on identifying specific instances of transfer through these mechanisms until mid-1970, primarily because of the emphasis on understanding the operation of the Tech Brief program.

Several project planning conferences were held in the spring of 1970 with Technology Utilization Office personnel and other persons knowledgeable in the field of technology transfer to determine how PATT operations should be reshaped to reflect the improved understanding of the technology transfer process which had evolved. A decision was made in July 1970 to develop a series of "technology transfer profiles." Each profile presentation would focus on a specific field of technology (e.g., plastics, contamination control, fire safety). For each technical field, the profile presentation would examine overall trends in the field; identify NASA contributions to the field by using appropriate technical and economic impact data; describe the ways such contributions have been communicated to persons outside of the space program; and finally, review the ways in which the communicated technologies are being utilized in nonaerospace sectors of the American economy. The following resources were to be used in developing the profile presentations:

- Information concerning NASA contributions should be derived primarily from related NASA documents and personal interviews with in-house and contractor personnel involved in the development of the technical contributions.

- Data on the operation of different communication mechanisms should be derived from personal interviews with NASA in-house and contractor personnel, a review of NASA-funded formal transfer programs (e.g., Technology Application Teams, Regional Dissemination Centers, Contractor Reports, Tech Briefs), and a review of magazine and newspaper clippings.

- Instances of technology transfer activities associated with NASA contributions to the field should include those cases

generated in the course of PATT research on uses made of Technical Support Packages, as well as others identified in the examination of different transfer mechanisms. When possible, the cases of technology transfer should be presented in a profile of transfer stages.

Two fundamental considerations, one pragmatic and another theoretical, led to the decision to develop technology transfer profile presentations of the sort described above. For some time, NASA descriptions of technology transfer activities focused on individual, and usually isolated, cases involving secondary applications of technology developed for the space program. This practice--citing instance after instance of transfer activity--was found wanting in several respects, particularly in terms of an audience's ability to understand what the transfer examples meant in some broader context. The technology transfer profiles, at least in concept, presented an alternate and hopefully more effective approach for dealing with the mode-of-presentation problem. At the same time, the development of a meaningful model of the technology transfer process required that the investigation of transfer activities be expanded systematically beyond the framework of the Tech Brief program.

The newly-integrated PATT program proceeded with the development of technology transfer profiles in July 1970. During the remaining months of the year, profile presentations were developed for the fields of plastics, lubrication, and contamination control. Appendices A, B, and C of this report contain comprehensive summaries of the technology transfer activities that were used in preparing the three profile presentations.

APPENDIX A

Summary of Technology Transfer Reports Involving NASA-Generated Plastics Technology

APPENDIX A

SUMMARY OF TECHNOLOGY TRANSFER REPORTS INVOLVING NASA-GENERATED PLASTICS TECHNOLOGY

NASA CONTRIBUTIONS	TRANSFER STAGES† 1 Cont.*	1 Term.	2 Cont.	2 Term.	3 Cont.	3 Term.
FORMULATIONS						
• HYSTL		2782**		1550	11194	
		2882			12760	
		9267			42552	
		11259				
• LOX-Compatible Adhesive					42937	
• LOX-Compatible Plastic				42936		
• Nylon-Filled Epoxy-Polyamine						27958
• P13N			42934		31988	
					42550	
• Polyurethane Foam		21798	42935	20138		
• Pyrrones	42930		9267			
	42931		44079		42928	
	42932				42929	
• Thermally Conducting Electron Transfer Polymers	43005	43004				
APPLICATIONS						
• Captive Plastic Seal					4574	
• Fluorel Flameproofing					43001	
					43002	
• Nonflammable Polyimide Plastic Laminates					43003	
• Plastic Gasket					5737	

* The action status, continuing or terminated, of transfer cases at the time DRI-PATT contacted users. Cases are classed as terminated when (a) no further adaptation or adoption is contemplated, (b) a better technical alternative has been found, or (c) continued transfer activity is not economically feasible.

** Numbers in columns refer to PATT case numbers.

† At the time the plastics presentation was developed, the transfer process was defined to include three "stages": awareness, evaluation, and in-house use or prototype testing. With the development of subsequent presentations, a fourth transfer stage--"marketing"--was added.

HYSTL

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

During 1964 a major aerospace contractor began work on a Lewis Research Center contract to develop new materials for rocket thrust chamber ablators. A new class of thermosetting plastics resulted from the research; and while it was unsatisfactory for ablator applications, its many unique properties were immediately obvious for other purposes. The material is noted for its processing simplicity. It has a long shelf life at ambient temperatures in an intermediate rubber stage, is workable in the precured state and cures rapidly. The end product has high thermal stability and strength at high temperatures, good chemical stability and stiffness, and unusual electrical properties and radiation stability. Title to the invention was waived to the aerospace firm, and a Tech Brief was published in 1967. Since then NASA has received more than 400 inquiries concerning the material.

In 1968 the aerospace firm helped establish a new company that would form and market plastic products incorporating the new material. Agreement was also reached with a major Japanese chemical firm to supply basic ingredients, in return for marketing rights in Japan. More than $1,500,000 has been invested in the commercial development of the new plastic. When it became commercially available, the price of the new material was approximately $1 per pound; potential reductions by as much as 50 percent are expected, as economies are achieved. The aerospace subsidiary firm is now perfecting a processing method that will allow forming the material into auto body parts. A maker of microwave ovens intends to utilize the plastic for trays for microwave ovens, where the material's radiation stability will be valuable. Experiments conducted for a clay pipe manufacturer indicate that a composite material with as little as 15 percent or less of the new plastic has considerable strength when molded into pipe fittings. They have excellent potential for transporting corrosive materials, including sewage (42552).

The NASA Tech Brief has been used by many other firms with varying success. One company (12760) developed a plastic housing for a photocell used for sun attitude control for unmanned rockets. The plastic was able to withstand the great thrust and vibration that had caused earlier models of the photocell to disintegrate. Another firm (11194) formulated a modification of the plastic and used it to coat an

oil temperature sensor, and anticipated that the increased value of the device would amount to $100,000 in annual sales.

A casket manufacturer (11259) evaluated the Tech Brief for possible innovations in casket material. This firm wanted an inexpensive plastic that could be easily cast rather than injection-molded, and the evaluation of the Tech Brief produced a negative judgment concerning the likely cost of the innovation. A maker of grinding wheels (9267) also decided against using this plastic as a binder for diamond grinding wheels. Evaluation of alternative plastics continues with the firm, and one of the new candidates is another NASA-originated plastic, called pyrrones.

Control Numbers

Tech Brief Number: 67-10197
NASA Center: Lewis Research Center
PATT Case Numbers: 9267, 11194, 11259, 12760, 42552
TEF Number: 6
Date of Latest Information Used: August 3, 1970

LOX-COMPATIBLE ADHESIVE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A California firm (42937), working under NASA contract, developed a structural adhesive system suitable for use with liquid oxygen. The work centered around the preparation of fluorinated polyurethanes and the synthesis and testing of various monomers and prepolymers.

As a result of its work, the firm has made several patent applications. One such patent application deals with the preparation of tetrafluor-m-phenylenediamine, a precursor of a liquid oxygen compatible, fluorinated polyurethane adhesive. Although there are no plans to use the diamine in meeting specific commercial needs, it may be useful with other specialized resins produced by the firm.

While expenditures to prepare the chemical for possible commercial applications have been modest, the firm has sold two pounds at $145 per pound to other research and development organizations.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 42937
TEF Number: 314
Date of Latest Information Used: August 12, 1970

LOX-COMPATIBLE PLASTIC

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A Southern chemical company (42936) performed basic research on polymers with the objective of developing new types of elastomers that would retain basic properties under temperature conditions created by contact with liquid oxygen. A chemist employed by the firm said that he thought that a process for synthesizing 1-2 difluorethylene would yield the desirable properties; however, the polymer did not have the required flexibility or resistance to attack in the presence of liquid oxygen. Management personnel said that the polymer might have properties of value in commercial applications and received a patent waiver from NASA in 1965.

After spending more than $5,000 in analyzing the commercial potential of the manufacturing process, the company officials decided the market was not favorable and abandoned the waiver and development project. Manufacturing costs were quite high, especially in relation to the attainable new properties. Because little information concerning the cryogenic plastic research was available, the company recently published its research findings.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 42936
TEF Number: A - Plastics
Date of Latest Information Used: August 12, 1970

NYLON-FILLED EPOXYPOLYAMINE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Employees of Telecomputing Corporation, under contract to NASA's Western Operations Office, devised a method of formulating an adhesive that cures at room temperature and maintains effective bonding at cryogenic temperatures. The method entails adding one part of powdered nylon filler to two parts of an epoxypolyamine resin. As described in a 1966 Tech Brief, the nylon filler also markedly improves the adhesive strength and toughness of the epoxypolyamine resin.

A small California firm (27958), engaged in custom compounding of epoxy resins, silicones, and polyurethanes for high and low temperature uses, employed the Tech Brief to guide preparation of a proposal and sample material for a potential client. When the client abandoned his project the proposal was rejected. Although he foresees no additional applicability of the Tech Brief in his work, the general manager of the firm estimated that the document saved him 40 to 50 hours of research time while preparing the sample and proposal.

Control Numbers

Tech Brief Number: 66-10185
NASA Center: Western Operations Office
PATT Case Number: 27958
TEF Number: 295
Date of Latest Information Used: August 13, 1970

P13N

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Polyimides, well-known as high temperature polymers, were first introduced in 1961 by DuPont. They are among the most thermally stable organic polymers in existence, retaining their properties under long-term use at 500°F and short-term use at even higher temperatures. In addition, polyimides are insoluble and infusible, have excellent radiation resistance and machining qualities, are inflammable, and are resistant to organic solvents and acids. They may be degraded by alkalies and tend to absorb water, which affects their electrical properties.

The common method for formulating polyimides is by a condensation reaction, which releases unwanted volatiles and water. While trying to develop ablator binders and adhesives under contract to NASA's Lewis Research Center, a theoretical chemist employed by a major California aerospace firm discovered a way to process a polyimide by an additive reaction. The method eliminates the evolution of water and volatiles; in addition, it permits rapid curing and simplifies storage and handling of the precured material. The resulting polymer, codenamed P13N, has high temperature thermal strength and stability and is impervious to a variety of chemicals. It should be widely applicable for uses in ablators, supersonic aircraft structures, jet engine components, circuit boards, flexible electrical cable insulation, and as a high temperature adhesive. P13N can be molded easily for applications in seals, self-lubricating bearings, valve seats and bushings. A Tech Brief describing the polymer was published in 1969.

NASA waived title to the invention to the contractor (42550). The firm developed commercial manufacturing processes, procedures for industrial processing, and introduced in limited quantities one product form, P13N. Subsequently, an exclusive license was taken by a large international chemical corporation. It is expected that this new arrangement will lead to a more expanded market and further development of the polymer.

A major electrical motor manufacturer (31988) is attempting to use P13N to develop a wire insulation for DC motors subject to

abnormal external heat conditions. In another application effort, an aerospace firm is evaluating the polymer for use in the SST (42934).

Control Numbers

Tech Brief Number: 69-10118
NASA Center: Lewis Research Center
PATT Case Numbers: 31988, 42550, 42934
TEF Number: 217
Date of Latest Information Used: August 3, 1970

POLYURETHANE FOAM

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

While performing research on heat shield materials, scientists at Ames Research Center invented a lightweight, fire-retardent plastic foam. As described in a 1968 Tech Brief, the material is a semirigid or rigid polyurethane foam having uniformly dispersed in it a halogenated polymer. When heated, the material chars and hydrogen halide is evolved. The char layer and released gases help quench the flame. The density of the foam can be varied from 2 to 50 pounds per cubic foot, enhancing the versatility of the material for fire protection in aircraft, spacecraft, homes, autos, boats, trains, and in industries such as petrochemicals, paint and chemical processing, and laboratories. NASA has received almost 100 inquiries since issuing a Tech Brief describing the foam.

An Eastern manufacturer (20138) used the TSP to develop material for controlling an induced explosion in a production process. The foam performed adequately in controlling the explosion, but it also had undesirable side effects and was therefore rejected as a possible solution to the problem. The Department of Labor of an Eastern state (21798) has the TSP on file for reference concerning fire safety. A large aerospace contractor (42935) is evaluating the foam for aircraft fireproofing potential. If the studies funded by NASA are fruitful, the firm will extend its explorations into potential commercial applications.

Control Numbers

Tech Brief Number: 68-10358
NASA Center: Ames Research Center
PATT Case Numbers: 20138, 21798, 42935
TEF Number: 17
Date of Latest Information Used: August 13, 1970

PYRRONES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Aerospace requirements for materials with exceptional resistance to heat, light, and radiation pose a never-ending research problem. In 1965 a Langley Research Center scientist, Vernon Bell, independently discovered a new class of aromatic/heterocyclic step-ladder and ladder organic polymers, designated "pyrrones." These thermosetting resins result from the reaction of an aromatic tetra-amine with an aromatic dianhydride. At an intermediary stage the polymer has a structure like nylon, and through a thermal-curing process it forms a polybenzimidazole (PBI) or polyimide (PI) before evolving to the pyrrone structure. The resulting combination of PBI and PI structures yields a polymer with greater rigidity than either PBI or PI, with exceptional thermal and radiolytic stability. The polymer is nonflammable and can be heated to incandescence without burning. Long-term stability to 500°F and short-term stability to 1,000°F suggest the heat resistance qualities of the new polymer. Up to ten times the amount of radiation that degrades other polymers can be withstood by pyrrones. The material has great potential for use in high temperature films, coatings, adhesives, resins for laminates and filament windings. Pyrrone moldings are easily filled with reinforcing materials and produce very hard machinable surfaces.

A NASA Technical Note (TN D-3148) was issued in 1965, followed by Tech Brief 66-10043. Interest was immediate and widespread, but few inquirers were decisively motivated to pursue their own development activities. A Southern company (42930) wanted to evaluate the material for use in production processes for a defluorinated phosphate feed supplement. Acid by-products and high temperatures (to 1,700°F) commended the use of a heat-stable plastic. The firm still wishes to purchase such material, and low price is a major criterion in evaluation of various alternatives. An Indiana electrical cable manufacturer (42931) also would like to purchase a material with pyrrone's characteristics, but has similarly been unable to locate a source. A major chemical company (42932) has been interested in pyrrones for over three years, but has been unable to obtain adequate information.

The unavilability of pyrrones, which slowed early attempts to transfer the technology, may end soon. Two major aerospace contractors (42928, 42929) have recently produced evaluation batches of

the material. Both of these contractors acquired their pyrrone formulating capabilities through contract work under a Langley program of collaboration with industry and universities to explore the application potential of pyrrones. Both firms are also continuing in-house programs to find commercial uses for pyrrones, with emphasis on laminates, bearing applications (42929) and electrical cable coatings (42928). Another aerospace company is comparing pyrrones with polyimides for SST applications (44079). In addition, an abrasive grinding wheel manufacturer is evaluating pyrrones for use as a binder for diamond grinding wheels (9267).

Control Numbers

Tech Brief Number: 66-10043
NASA Center: Langley Research Center
PATT Case Numbers: 9267, 42928, 42929, 42930, 42931, 42932, 44079
TEF Number: 5
Date of Latest Information Used: September 3, 1970

THERMALLY CONDUCTING ELECTRON TRANSFER POLYMERS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Advances in electronic circuitry, such as subminiaturization of components and modular circuit construction have been accompanied by serious problems in environmental protection, mechanical shock, radiation and temperature. Some potting compounds provide good mechanical shock and radiation protection; but because they are poor heat conductors, and therefore act as thermal insulators, they often cause poor electronic performance.

In 1969, scientists employed by McDonnell-Douglas Corporation published a Tech Brief summarizing the results of their work under NASA contract, which resulted in new polymeric materials that exhibit outstanding thermal conductivity in addition to excellent shock protection and electrical resistance. The thermal conductivity of the polymers is larger by a factor of 10 than that of most organic polymers; and their electrical resistivity is about double that of other charge-transfer polymers.

The president of a small Eastern plastics firm (43004) inquired about commercial use of the invention, but upon evaluating the market potential of the material, decided that he could not afford the substantial investment necessary to market it. In another application effort, a major aerospace contractor (43005) with greater financial resources is evaluating the technical information for potential commercial use.

Control Numbers

Tech Brief Number: 69-10511
NASA Center: Goddard Space Flight Center
PATT Case Numbers: 43004, 43005
TEF Number: 325
Date of Latest Information Used: August 20, 1970

CAPTIVE PLASTIC SEAL

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Cryogenic temperatures impose especially difficult conditions for the functional integrity of most plastics and elastomers used in seals. In order to obtain zero leakage of cryogenic materials, a seal must have total surface conformity; but the very low temperatures cause plastics to become brittle, shrink, and lose resiliance with the result that a seal using these materials does not perform well.

An engineer employed by a NASA contractor invented a "captive plastic seal" that achieves total surface conformity. For cryogenic applications, teflon provides ideal sealing characteristics when its extrusion under pressure is contained by abrasion-resistant metal rings. The surfaces to be sealed are tightly compressed; the resulting pressure on the teflon exceeds its compressive yield point and causes it to act as a fluid flowing into adjacent surface irregularities to provide sealing. The reusable seal thus minimizes requirements for "super-finishing" sealing surfaces and it can accommodate misalignment and surface separations. It operates under fluid pressures to 12, 500 psi and temperature ranges from -450°F to +550°F.

The basic invention was described in a 1967 Tech Brief. In August 1967, a waiver was granted to the contractor. He, in turn, licensed a California plastics manufacturer (4574) to produce and market the device. Initially, only one size was produced; but the firm now offers a full range of standard sizes. Captive plastic seals may be used for all flange-type plumbing, and as components in hydraulic systems, hazardous fluid systems and cryogenic systems.

Control Numbers

Tech Brief Number: 67-10600
NASA Center: Marshall Space Flight Center
PATT Case Number: 4574
TEF Number: 207
Date of Latest Information Used: July 27, 1970

FLUOREL FLAMEPROOFING

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Fluorel, a copolymer of hexafluoropropene and vinylidene fluoride, is a nonflammable elastomer available under various names from several major chemical companies. NASA's search for flameproof materials for the interior of Apollo command modules culminated with fluorel, which was also used for walls and furnishings in the mobile quarantine facility used after the moon flights.

Two rubber manufacturers were involved in projects that yielded modifications of basic fluorel for the Apollo applications. Both are pursuing nonspace applications, largely in aircraft interiors but also in oceanographic and other oxygen-rich environments. One of these firms (43002) anticipates a large market in such applications where price is not a decisive factor and safety is a primary consideration. Some aircraft are already equipped with structural and decorative fluorel materials supplied by this firm. The other company (43001) has achieved promising initial test results with aircraft wire bundle coatings and carpeting and tile for aircraft galleys. A serendipitous by-product of the company's ongoing development work with fluorel is a new potting compound consisting of several polymers, some of them proprietary with the firm. The compound will not burn and cures at room temperature. If it passes tests being conducted by several aircraft manufacturers, it will constitute a major advance in the state-of-the-art, since no existing potting compounds are nonflammable.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Numbers: 43001, 43002
TEF Number: 324
Date of Latest Information Used: August 20, 1970

NONFLAMMABLE POLYIMIDE PLASTIC LAMINATES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A California aerospace firm (43003) became involved in developing a new fireproof polymer in 1968, following the Apollo 7 fire. Under NASA contract, the firm discovered a new process for formulating a preimpregnated B-stage polyimide by dissolving a commercially available material, N-methyl pyrrolidone (NMP) solvent, to form a 12-15 percent solution. The resulting PI structural laminate is self-extinquishing in 16.5 psia pure oxygen. The patented process requires rigorous controls, since NMP boils at 395°F and water condensation occurs. Reinforced with glass laminate material, the PI can be cast in an RTV silicone rubber coated mold, and it is readily tooled at temperatures to 600°F. It is dimensionally stable, so shrinkage is easily predictable. Low outgassing properties assured its safety for use in an Apollo food storage container. Flame tests have demonstrated the nonflammability of the PI in 16.5 psia pure oxygen. Compared with aluminum, the material has superior strength-to-weight ratios and is far less costly for making complex parts.

The firm has made more than 3,000 Apollo parts in more than 50 design configurations, ranging from battery terminal covers to large protective panels. Commercial possibilities are being investigated for fireproofing applications in aircraft, autos, marine vehicles, furnaces, fuel systems, engines, electrical components and railroad tank cars.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Number: 43003
TEF Number: 326
Date of Latest Information Used: August 20, 1970

PLASTIC GASKET

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Axial joints incorporating metals of differing hardness, or metal alloys with an affinity for each other, in close stressful contact often deteriorate because of fretting. Expensive plating of the mating surfaces has been a common remedy. In 1966, R. L. Stremel of North American Aviation, under contract to NASA, discovered that an ordinary thin plastic sheet could be interposed between the mating surfaces and completely eliminate the fretting.

A Tech Brief describing the plastic gasket technique was used by a materials engineer, employed by an Ohio power equipment manufacturer (5737), to help solve a fretting problem. In the process, he tested a variety of plastic materials. He discovered that teflon was too soft; he rejected polyphenylsulfide because it squeezed out of the joint. Nylon, which passed all laboratory tests, is now being field tested by an airline. Early research with the airline has been aimed at increasing the maintenance-free time of gasket units from 1,000 hours to 5,000 hours.

Control Numbers

Tech Brief Number: 66-10681
NASA Center: Marshall Space Flight Center
PATT Case Number: 5737
TEF Number: 236
Date of Latest Information Used: August 3, 1970

APPENDIX B

Summary of Technology Transfer Reports Involving NASA-Generated Lubrication Technology

APPENDIX B

SUMMARY OF TECHNOLOGY TRANSFER REPORTS INVOLVING NASA-GENERATED LUBRICATION TECHNOLOGY

NASA CONTRIBUTIONS	TRANSFER STAGES							
	1		2		3		4	
	Cont. *	Term.	Cont.	Term.	Cont.	Term.	Cont.	Term.
NEW OR IMPROVED LUBRICANTS								
• Ceramic Bonded Calcium Fluoride		2851**					44299 44300	
• Ceramic Bonded Lead Monoxide					44293		44297 44298	
• Graphite Fluoride			44078				44077	
• Polyimide Resin Binder For Solid Film Lubricants							43633	
METHODS FOR APPLYING OR PROVIDING LUBRICATION								
• Dynamic Reservoir Lubricating Device	44074		22290					
• Hexagonal Crystal Alloy Provides Improved Lubrication			44075					
• Improved Lubrication of Miniature Slip Rings				9025				
• Ion Plating of Solid Film Lubricants					44290		44289	
• Porous Metal/Solid Lubricant Composites			44291	19765			37424	
• Sputter Bonding of Solid Film Lubricants		23994					44295 44296	
LUBRICANT TEST								
• Fluid Lubricated Bearing Testing					44284 44285		44287	

* The action status, continuing or terminated, of transfer cases at the time DRI-PATT contacted users. Cases are classed as terminated when (a) no further adaptation or adoption is contemplated, (b) a better technical alternative has been found, or (c) continued transfer activity is not economically feasible.

** Numbers in columns refer to PATT case numbers.

CERAMIC BONDED CALCIUM FLUORIDE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Load-bearing surfaces in space vehicles require special lubrication systems, of which solid-film lubricants provide unique characteristics. In nonspace uses a solid-film lubricant is often advantageous because (1) it can be operated at temperature extremes beyond the capabilities of oil or grease lubrication systems; (2) it does not require cooling, recirculating oil systems with their associated pumps and heat exchangers; and (3) it allows shorter rotating shafts because dry-lubricated surfaces can be located closer to heat sources.

As a result of basic research performed at Lewis Research Center, Harold Sliney developed a mixture of calcium fluoride (CaF_2) and a compatible inorganic binder, which is mixed with water to form a slurry and sprayed or brushed on the surface to be lubricated. The coating may vary from 0.0008 to 0.0035 inch. After firing, the lubricating particles are fused to each other and bond the film to the base material. This lubricant has proven effective on a variety of metals, including nickel-base alloys, at temperatures to 1,900°F, in atmospheres containing oxygen or inert gases at pressures from normal atmospheric to high vacuum. It is unstable in hydrogen and other reducing atmospheres.

Marlin Rockwell Division of TRW, Incorporated in Jamestown, New York (44299) installed equipment to apply the ceramic bonded coating of calcium fluoride in 1963. The transfer mechanism in this case was personal contact by the Marlin Rockwell research and development manager on a trip to Lewis. The company coats some of its bearing products on special order from customers. The company's principle application of the technology has been to rolling contact and sliding bearings for high temperature environments such as aircraft engines and conveyer belts for ovens. A company spokesman reports there has been a steadily increasing number of customers for the calcium fluoride coated bearings since 1963.

The president of Hohman Plating and Manufacturing Company in Dayton, Ohio (44300) first learned of the ceramic bonded calcium fluoride innovation when it was described at a technical society meeting in 1963. The company installed equipment to apply the coating in 1963. The principle application has been to bearings for aircraft engines and

conveyer belts in ovens. Hohman has had an increasing number of customers for the service since 1963. The company is continuing its investigation for new applications of the ceramic coating.

S.F.D. Laboratories, Incorporated in Union, New Jersey (2851) has utilized the ceramic bonded calcium fluoride technology in manufacturing magnetron tubes for radar transmitters. The tubes incorporate a bearing that must operate in a vacuum. When S.F.D. research engineers first learned of the Lewis work with calcium fluoride, they investigated the possibility of installing equipment to apply the lubricant to the bearing. Economic factors, however, caused them to abandon their in-house application effort. Instead, S.F.D. contracted with another company to apply the same lubricant film to the S.F.D. bearings. The contract held by S.F.D. to produce magnetron tubes has since been completed.

Control Numbers

Tech Brief Number: 66-10087
NASA Center: Lewis Research Center
PATT Case Numbers: 2851, 44299, 44300
TEF Number: 130
Date of Latest Information Used: October 1, 1970

CERAMIC BONDED LEAD MONOXIDE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Conventional lubricants tend to break down in high temperature applications. A dry lubricant in ceramic form made of 95 percent lead monoxide and 5 percent silicon dioxide was developed and tested at Lewis Research Center. Their method of application produces a smooth coating approximately .001-inch thick.

Lead monoxide and silicon dioxide powders are mixed with water to form a slurry which is sprayed onto a preheated surface to be coated. The water evaporates leaving a weakly adherent coating and the surface is then heated to 1,650°F to develop a fusion bond. Only certain metal substrates were recommended for this coating and operation at high surface temperature (above 1,000°F) is necessary to obtain low friction with most ceramic dry film lubricants including this one. With these restrictions, lead oxide ceramic was demonstrated at Lewis to have excellent wear life characteristics.

National Standard Company in Niles, Michigan (44293) has been using ceramic bonded lead oxide in their production of wire for almost five years. In the early 1960's the company developed a high pressure coating process for wire and wanted to produce this type of coated wire commercially. They experienced difficulty in the manufacturing process which required that the wire be pulled through a hole in tool steel. The wire galled and broke in the hole as a result of poor lubrication. Several methods of lubricating the hole were tried. The only successful method was filling the hole with lead oxide frit, baking the mixture to form a ceramic plug, and drilling through this plug to form a ceramic lined hole in the steel. This method has been used since 1966. Earl Weaver of National Standard Company said they would not be making this particular product had they not learned of the ceramic bonded lead oxide development at Lewis.

Holman Plating and Manufacturing Company in Dayton, Ohio (44298) and Marlin Rockwell Division of TRW, Incorporated in Jamestown, New York (44297) have both had facilities to do ceramic bonding of lead oxide for customers since 1964 when the Tech Brief announcing the process was published. Both companies have developed various uses for the technology and have customers for the service.

Since the conditions which require dry film lubricants are comparatively extreme, there is not a wide market for this service; although, as in the case above, when such lubricants are used their use is crucial.

Control Numbers

Tech Brief Number: 64-10116
NASA Center: Lewis Research Center
PATT Case Numbers: 44293, 44297, 44298
TEF Number: 337
Date of Latest Information Used: September 29, 1970

GRAPHITE FLUORIDE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Graphite fluoride is a lamellar compound of carbon formed by a controlled chemical reaction of graphite with gaseous fluorine. The resulting crystal structure is similar to graphite, but the distance between lamellar planes is greater. Several years ago Marco Petronio and his associates at the U.S. Army's Frankford Arsenal began to stimulate thinking about using graphite fluoride as a solid lubricant. Robert Fusaro and Harold Sliney of NASA's Lewis Research Center agreed that the material had promising characteristics and acquired from Rice University, through Frankford Arsenal, some graphite fluoride powder for evaluation. In comparative tests with graphite and molybdenum disulfide, the new compound exhibited a comparable or superior coefficient of friction and a wear life up to six times greater. These results were published in a 1969 Tech Brief.

Ozark-Mahoning Company in Tulsa, Oklahoma (44077), a manufacturer of fluorine compounds, is producing new fluorine-carbon compounds including a polymeric carbon monofluoride, wherein the carbon to fluorine ratio is essentially 1:1. Contacts with Lewis Research Center personnel and a Tech Brief describing Lewis tests of graphite fluoride as a lubricant stimulated the firm's entry into this new area. The firm's expertise in fluorine compound manufacturing had led to its selection by Lewis to provide some sample graphite fluoride, and several inquiries were received by the firm as a result of potential users becoming aware of the material through Lewis or Frankford Arsenal contacts. Following issuance of the 1969 Tech Brief, the volume of inquiries increased significantly and the firm established a small-scale production facility in January 1970. The process and equipment are being developed for the production of different grades of carbon-fluorine compounds in order to meet the needs which are expected to develop.

Halo Carbon Products Corporation in Hackensack, New Jersey (44078) first became aware of the characteristics of graphite fluoride through a Japanese publication reviewed during normal literature review

activities. When the NASA test results were announced in the 1969 Tech Brief, the firm was encouraged to begin a development program that may yield a new lubricating product for its product lines.

Control Numbers

Tech Brief Number: 69-10250
NASA Center: Lewis Research Center
PATT Case Numbers: 44077, 44078
TEF Number: 333
Date of Latest Information Used: September 3, 1970

POLYIMIDE RESIN BINDER FOR SOLID FILM LUBRICANTS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Under a NASA contract for the development of bearing lubricants, Midwest Research Institute developed several dry solid film lubricants for use in the space program. One such lubricant, developed under the NASA-funded contract, is a solid film lubricant which uses a polyimide resin binder and has exceptional wear life characteristics over a wide range of operating temperatures. Vern Hopkins, assistant director of engineering at the Midwest Research Institute, reported that under the NASA contract they were concerned with developing lubricants which would meet the Marshall Space Flight Center requirements and have the characteristics required for operating temperature, vacuum, environment and durability. Through the inclusion of the polyimide resin binder, Hopkins said they were able to meet the requirements; because the lubricant does have exceptional wear life characteristics, it was felt that the lubricant could also be used commercially. After obtaining a patent waiver from NASA, the Midwest Research Institute licensed National Process Industries in South Gate, California (43633) to manufacture and market the new lubricant commercially.

National Process Industries has a line of dry film lubricants which are used primarily in the aircraft industry. Although the new lubricant may see a wide range of commercial uses, it is primarily aimed at the aircraft industry. Currently the lubricant is being used on the Boeing 737 and by NASA in space programs. Roy Smith, president of National Process Industries, also stated that the lubricant is being considered for use on the SST; attempts are being made to have the lubricant included in the specifications of other aircraft manufacturers. Although the sales on this new lubricant are only about $1,000 per month, Smith expects the volume to be doubled or tripled within two years. To date Smith feels that the company has only managed to break even on the new lubricants' sales since it has spent over $10,000 in promoting the new product through direct sales contact with aircraft manufacturers.

Although the lubricant has many advantages, Smith said that its acceptance by the commercial market is somewhat hindered by the polyimide binder which requires the material to be refrigerated. At

the present time, the cost of the lubricant and the need for refrigeration means that the lubricant will be limited to a narrow band of hardware items.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 43633
TEF Number: 336
Date of Latest Information Used: September 9, 1970

DYNAMIC-RESERVOIR LUBRICATING DEVICES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The process of supplying lubrication to ball bearings often results in consumption of power, notably when wick feeds are used to transmit oil from a reservoir to the bearing. The wicks introduce friction which consumes power and wastes oil.

In July 1968 a new lubrication method was announced in a Tech Brief. Two employees of the Bendix Corporation, working on a Marshall Space Flight Center contract, designed a system that utilizes the centrifugal force of the rotating bearing to exert an outlet pressure on oil contained in an adjacent reservoir. This assures a controlled supply of lubricant to the bearing only during bearing operation.

Lipe-Rollway Corporation in Liverpool, New York (22290) built and is testing a prototype system for lubricating a roller bearing used under heavy load. The firm has scheduled extensive testing and comparison with alternative methods. If test results are quite favorable, the concept may be incorporated into new bearing design. The J. H. Day Company in Cincinnati, Ohio (44074) also recently evaluated the TSP. The company makes industrial food and chemical mixers, including a unit that operates at variable rpm, as high as 10,000 rpm. No problems have been experienced with the unit's present lubrication system, but the product engineer who requested and studied the TSP concluded that the NASA device would be an excellent design improvement were the present design to prove inadequate. He also said that the configuration of the reservoir and bearing retainer would provide useful sealing features, apart from the lubrication-system characteristics.

Control Numbers

Tech Brief Number: 68-10261
NASA Center: Marshall Space Flight Center
PATT Case Numbers: 22290, 44074
TEF Number: 319
Date of Latest Information Used: August 27, 1970

HEXAGONAL CRYSTAL ALLOY PROVIDES IMPROVED LUBRICATION

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The long experience of Lewis Research Center engineers in designing lubricants for space use is yielding new metallurgical compositions for medical applications. In the especially difficult lubrication conditions of space where conventional lubricants evaporate and surface oxide films do not re-form when worn away, the loss of lubricant film results in metal-to-metal contact, high friction, repeated surface welding-shear reactions, metal transfer, and bearing failure.

A solution devised by Robert L. Johnson and Donald H. Buckley of Lewis is to make bearings from alloys with a hexagonal crystal lattice structure and increase their crystal lattice ratio. Extensive research indicated the existence of large and consistent differences between the shear forces of cubic and hexagonal crystals. When welding occurs between two metal surfaces and the weld shears, it does so along distinct planes in the crystals. Cubic crystals typically exhibit shear forces up to 100 times greater than those in hexagonal crystals, and hexagonal crystals shear smoothly at the surface without changing the surface geometry. As a result, bearings with hexagonal crystal structures will operate much longer than those with the cubic structures.

Lewis studies indicated that cobalt and titanium, both commonly used, can be alloyed in a manner that (1) stabilizes their hexagonal crystal structure over a greater temperature range and (2) increases their crystal lattice ratio. Cobalt normally transforms from hexagonal to cubic structure at 750°F, but alloy additions of tungsten and molybdenum stabilize the hexagonal structure over a wider temperature range. Similarly, binary alloys of titanium with tin or aluminum provide the desired hexagonal structure, and a higher proportion of tin or aluminum yields higher crystal lattice ratios, greatly reduced friction, and minimized surface failure tendencies.

In the medical field,a cubic crystal cobalt-molybdenum alloy is used in artificial human hip and elbow joints. Lewis studies using a stimulated artificial hip joint suggest that wear in these joints probably begins with adhesive wear (interface welds), followed by corrosive wear (chemical surface reactions), and abrasive wear (rough surface and free particle cutting). Consequently, it is likely that artificial hip joint

performance can be improved and prolonged by using hexagonal crystal structure alloys, with optimized crystal lattice ratios. New alloys formulated at the center have a coefficient of friction about half that of conventional prosthetic alloys, and wear rates only one percent of those obtained with currently used alloys.

An orthopedic surgeon at the University of California at Los Angeles (44075) is cooperating with Lewis in experiments to find optimum materials. Tissue compatibility is always of concern when substances are implanted in living tissue, and the surgeon is testing various materials by implanting them in rabbits. Preliminary results of the long-term study suggest that some of the tested alloys are promising materials with respect to tissue compatibility. There is evidence that increasing the chromium content of the alloys improves tissue compatibility without destroying the hexagonal crystal structure. Other materials being evaluated include polyimide plastics and pyrolitic carbon, both of which also show good potential. A continuing problem in the research is the probability that synovial fluid, the body's natural lubricant, may degrade in a diseased joint, complicating the malfunction and even affecting the operation of an artificial replacement.

Control Numbers

Tech Brief Number: 66-10373 (See also TM X-52745)
NASA Center: Lewis Research Center
PATT Case Number: 44075
TEF Number: 220
Date of Latest Information Used: August 27, 1970

IMPROVED LUBRICATION OF MINIATURE SLIP RINGS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Space vehicle inertial guidance systems typically incorporate miniature slip ring assemblies to transmit electrical information across the guidance system axes. Circuit performance, especially in null-seeking circuits, is hampered if excessive electrical noise occurs at the sliding contact. The high vacuum of outer space imposes severe environmental conditions for slip ring performance, which must remain operable even on extended missions. Prior to 1966 it was known that unlubricated systems experience galling and erosion effects that cause high localized temperatures, and that reduced heat transfer characteristics of a high vacuum environment would increase the possibility of localized hot spots at contact points. Heightened wear and electrical noise also result from increased friction and surface damage due to cold welding of microasperities.

To extend knowledge of long-term slip ring performance under high vacuum conditions, J. L. Radnik of IITRI was engaged by NASA to perform a laboratory study. The investigation included assessment of the influence of ring, brush, and insulator materials on electrical noise and mechanical wear. The results of the study were published in a September 1966 report and further publicized in a 1967 Tech Brief. Among the more important findings were that soft metal lubricants such as gallium and indium, deposited by a sublimation process on slip rings, provide a considerable improvement in wear and electrical noise characteristics. Also, slip rings made of niobium diselinide in a silver matrix performed better than standard gold slip rings. The silver matrix provides excellent conductivity, and the niobium diselinide functions as a dry lubricant to give low-friction sliding across the contact points. The lubricant transfers back and forth across the metal surfaces, healing tiny faults that may occur in the lubricant film. A 400 hour slip ring operation was evaluated, indicating that electrical noise from slip rings made with these materials quickly reached a maximum level (about the same as that of new unlubricated rings) but did not increase thereafter, because of the low wear characteristic.

Scot, Inc. in Downer Grove, Illinois (9025), an electronic components manufacturer, used the report to confirm in-house knowledge that lubrication would improve slip ring performance. The firm made plans to introduce lubricated slip rings into its miniature

synchromechanisms for commercial aviation instruments and automatic direction finders. The firm's direction finder uses a null-seeking circuit, which the NASA report cited as being especially susceptible to spurious output from brush and slip ring contact.

After prototype testing with a variety of lubricants, it was decided that although performance was improved, the required increase retail price would be too much. Another method for improving their product was developed.

Control Numbers

Tech Brief Number: 67-10210
NASA Center: Marshall Space Flight Center
PATT Case Number: 9025
TEF Number: 74
Date of Latest Information Used: October 28, 1970

ION PLATING OF SOLID FILM LUBRICANTS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Solid film lubricants are used in both conventional and high temperature/high vacuum environments. Their use is often limited by problems of obtaining a uniform, strongly bonded film on the substrate metal. Conventional application methods include binders and burnishing.

Binders generally reduce the lubricating properties of the film and undergo chemical decomposition; in addition, their application methods preclude the use of many substrate metals. Unusual storage conditions for the coated surface are a problem with some binders. Burnished films have poor bonding and nonuniform thickness. Both methods produce relatively thick coatings, which creates an adjustment problem in the dimensions of the metal parts being coated.

Lewis Research Center scientists developed another process, somewhat similar to sputtering, which provides a superior lubricant coating for surfaces. As in the sputtering method, an ionized Argon atmosphere is used. The solid lubricant is introduced as a vapor into this atmosphere and the lubricant molecules become ionized. A negative electrical potential is applied to the surface of the material to be plated, causing the positively charged lubricant ions to be attracted with considerable force. When a very large potential is used, ions collide with the surface at such high velocities that they diffuse into the substructure of the material being plated. An extremely well-bonded film is formed. In order to plate nonconducting materials in this manner, a conducting screen is placed directly in front of the substrate surface. The positive ions are attracted to the charged screen, and many of them pass through to impinge on the substrate surface. The wear life of ion-plated solid lubricant coatings is superior to that of any other method for solid film application.

Hohman Plating and Manufacturing Company in Dayton, Ohio (44289) has installed equipment to do ion plating for their customers. This part of their business is currently small with high potential. They have already applied the technique on such diverse jobs as coating internal monitors to be used for hospital patients and coating electrical equipment to eliminate electrical noise and corrosion. Hohman is active in developing the market for this plating technique by finding new

applications, building prototypes and testing their properties. One example of this effort is their research in plating artificial human joints for transplanting.

Another example involves the Fafnir Bearing Company in New Britain, Connecticut (44290). At the recommendation of Lewis engineer Donald Buckley, Hohman applied the technique to improve the silver plating on Fafnir's bearings, which are used in X-ray equipment under vacuum conditions. Hohman does the ion plating for Fafnir. Fafnir is presently negotiating the price of these coated bearings with their X-ray equipment customers. In addition, Fafnir has had some of their other products ion-plated by Hohman in order to test these prototypes for properties and potential cost benefit to customers.

Control Numbers

Tech Brief Number: None
NASA Center: Lewis Research Center
PATT Case Numbers: 44289, 44290
TEF Number: 338
Date of Latest Information Used: October 2, 1970

POROUS METAL/SOLID LUBRICANT COMPOSITES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Greases and oils may evaporate or break down under high temperatures or vacuum conditions; in such cases, solid bearing lubricants are superior to liquid lubricants. Most dry lubricants, however, tend to wear through metallic surfaces causing loss of lubrication and bearing damage.

In 1966 NASA employees at the Lewis Research Center developed a solid lubricant system for use on a rotating seal of a pump for liquid fluoride propellants. The system was designed to withstand extremely high temperatures (1,000°F - 1,900°F) and to operate in vacuum environments. The system also was applied in making composite self-lubricating bearing surfaces used for control surfaces in reentry systems.

NASA Tech Brief 67-10007, published in 1967, described the new self-lubricating materials. To produce those materials, NASA engineers sintered alloys to form a porous structure which they impregnated with fluoride salts. A thin film of the resulting solid lubricant is added to the load bearing surfaces. NASA filed for a patent on the system and made available nonexclusive, royalty-free licenses.

The technique of impregnating porous metal substrates with calcium fluoride - barium fluoride was originated at Lewis and the metal substrate was further developed at Midwest Research Institute. This new method of application of the lubricant gave longer wear life. The Boeing Company (44291) monitored the progress in this technology. After additional development of the metal substrate at Boeing, prototypes were made and successfully tested using metal matrix lubricants, as they are now called, for hot duct seals in the Boeing 727. More uses are being investigated at Boeing and prototypes from this material for other seals and high temperature (1,200°F) bearing cages are now being tested.

Late in 1968, Clevite Corporation in Cleveland, Ohio (19765), an automotive bearing manufacturer, began working with the NASA information to develop a new bearing design for truck and aircraft turbines. Company officials estimated saving $75,000 and one year of development time by using the NASA technology. A brief market survey with

negative results and further engineering evaluation of the design resulted in abandonment of the intended application late in 1969. The firm is exploring other high temperature turbine applications.

Astro Met Associates, Inc. in Cincinnati, Ohio (37424) was granted a license in September 1969 to use the NASA solid lubricant technology. Company engineers developed their own production methods. Small orders for prototype and evaluation specimens are being filled. The company advertises the applicability of its self-lubricating composites for a variety of industrial uses, including armament sliding components, bearings and seals in vacuum processing equipment, hot gas blowers and pump impellers.

Control Numbers

Tech Brief Number: 67-10007
NASA Center: Lewis Research Center
PATT Case Numbers: 19765, 37424, 44291
TEF Number: 63
Date of Latest Information Used: October 5, 1970

SPUTTER BONDING OF SOLID FILM LUBRICANTS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Solid film lubricants are used in both conventional and high temperature/high vacuum environments. Their use is often limited by problems of obtaining a uniform, strongly-bonded film on the substrate metal. Conventional application methods include binders and burnishing.

Binders generally reduce the lubricating properties of the film and undergo chemical decomposition; in addition, their application methods preclude the use of many substrate metals. Unusual storage conditions for the coated surface are a problem with some binders. Burnished films have poor bonding and nonuniform thickness. Both methods produce relatively thick coatings, which creates an adjustment problem in the dimensions of the metal parts being coated.

Two Lewis Research Center scientists adapted the fairly old surface coating technique of sputtering to apply solid lubricants, in particular molybdenum disulfide, to surfaces. The sputtering process is carried out in an Argon atmosphere wherein the Argon molecules have been heated to form Argonions. By using an electric potential drop, these ions are first used to bombard and clean the substrate metal surface. The direction of the electric field is then changed, and the ions now impinge on a compact cylinder of dry lubricant (called the "target") transferring their energy to the lubricant molecules. The effect here is much like that with billiard balls. Most of the energized lubricant molecules tend to move in one direction, and the surface to be coated has been placed in their path. As these molecules strike the surface, their energy causes some penetration into the surface. After a short time a thin, graded layer of lubricant is deposited on the surface. The layer is quite uniform in thickness and has a strong, covalent bonding to the substrate metal. The wear life of coatings prepared in this fashion has proved to be exceptionally good.

Varian Vacuum in Palo Alto, California (44296) now uses the sputtering technique for applying dry film lubricant coatings to components in their own products and offers their facilities to perform this service for customers. Varian had contracted with another company to apply dry film lubricants by an expensive, nonsputtering method. The method used did not produce satisfactory results. The Varian sales manager

visited Lewis to investigate developments in coating techniques for high vacuum use and learned of the Lewis innovation in sputtering of dry film lubricants. Varian equipment was slightly modified to do sputter coating in-house and the company both improved the coating on their components and greatly reduced the cost of application. They have a growing number of customers for their coating service and are active in promoting the advantages discovered at Lewis of the technique. Varian is trying to find additional uses of dry film lubrication which might be improved by sputtering.

Hohman Plating and Manufacturing Company in Dayton, Ohio (44295) has installed equipment to perform sputter coating of dry film lubricants for customers. The company president said he first learned of the new coating method when he attended a technical society meeting at which the NASA innovators described the sputtering of lubricants. Hohman offers all of the dry film lubricant coating methods developed at Lewis and is active in finding more uses for all of them.

Anchor Hocking Glass Corporation in Lancaster, Ohio (23994) evaluated the TSP as part of a broad study of methods to improve efficiency and protection of cast iron molds used in glass-making. The sputtering method was deemed inapplicable to the firm's operations because an average of forty mold changes per day necessitates use of a more simple method to apply protective coatings to the molds. However, the TSP confirmed the validity of the firm's judgments about areas needing investigation, and the information made additional research the firm had planned unnecessary.

Control Numbers

Tech Brief Number: 68-10340
NASA Center: Lewis Research Center
PATT Case Numbers: 23994, 44295, 44296
TEF Number: 293
Date of Latest Information Used: October 2, 1970

FLUID LUBRICATED BEARING TESTING

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

NASA has conducted extensive programs for testing fluid lubricants and lubrication used in ball bearings. Information generated by the analysis of tests has benefited both lubricant producers and bearing manufacturers. The examples given below relate to two different NASA programs: improving bearing wear life under high speed/high temperature operating conditions and stabilizing instrument bearings.

The first program is conducted through the Lewis Research Center to provide lubrication and bearing technology which is required for the continuing development of gas turbine engines. A conventional measurement of bearing operation is the parameter DN, which is the product of shaft diameter (in mm) and shaft speed (in rpm). First generation gas turbine engines operated with mainshaft DN values near one million and temperatures up to 300 °F. Current production models operate at DN values to 1.7 million (to 400 °F), and development prototypes operate in the 1.8 to 2.5 million DN range (450 °F). Engines now in the conceptual stage will require bearing speeds as high as 3 million DN and temperatures above 500 °F.

One parameter of the program at Lewis has been the evaluation of fluid lubricants for use in severe operating conditions. In the past, the thermal capacity of lubricating fluids has limited ball bearing design and operation. Lewis scientists conducted an investigation of alternative lubricants for comparison with synthetic diesters, which have been the standard lubricants for gas turbine ball bearings since the early 1950's. Several new synthetic fluids were selected as potential lubricants on the basis of preliminary testing. The fluids were then tested extensively under high temperature operating conditions at SKF Industries, Incorporated in King of Prussia, Pennsylvania (44285), under contract to Lewis. The tests consisted of running similar ball bearings lubricated by the different fluids with similar conditions of speed, load and high temperature. SKF scientists reported the results of these tests in NASA CR-74097. The test results also appeared in NASA TN D-4146 and in a technical paper published in Transactions of the ASME.

A company spokesman reported recently that SKF researchers have derived from the tests several findings regarding lubricant/bearing

surface interaction. The findings have been used in specifying more resistant high temperature fluid lubricated bearing surfaces for improved wear life of SKF bearing products. The specifications pertain to roughness and asperity slope effects, material hot hardness influence on surface fatigue, and the use of solid lubricating surface treatments. A value estimate of the benefits to SKF is not available.

One of the fluids tested at SKF, a synthetic hydrocarbon designated Mobil XRM 177, was developed in the 1950's by Mobil Oil Company in Paulsborough, New Jersey (44287). The Mobil fluid was not referred to as a lubricant prior to the SKF tests, which first established its lubricating properties. Mobil XRM 177 provided bearing wear life superior to any other fluid tested. SKF recommends it to bearing customers as the best known fluid lubricant. The fluid is currently used in military aircraft hydraulic systems and additional applications are quite probable as a result of the tests. Sales figures are not available from Mobil for this particular product.

Another NASA program which has produced important lubrication technology through testing is the development and production of gyroscopes by A.C. Electronics, a division of the General Motors Corporation, under contract (NAS 9-469) to Manned Spacecraft Center. Three of the inertial reference integrating gyroscopes produced by A.C. Electronics are used in the primary guidance system of each spacecraft. Another General Motors Division, New Departure-Hyatt (NDH), in Sandusky, Ohio (44284), received a subcontract from A.C. Electronics in 1962 to design and produce the ball bearings for the gyroscope spin axis.

Since the amount of lubricant is inversely related to the stability of the gyroscope, the bearing was required to have a long wear life with little lubrication. The combination of a microscopically rough bearing surface and very little lubricating fluid does not allow elastohydrodynamic (EHD) lubrication. Without EHD lubrication, the bearing surface deteriorates as microscopic metal pieces are spalled from it. The metal pieces act in the lubricating fluid to increase its torque which effects the precision of the gyroscope. NDH researchers conducted extensive tests while working on these technical problems. Analysis at NDH of the test results has generated significant insight into the relationships among (1) the surface finish of bearings, (2) lubricant behavior, and (3) bearing surface deterioration. A company spokesman

recently indicated that the NDH research facilities and technical expertise acquired during the NASA subcontract work have been used to create a new manufacturing process at NDH. The process has significantly increased the wear life of certain NDH ball bearings that are used in aircraft engines.

Control Numbers

Tech Brief Number:	None
NASA Centers:	Lewis Research Center and Manned Spacecraft Center
PATT Case Numbers:	44284, 44285, 44287
TEF Number:	339

Date of Latest Information Used: January 25, 1971

APPENDIX C

Summary of Technology Transfer Reports Involving NASA-Generated Contamination Control Technology

APPENDIX C

SUMMARY OF TECHNOLOGY TRANSFER REPORTS INVOLVING
NASA-GENERATED CONTAMINATION CONTROL TECHNOLOGY

CONTAMINATION CONTROL TECHNOLOGIES INVOLVED	TRANSFER STAGES							
	1		2		3		4	
	Cont.*	Term.	Cont.	Term.	Cont.	Term.	Cont.	Term.
PREVENTION								
• Aircraft Galley and Cargo Refrigeration System					430**			
• Bacteriostatic Conformal Coating				27782			44974	
• Encapsulation of Surgical Instruments					44955			
• Gas Chromatograph Protective Device					35190			
• Medical Application of Clean Room Technology							35907	
• Noncontaminating Swabs							37429	
• Polyurethane Filter for Burn Treatment					38611			
• Special-Suit Technologies					44073			
DETECTION AND MONITORING								
• Microbiological Vacuum Probe					44301			
• Photo-Cell Inspection Meter					23829			
ABATEMENT								
• Filter Eliminates Gases and Contamination From Water			44964					
• Filter for High-Pressure Gases			44956		44957			
• Portable Tube Cleaning Tool							44965	
EDUCATION								
• Contamination Control Handbook	23044 23944 27506 28147 32236		26258 26614 27847 27857 27862 28008 29226 29236 30506 31286		23188 24098 25330 26764 27830 27837 27850 27858 28149 28246 29174 29250 29742 30612 31324 31368 31762 34100 38142 39662		27878 33050	
• Health Hazards of Ultrafine Metal and Metal Oxide Powders	32560 33328							

* The action status, continuing or terminated, of transfer cases at the time DRI-PATT contacted users. Cases are classed as terminated when (a) no further adaptation or adoption is contemplated, (b) a better technical alternative has been found, or (c) continued transfer activity is not economically feasible.

** Numbers in columns refer to PATT case numbers.

AIRCRAFT GALLEY AND CARGO REFRIGERATION SYSTEM TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The AiResearch Manufacturing Division of the Garrett Corporation (430) has on the market a refrigeration system for aircraft galleys and cargo containers. The basic technology was developed under contracts with the Air Force and NASA. The Air Force work resulted in a cooling and ventilating system for suited personnel handling toxic materials at missile sites. Later, under contract with the Manned Spacecraft Center, Garrett applied the technology in suits worn by Gemini astronauts during extra-vehicular activity. Finally, the technology was adapted by Garrett to an aircraft refrigeration system which was first marketed in mid-1968.

The technology is simple and reliable. Liquid nitrogen is vaporized in a heat exchanger and vented into the enclosure (food compartment or space suit) by a jet pump ejector. The vaporized nitrogen mixes with compartment air and the mixture is cooled as it flows across the heat exchanger. The cooled air recirculates through the compartment, providing continuous forced low-velocity circulation capable of maintaining temperatures within a two-degree range.

The aircraft systems are self-contained, use no batteries or external power, need no mechanical maintenance, and the nitrogen atmosphere retards food spoilage. Operating costs are low: liquid nitrogen for 24 hours' operation costs only 27¢.

The cargo refrigeration unit is containerized, providing capability for many uses from the field to the supermarket. Since the unit is entirely self-contained and requires no external power, it is remarkably adaptable for shipping all kinds of perishables. Evaluation by a major airline has been completed with excellent results. Vine-ripened Hawaiian pineapples were flown to California and immediately displayed in a supermarket. Despite a price increase of 5¢ per pound, pineapple sales rose 40 percent within a few weeks. Meat and papayas have also been shipped successfully.

During the first year of sales of the galley refrigeration unit, 55 planes were equipped. The unit price was $4,000 for each of the

25 units installed in Boeing 737's, and $9,000 for each of the 30 systems placed in Boeing 707's and 727's. The Royal Canadian Air Force has made a recent purchase: four units are now in operation on RCAF planes.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Number: 430
TEF Number: 228
Date of Latest Information Used: July 10, 1970

BACTERIOSTATIC CONFORMAL COATING

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In a thorough effort to minimize the number of viable, earth-originated bacteria carried by spacecraft to other planets, NASA has had to develop the technology for a planetary quarantine. Since many of the standard techniques for obtaining and maintaining a bacteria-free surface would be damaging to the delicate parts of a spacecraft, alternative methods have been developed.

One of these new methods was invented by Messrs. LeDoux and Bland at Goddard Space Flight Center. It was originally designed for the electronic components in a spacecraft and consists of ether sterilization of a component followed by the application of a bacteriostatic, epoxy-based coating using standard brushing, dipping or spraying techniques. The coating is then cured at an appropriate temperature and additional coats may be applied with alternative curing cycles. The finished product should have a coating thickness of from 0.005 to 0.010 inch.

Chemically, the coating is comprised of a polymeric epoxy compound, a monomeric epoxy compound, a polyamide resin, and an organic amine curing agent. Physically, it exhibits high electrical resistivity, a low outgassing rate, and is capable of restraining electronic components when subjected to mechanical vibration. This technology has several potential applications outside the space program and Tech Brief 67-10599 was issued to describe it.

Mr. D. McGonigal, director of R & D for Polyscience, Inc. (44974), read this Tech Brief and he thought a market could probably be developed for the technology. The company received a NASA license in April of 1969 for commercial use of the invention and a few sales have been made. McGonigal said the present market is small because the company has not yet conducted research to determine additional applications of the coating. They plan to develop new uses in the near future and there will be a sales push for the coating when this research is done.

Steri-tized, Inc., a small chemical company in New York (27782), manufactures bacteriostats, fungicides, and other bactericides for industry. In conjunction with its line of bactericides, the company is constantly looking for new product lines and for new areas

of potential sales application. Company president M. Kadison stated that his firm was working on a new bacteriostatic coating when he read the Tech Brief.

The company is not marketing the bacteriostatic coating as described in TB 67-10599, but the technology has been incorporated into improved versions of two coating products the company had been making for some time. The improved products are made at a cost reduction of 26 percent, which Kadison attributed directly to the Tech Brief. Due to the improvement, additional markets for the two coatings have developed which include textiles (canvas for tenting, boat covers, and shoe liners and cotton for sheets and pillow cases) and vinyl extrusions (shower curtains and swimming pool liners). These items were previously coated with bactericides and fungicides which contained mercury, tin or lead. Public outrage and government regulations have severely restricted the use of such metals. Kadison said their own coating products contained phenyl mercury which was replaced by the organic compounds described in the Tech Brief.

Control Numbers

Tech Brief Number: 67-10599
NASA Center: Goddard Space Flight Center
PATT Case Numbers: 27782, 44974
TEF Number: 299
Date of Latest Information Used: November 11, 1970

ENCAPSULATION OF SURGICAL INSTRUMENTS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Under the terms of the International Planetary Quarantine Agreement, the number of viable, earth-originated microorganisms transferred to other planets must be minimized. NASA has generated a broad area of technology to meet this requirement. Many special techniques have been devised because a sterilizing process or agent must be compatible with the rigidly specified component it sterilizes.

In particular, the fuel must be sterile but still provide the specified thrust per pound. Scientists at the Jet Propulsion Laboratory have developed a process for sterilizing propellants of lunar landing vehicles. This was done by adding ethylene oxide (a sterilizing agent) to the polyurethane propellant which produced a sterilized but still effective fuel. In the process of this investigation, they observed that ethylene oxide could also be added to other polymeric materials without affecting their material properties and proposed this method for encapsulating surgical instruments.

After reading a 1964 Tech Brief on this proposed use, the president of Scientific Enterprises (44955) in Broomfield, Colorado applied, in 1965, for a license to use the technology commercially. His company does sophisticated packaging for aerospace and medical industries. Scientific Enterprises has found several organic polymers suitable for use with ethylene oxide to form a sterile encapsulation. Since these polymers do not form a bond with the instrument metal, the coatings are easily removed so the instrument may be used. The process gives very satisfactory results as shown by the company's prototype testing, and they offer to apply this sterile coating for customers. The company is attempting to reduce costs for external commercial market use.

Control Numbers

Tech Brief Number: 64-10066
NASA Center: Jet Propulsion Laboratory
PATT Case Number: 44955
TEF Number: 342
Date of Latest Information Used: October 30, 1970

GAS CHROMATOGRAPH PROTECTIVE DEVICE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Gas chromatographic chemical analysis is applicable to solid/liquid propellants, pollution and contamination surveillance, polymers, oils, low-boiling impurities, etc. Samples containing nonvolatile substances are not usually analyzed by gas chromatographic procedures because nonvolatiles and other deleterious foreign materials "poison" the columns. This condition invalidates results and necessitates reworking lengthy column preparations, installations, and calibrations. However, hydrazine fuels used in rockets and turbine engines must be frequently tested for quality control by this method; when they include hydrazine nitrate, which is a nonvolatile, the testing is inaccurate and quite difficult. The rapid "poisoning" in this case is caused by the deposition of hydrazine nitrates and the buildup of acidic salts. Messrs. E. A. Welz and M. D. Robertson of North American Rockwell Corporation, under contract to Marshall Space Flight Center, developed a procedure and a device to eliminate these problems.

The first problem was solved by reacting a small portion of the sample with sodium methoxide to liberate hydrazines from any free radicals present. The acidic salt buildup is eliminated by installing an on-column inlet modified to hold an exchangeable insert, which was packed with Polyethyleneimine (PEI) on a standard filler material. PEI is known to be an efficient trap for acidic and highly polar material. These techniques have increased the lifetime of the chromatographic column to three months of continuous service. The protection is ensured simply and inexpensively, and selective retention of undesirable materials is easily accomplished.

Sundstrand Aviation, an Illinois division of Sundstrand Corporation (35190), produces various hydrazine fuels, and one of them includes hydrazine nitrate (Sundstrand 70-20-10). Sundstrand's quality control monitoring had been costly and inefficient. After reading TB 69-10788, which described the protective device, the project chemist tried it out

in his laboratory. He plans to use it for any future fuel analysis and regrets it was not available a year ago.

Control Numbers

Tech Brief Number: 69-10788
NASA Center: Marshall Space Flight Center
PATT Case Number: 35190
TEF Number: 343
Date of Latest Information Used: October 27, 1970

MEDICAL APPLICATIONS OF CLEAN ROOM TECHNOLOGY

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Hospital environments are subject to strict controls to minimize possibilities of infection; nonetheless, it is quite difficult to eliminate inflection entirely. Airborne bacteria are especially troublesome in operating rooms. As many as five percent of surgical patients become infected despite thorough scrubbing of the operating room with disinfectant detergents, use of sterile clothing, prevention of air currents by keeping doors closed, use of ultraviolet lights, and administration of prophylactic antibiotics. Significant advancement in operating room sterility has been achieved by a transfer of technology from NASA's body of contamination control techniques.

The transfer was accomplished by an engineer who had worked on the development of dust covers for spacecraft assembly operations under a NASA subcontract. The engineer now works for Contamination Reduction Systems (35907) in Conshohocken, Pennsylvania. The NASA artifact incorporated a high efficiency particulate air filter (HEPA filter) developed originally by the Atomic Energy Commission. Other components of a vertical flow air circulation system were added by the engineer to develop the patented air filtration system for CRS which is used in hospitals and other medical facilities. Sales of the system are presently about $800,000 annually.

The combination of 99.97 percent efficient HEPA filters, a vertical flow system, and a clean room enclosure constitutes the patented medical system, which virtually eliminates airborne bacteria from the enclosure within a few minutes. Among the hospital applications are operation room sterility, reverse isolation of patients with depressed immunological defenses (e.g., transplant recipients, patients undergoing irradiation, cancer chemotherapy, and those with blood dyscrasia), protection of premature infants and patients with respiratory diseases such as emphysema and bronchial asthma, and protection of patients undergoing open treatment of burns. The system also performs valuable functions in rooms for preparing intravenous medications, infant formulas, culture media, and sterile supplies. Research laboratories in the pharmaceutical industry, microbiological studies, and other scientific applications are now a major market for the CRS product.

An article in the Journal of the American Medical Association (March 18, 1968) reported the results of using the system in operating rooms: the principal sources of operating room infections (staphylococcal and psendomonas particles) were reduced ten to eighteen fold within two to three minutes of turning on the filter. A research clean room located in a room in which small animals were housed was equipped with the system for an experiment reported in the American Journal of Public Health (October 1967). In combination with conventional floor scrubbing techniques, the "washing" of the room with sterile filtered air created an essentially sterile environment under very adverse conditions. In the August 1969 issue of Applied Microbiology, similar success was described for an animal care laboratory; the system reduced the volume of airborne contaminants stirred up during cage cleaning and changing activities to the level observed when no personnel activity occurred. Airborne infection of the animals was greatly reduced, and for the first time experimenters were able to quantify the various factors contributing to the spread of airborne infection.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 35907
TEF Number: 308
Date of Latest Information Used: March 31, 1970

NONCONTAMINATING SWABS PRODUCED BY HANDICAPPED WORKERS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

While assembling rockets, North American Rockwell, under contract to Marshall Space Flight Center, established clean room operations involving a dust free, temperature-controlled environment. Grease marks, filings, and all other contaminants had to be removed in order to avoid potential explosion hazards when the rocket components were eventually exposed to propellants. Attempts were made to remove small bits of contaminants with cotton swabs, but sharp corners and surface irregularities tended to snag the cotton and produce a small lint deposit contamination. Also, fragments of wood from the swab handle contributed contamination.

A North American Rockwell technician devised a modification involving placement of a nylon cover over the cotton, and heat-shrinkable rubber tubing over the wooden handle. The modified swab performed well and could be reused.

Technology utilization engineers at North American Rockwell perceived a transfer potential early in 1968, and conveyed the idea to Build-Rehabilitation Industries (37429). The nonprofit firm employs and rehabilitates handicapped workers in North Hollywood, California. Since May 1968, the firm has produced more than 20,000 swabs and sold about $3,000 worth. Efforts are being made to find new markets for the swabs.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 37429
TEF Number: 212
Date of Latest Information Used: May 6, 1970

POLYURETHANE FILTER FOR BURN TREATMENT

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

NASA's program to land an unmanned craft on Mars included a project in which balloons were sent 100,000 feet above the earth to test for microbiological contamination. The testing device included a special polyurethane filter. Edward Rich, Jr., a NASA employee for nine years, conceived the idea of adapting the filter to medical uses, specifically for burn treatment.

After taking a job with the National Institutes of Health (NIH), Rich performed additional research to develop a new burn bandage known as Burn Aid (38611). Burn Aid is inexpensive and can be used at home as well as in a hospital. A portable unit provides a supply of air or specific gases, which flow through the filter to the burn. The filter itself is sandwiched between two sheets of vinyl that are sealed on all edges. The bottom sheet is coated with an adhesive and covered with paper. The physician cuts a hole in the bottom sheet, large enough to avoid contact between the bandage and the injured area, then peels off the remaining paper to expose the adhesive for application to unburned skin around the injury. The flow of gas is then started through the filter. Only the filtered air contacts the wound, preventing infection and hastening the healing process. NIH has filed a patent application for the medical use of the filter.

Control Numbers

Tech Brief Number: None
NASA Center: Goddard Space Flight Center
PATT Case Number: 38611
TEF Number: 84
Date of Latest Information Used: April 24, 1970

SPECIAL-SUIT TECHNOLOGIES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Garrett Corporation (44073), a Los Angeles, California firm with a broad background in providing special suits for aerospace uses, is using its expertise to design and fabricate new garments for several unique nonspace applications. Several years ago the company's experience in developing a protective suit for handlers of toxic materials led to its developing a new aircraft galley refrigeration system which incorporates a novel nitrogen-coolant system similar to that used to cool the wearer of the protective suit. (See "Aircraft Galley and Cargo Refrigeration System" above.)

In recent months the firm has drawn on other special-suit technology developed initially for NASA, to design a unique surgical garment. Under contract to Langley Research Center, the firm developed a suit for use in research into metabolic rate variations under lunar-gravity conditions and a variety of physical activities. This background provided conceptual inputs to development of a positive-pressure suit for surgeons, of which prototypes are in use. The surgeon's suit involves a hood through which a forced air flow is introduced to circulate past the face and downward to be expelled into a laminar air flow below the operating table. The idea of using a laminar flow enclosure and a means of transporting the surgeon's exhaled breath away from the operating area originated in England. A noted British hip surgeon observed that dust from clothing, carrying bacteria from the surgeon's breath, easily settled in on the large tissue area exposed in hip surgery, causing an unacceptably high rate of infection. His solution to the problem was to set up a portable laminar flow enclosure about the operating table, and draw the surgeon's breath away from the area by a flexible suction hose. A California hip surgeon visited England to observe the advanced techniques developed by the British surgeon, and decided that the breath-removal problem would be better handled with a positive-pressure suit. He collaborated with the developers of the Langley metabolism-measuring suit in designing the new surgical suit. He has performed 240 hip operations using the suit and a laminar flow enclosure, and has not had a single instance of infection. In his judgment, these surgical arrangements mark a new definition of competent hip surgery, and the hospitals without

the technology -- still experiencing an infection rate of 7-8 percent -- must soon adopt it.

Control Numbers

Tech Brief Number: None
NASA Center: Langley Research Center
PATT Case Number: 44073
TEF Number: 334
Date of Latest Information Used: September 3, 1970

MICROBIOLOGICAL VACUUM PROBE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The recovery of microorganisms from surfaces has been studied by microbiologists since the early part of the century. During this period five basic methods have evolved for the microbiological examination of surfaces: the agar overlay method, the agar contact method, the swab-rinse method, the rinse method, and the agar-dip method. Each method has individual advantages and disadvantages, but all were designed for sampling relatively large populations of microorganisms on small to moderately sized surfaces.

The planetary quarantine requirement that space vehicles landing on planets designated as biological preserves be sterilized, has imposed a requirement for the sampling of large surface areas with small amounts of microbial contamination.

The settling strip method has been developed and used for estimating the viable contamination deposited on surfaces. With this method, sterile stainless steel strips are placed in the same environment as the surface, and after a determined period of environmental exposure, the strips are assayed for microbial contamination. The criticisms of this method are that it is indirect and inaccurate when the amount of microbial contamination is small.

The need for a microbiological surface sampling device, with the capability for sampling large areas that are lightly loaded with microorganisms, has been met by the invention of a vacuum probe sampler at Sandia Corporation under contract from NASA's Office of Space Science Applications. The results of this development by the Planetary Quarantine Group at Sandia were published by Sandia Corporation in the following reports: SC-RR-67-688, SC-RR-68-592, SC-RR-68-593. The group also published an article on the vacuum probe in Applied Microbiology, January 1969, pp. 164-168 (Journal for the American Society for Microbiology).

The vacuum probe is an instrument that utilizes airflow through an orifice to remove particles from surfaces and a membrane filter to capture these particles. This device has demonstrated the ability to repeatably remove in excess of 90 percent of the settled microbiological foci, which are in the micron size range or larger, from a smooth surface without harming the surface.

Becton, Dickinson Research Center (44301), in Raleigh, North Carolina, received a contract from Langley Research Center to convert the metal probe invented at Sandia to a plastic version and, later, another contract from Langley to improve the design of the plastic probe. The two contracts included the purchase, by NASA, of 1,000 plastic probes. Center director Dr. Briggs Phillips stated Becton, Dickinson has patents pending on the most advanced models. The company's marketing component anticipates that the food and drug industry will become a substantial market for the probe.

Control Numbers

Tech Brief Number: None
NASA Center: Langley Research Center
PATT Case Number: 44301
TEF Number: 346
Date of Latest Information Used: October 29, 1970

PHOTO-CELL INSPECTION METER

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In April 1966 a contamination monitor was proposed to detect possible contamination deposits on spacecraft surfaces during launch and booster-stage separations. The need for the instrument was indicated by the thermal design engineer of the AIMP-D satellite, when his analysis of an overheating battery failure suggested that contamination of the satellite may have occurred from the fourth-stage rocket. Contamination would alter the optical properties of the satellite's surface coating, causing increased effective solar absorptance and thermal emittance of the thermal control surfaces. The successor satellite AIMP-E was redesigned to compensate for the problem, and a monitoring instrument was attached for the flight of AIMP-E.

Robert Sheehy and Albert Bush of Goddard Space Flight Center developed the monitor using light bulb performance data from a manufacturer's catalog, and a continuous intensive testing program. The monitor, described in Tech Brief 68-10089, projects light from a tungsten lamp through a collimating lens onto the sample surface. The light is reflected from the sample surface through a second lens that focuses the image on a two-millimeter silicon sensor cell. The sensor cell output is proportional to the output signal from the light source, and is compared with the signal from another sensor mounted in the lamp housing to provide an internal calibration standard. Changes in the monitor output signal are proportional to changes in the optical absorption characteristics of the sample surface.

Hermaseal Company (23829), a mercury switch manufacturer in Elkhart, Indiana, has used the basic ideas underlying the NASA monitor to construct a monitor for determining cleanliness standards for production quality control. The firm's test machine was built at a cost of $75 and has reduced inspection time by 60 percent, accounting for annual savings of about $1,000.

Control Numbers

Tech Brief Number: 68-10089
NASA Center: Goddard Space Flight Center
PATT Case Number: 23829
TEF Number: 25
Date of Latest Information Used: September 16, 1969

FILTER ELIMINATES GASES AND CONTAMINATION FROM WATER

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The stringent weight requirements for manned spacecraft have forced the development of recycling technology. A typical recycling problem occurred with fuel cells used in spacecraft. The "waste" from fuel cell operation is water containing hydrogen gas. The water and hydrogen must be reused separately and this requires a separation process from which both parts are recoverable.

Trans World Airlines, Inc., under contract to Kennedy Space Center, has designed a simple and inexpensive filter that solves this problem. The device will handle pressures up to 100 $lb/in.^2$ at temperatures up to 121°C; depends in no way on gravity; gives absolute filtration, with automatic venting of freed gases; and prevents backward transmission of contamination. Other gas/fluid combinations may be separated by modifying the filter material. It will also filter bacterial contamination from water and prevent bacterial growth through the filter. Even viruses could be filtered.

Product manager J. M. Brammer of Health Science Industries, Inc. (44964) in Bellevue, Washington learned about this development in a Tech Brief from NASA. He believes that it will solve a problem of long standing for manufacturers of hemodialysis fluid delivery systems (including artificial kidneys), namely: deaeration of the fluid flowing to the patient.

The fluid, a dialysate solution, becomes aerated in the mixing processes and it will contain from one to four cc's of air per liter afterward. The air must be removed before the fluid enters the patient, and this has been done in the past by allowing it to stand still for a time under low pressure,which is inefficient and inadequate. The company is currently testing the filtration device and preliminary results are favorable.

Control Numbers

Tech Brief Number: 70-10456
NASA Center: Kennedy Space Center
PATT Case Number: 44964
TEF Number: 345
Date of Latest Information Used: November 5, 1970

FILTER FOR HIGH-PRESSURE GASES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

During NASA's development of the Ranger, one of the contamination control problems that was solved concerned the filtration of high temperature, high-pressure (12, 500 psi) sterilizing gases. A small, simple filter was designed by W. F. MacGlashan at the Jet Propulsion Laboratory which could be placed on the gas supply tubing and yet be easily assembled and disassembled for cleaning. The filter cartridge is also suitable for chemical sterilizing gases. The design is such that the device would be suitable for use in other high-pressure tubing systems requiring a filter that can be readily taken apart.

Barclay and Associates (44956) in Port Chester, New York is conducting a process feasibility study for a major oil company, and a high-pressure gas filter will be required in the process. The filter developed at JPL is being considered for this use along with several other filters.

The Rogg Corporation (44957) in New Milford, Connecticut is a small manufacturer of precision components and actively seeks new products. The company applied to NASA for a commercial license to produce the filter after receiving a Tech Brief describing the technology. A license was granted in June of 1964. Since that time 50 filters have been produced, most of which have been sold or given away on a trial basis.

Mr. Rogg, owner of the company, said there has been no market for the filter. He has found this is due to its being an isolated item in their line of products. Rogg is presently expanding their line to include items related to the filter's use which should improve its marketability.

Control Numbers

Tech Brief Number: 63-10234
NASA Center: Jet Propulsion Laboratory
PATT Case Numbers: 44956, 44957
TEF Number: 341
Date of Latest Information Used: October 30, 1970

PORTABLE TUBE CLEANING TOOL

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In the design of any type of transportation system, safety and reliability are important considerations. In the design of manned space vehicles, these considerations are paramount. Long hours are spent engineering reliability into that equipment which is absolutely essential to the safety of the crew. This essential equipment includes the familiar retro-rockets which provide the deceleration thrust, and the reaction control system which enables the spacecraft to maintain the proper attitude during the firing of the retro-rockets. To insure that the reaction control system would function properly after the Gemini spacecraft has orbited around the earth for up to two weeks, not only were dual systems provided, but, in addition, all screw fittings in the reaction control system were eliminated and replaced by brazed connections to insure against leakage of the very corrosive hypergolic propellants used in the system. To prepare the tubing for a brazing operation which would produce a leakproof connection, special tools had to be devised because of the limited access and restricted working conditions. One of the implements created to perform this task is a portable cleaning tool.

The portable cleaning tool comprises a hand-held device for cleaning or polishing the exterior of a tube or pipe end. The work engaging portion of the tool has an opening with a rotating abrasive member provided within, adapted to be positioned over the end of the member to be cleaned. Because the diameter of the rotating abrasive member is larger than the tubes which it will clean, the cleaning operation is accomplished by working the tool about so that the entire outside surface of the tube to be cleaned is brought into contact with the abrasive member. A vacuum suction arrangement removes the residue from the cleaning operation and also insures that none of the residue enters the tube being cleaned.

Upon receiving a waiver from NASA, McDonnell licensed the invention to the Aeroquip Corporation (44965) of Jackson, Michigan. Aeroquip produces auxiliary equipment for aerospace use, including a line of hardware to be used for induction brazing of metal tubing which now incorporates the cleaning tool. Although the brazing method costs twice as much as ordinary threading, the result is much safer and longer lasting. These factors are important in such applications as cryogenics, chemical refining, water desalinization, and nuclear reactor plumbing. The company is actively seeking a wider market for its system of brazing hardware in these areas of application. About 35

of the systems have been sold and brochures showing the system's advantages are currently being distributed to industry.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Number: 44965
TEF Number: 344
Date of Latest Information Used: November 9, 1970

CONTAMINATION CONTROL HANDBOOK

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The reliability and precision demanded for manned space flight require extreme cleanliness in all stages of manufacture and assembly of components. Throughout industry, aerospace components are fabricated in "clean rooms" that are more sterile and clean than were hospital operating rooms of a few decades ago. In order to facilitate use of advanced contamination control methods in the many industries in which cleanliness is important, NASA's Office of Technology Utilization has issued three Special Publications dealing with the technology.

A widespread need for guideline information was met by the 1967 publication of Contamination Control Principles (SP-5045). A series of lectures for a Lewis Research Center course for clean room technicians and supervisors was published in Clean Room Technology (SP-5074). Finally, Contamination Control Handbook (SP-5076) was published in 1969, and publicized in Tech Brief 68-10392. Prepared for NASA by Sandia Laboratories, the handbook contains in one volume the information and data most likely to be useful to persons with industrial and other contamination control duties.

Among the topics treated in the handbook are an introductory description of different kinds of contamination and environments, followed by intensive examination of contamination control in product design, clean packaging, maintaining product cleanliness, and control of contamination of surfaces, gases, and liquids. Airborne contamination, microbial contamination, and radiation also receive thorough treatment. A glossary and abundant bibliographical citations complete the volume.

The handbook has stimulated a great deal of interest among electronics manufacturing firms, who have used it variously to improve production standards, establish clean room specifications and aid in designing new facilities, identify substitutes for contaminating solvents, and train clean room personnel. Specific, documented savings by the fourteen electronics firms interviewed have exceeded $60,000. Six chemical manufacturers report having used the document for similar purposes, and two have been able to develop new products through establishment of capabilities and techniques described in the book. An Air Force installation saves $20,000 annually through improved quality control methods; and a manufacturer of aerospace hydraulic mechanisms used the book to improve precision parts cleaning techniques and saved $20,000 per year.

Other organizations have used the handbook to improve quality control and production controls in bearing manufacturing; to establish industrial hygiene standards in copper refining which so far have led to savings of 100 man-hours per year; to devise effluent measures for producing pollution control equipment which produced savings totaling $2,500; to develop a new ceramics product by acquiring sophisticated quality control capabilities; to design, build, and increase sales by $50,000 of new clean room equipment; to develop photographic processing facilities at a state university; to improve contamination control in manufacturing computer hardware which has allowed the production rate to double; and to modify production technology in the manufacture of special-purpose dry cleaning equipment, which increased sales by $150,000 per year.

A standards handbook was formulated for the hydraulic power equipment industry, largely with information from the handbook. Service industries also are benefitting from use of the manual. A pathologist uses it to prepare articles and lectures for hospital personnel. He estimates that hospitals throughout the nation have saved $100,000 and 1,000 man-hours per year, in addition to enhancing patient care through use of the information. An insurance company uses the handbook to assist in evaluating claims, and has prepared an accident prevention booklet with some of the handbook information. The U.S. Department of Agriculture established several clean rooms to prevent microbiological contamination of materials in research to develop new protein-rich foods from cottonseed. A public health agency uses the handbook as a reference source in its supervision and certification of medical equipment manufacturers. A NASA Biomedical Applications Team used the handbook and other sources to assist a surgeon in preparing a proposal for installation of laminar flow ventilation and clean room techniques in

a major university hospital's operating rooms. Open heart operations demand the most rigid observance of sterile techniques, and the clean room conditions are expected to contribute significantly to reduction of infection.

Control Numbers

Tech Brief Number:	68-10392
NASA Center:	Marshall Space Flight Center
PATT Case Numbers:	23044, 23188, 23944, 24098, 25330, 26258, 26614, 26764, 27506, 27830, 27837, 27847, 27850, 27857, 27858, 27862, 27878, 28008, 28147, 28149, 28246, 29174, 29226, 29236, 29250, 29742, 30506, 30612, 31286, 31324, 31368, 31762, 32236, 33050, 34100, 38142, 39662
TEF Number:	262

Date of Latest Information Used: October 27, 1970

HEALTH HAZARDS OF ULTRAFINE METAL AND METAL OXIDE POWDERS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

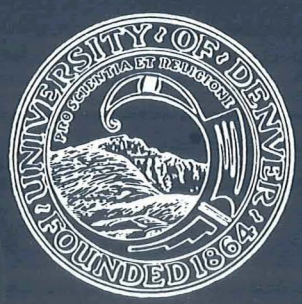
Special studies conducted for Lewis Research Center by a Massachusetts contractor facilitated establishment of guidelines for operations and handling fine powder materials. After several years' experience with the guidelines, no clinical signs of chemical toxicity have been found in any Lewis operating personnel. Because of this success and the belief that the studies would have value in many operations that generate potentially toxic fine dusts, a 1969 Tech Brief was published to announce availability of the information to the general public.

The documentation is based on a review of toxicological data in the literature; experimental studies dealing with electron microscopy, particle size, aerosol generation and sampling, and related matters; and an industrial hygiene survey of laboratory work areas. The results of these studies included specification of threshold limit values for exposure to ultrafine dusts, identification of the necessity of air monitoring for controlling dust levels, recommendations for control measures for all operations, an outline for a continuing industrial hygiene and surveillance program, and recommendations for future toxicological research.

Wright Industries (32560), a small manufacturing company in Brooklyn, New York, used the NASA document to evaluate its safety standards and concluded that its current practices were adequate for employee safety. Olin Mathieson Chemical Corporation (33328) in New Haven, Connecticut, has found the information useful for reference purposes.

Control Numbers

Tech Brief Number: 69-10268
NASA Center: Lewis Research Center
PATT Case Numbers: 32560, 33328
TEF Number: 323
Date of Latest Information Used: June 25, 1970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