PROJECT FOR THE ANALYSIS OF TECHNOLOGY TRANSFER
Contract NSR 06-004-063

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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 January through June 1971 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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REPORT HIGHLIGHTS

- The special task of preparing technology transfer profiles during the first six months of 1971 produced two major results: refining a new method for identifying and describing technology transfer activities, and generating practical insights into a number of issues associated with transfer programs (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 9,090 TSP request letters, PATT interviewers completed approximately 165 telephone interviews with TSP requestors to document the transfer experiences of persons using these documents (Section I).

- A recent change in both the format and contents of Technology Utilization Compilations led to a substantial increase in the volume of technical information being requested from NASA (Sections I and III).
PATT research activities conducted from January 1 through June 30, 1971 are reviewed in this section.

**Tech Brief—Technical Support Package Program**

During the first six months of 1971, PATT received 12,320 inquiries which had been sent to NASA by persons requesting Technical Support Packages (TSP's). This number reflects an increase of 56 percent over the number of TSP requests made during the first six months of 1970 (see Figure 1-1). * By the end of June, 9,090 of the 1971 TSP requests had been coded by PATT personnel, bringing the total number of requests processed since the inception of the project to 56,300.

*Increase does not include TSP requests related to Tech Briefs republished in TU Compilations (See Section III).*
<table>
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<th>TABLE 1-1. REQUESTS FOR TECHNICAL SUPPORT PACKAGES, BY NASA CENTER, JANUARY 1970 - JUNE 1971</th>
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<tr>
<td>Ames Research Center</td>
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<tr>
<td>NASA Pasadena Office (JPL)</td>
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<td>Space Nuclear Propulsion Office</td>
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<td><strong>TOTAL</strong></td>
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the first six months of 1971, TSP's originating at Marshall Space Flight Center generated approximately 31 percent of all requests; those developed at Manned Spacecraft Center, Langley Research Center, and Lewis Research Center collectively accounted for another 33 percent. This variation in TSP request frequency can be accounted for, in part, by the different rate of TSP production among the field centers (see Figure 1-2), and by the fact that some centers produce a few Tech Briefs having very popular TSP's (see Table 1-2).

![Figure 1-2. 1970 Tech Brief Production and January - June 1971 TSP Request Frequency by NASA Field Center](image)

Transfer Documentation Activities

Interviews with persons attempting to make further use of NASA-generated technology continued to be an important part of PATT activity during this reporting period. Approximately 165 telephone interviews were conducted with such persons, most of whom had requested Technical Support Packages. Since the inception of PATT in November 1967, 1,219 such interviews have been completed; approximately 20 percent
<table>
<thead>
<tr>
<th>TSP Number</th>
<th>Request Frequency</th>
<th>Originating Center</th>
<th>Title</th>
</tr>
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<tbody>
<tr>
<td>70-10520</td>
<td>675</td>
<td>LARC</td>
<td>Nondestructive Spot Tests Allow Rapid Identification of Metals</td>
</tr>
<tr>
<td>70-10715</td>
<td>374</td>
<td>MSFC</td>
<td>Strain Gage Installation Manual</td>
</tr>
<tr>
<td>70-10543</td>
<td>340</td>
<td>KSC</td>
<td>Easy Manual Operation of Overhead Garage Doors: A Concept</td>
</tr>
<tr>
<td>70-10255</td>
<td>271</td>
<td>MSFC</td>
<td>Biological Handbook for Engineers</td>
</tr>
<tr>
<td>70-10638</td>
<td>261</td>
<td>ARC</td>
<td>Intruder Detection System</td>
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<td>70-10511</td>
<td>242</td>
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<td>Metal Detector System</td>
</tr>
<tr>
<td>70-10456</td>
<td>218</td>
<td>KSC</td>
<td>Elimination of Gases and Contamination from Water</td>
</tr>
<tr>
<td>69-10406</td>
<td>192</td>
<td>NPO</td>
<td>Quick-Set Temporary Bonding Clamps</td>
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<tr>
<td>70-10662</td>
<td>191</td>
<td>LARC</td>
<td>Water Velocity Meter</td>
</tr>
<tr>
<td>70-10303</td>
<td>181</td>
<td>MSC</td>
<td>Simple, Accurate Temperature-Measuring Instrument</td>
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of those interviews involved a recontact to determine the user's progress in attempting to adopt the technology. Results from some of the interviews are presented in summary form in Appendices A and B of this report.

Other PATT Activities

Technology Transfer Profiles. The preparation of transfer profiles describing nonaerospace applications of NASA-developed technologies continued during the reporting period. By June 30, 1971, a total of five transfer profiles had been readied for publication. The five profiles examined transfers of NASA contributions to the fields of plastics, lubrication, contamination control, fire safety and cryogenics. Section II of this report highlights the more significant transfer issues that were treated in developing these profiles. The transfer example summary statements prepared for use in the fire safety and cryogenics profiles are presented in Appendices A and B.

A Technology Transfer Model. Further progress was made during the reporting period in developing a model of the technology transfer process for the NASA Office of Industry Affairs and Technology Utilization. Major dimensions of the emerging model were described in the PATT Annual Report 1970. The model generated and refined primarily through the preparation of technology transfer profiles, has been useful in identifying areas where Agency-wide efforts to facilitate technology transfer have been operating in concert with the Technology Utilization Program.

Technology Utilization Compilations. During this reporting period, PATT initiated activities for examining the "Compilations" area of the Technology Utilization Office's Special Publications program. Compilations aggregate and briefly describe innovations related to a particular technological field (e.g., Selected Shop Techniques, Hand Tools, Measurement Technology). The documents, which have been published as a series, were designed to provide American industry with access to technical accomplishments generated for space program purposes, accomplishments that generally are not documented in other publications.

Late in 1970, the Technology Utilization Office modified the publication format of Compilations to include detachable reader service cards. The use of these cards, which enable readers to request
additional information on individual items described in the Compilations, has led to a significant increase in the volume of technical information being distributed by the NASA centers. A more detailed discussion of this activity is presented in Section III.

**Technology Transfer Example Files.** Development activities associated with the files continued in 1971, both to supplement the technology transfer profiles and to provide interested persons with ready access to information on NASA-related technology transfer activities. By the end of this reporting period, 380 individual files had been established, involving 740 transfer cases associated with nonaerospace uses of NASA-developed technologies. A total of 125 files had been updated, including the preparation of comprehensive file summaries. 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 2,416 titles through June 1971. A revised bibliography on technology transfer, which contains 60 abstracts of the key literature in the field, was published in February 1971 as NASA Contractor Report 1724. It is available from the National Technical Information Service in Springfield, Virginia.

**NASA-Related News Clippings.** In order to supplement PATT sources of leads to technology transfer activities, news clippings taken from magazines and newspapers are reviewed on a regular basis. The clippings, compiled for NASA's Technology Utilization Office by a professional clipping service, include news items which reference space program activities ranging from moon landings and satellite programs to newly-developed NASA technology.

During the first six months of 1971, PATT personnel processed 619 individual news clippings. Those items that identified transfer activities among nonaerospace users of technology generated originally for application in the space program were selected for follow-up. Resulting information subsequently was used to provide new transfer cases for the technology transfer example files.
SECTION II. ISSUES AND FACTORS IN TECHNOLOGY TRANSFER

The primary output of Project activities during the twelve-month period ending in June 1971 was a series of so-called "technology transfer profile" presentations. Each of the five profile presentations developed in that period considered a specific field of technology: plastics, lubrications, contamination control, fire safety, and cryogenics. For these fields, the presentations described overall trends in the technology; related significant NASA contributions by citing appropriate technical and economic impact data; examined major ways such contributions have been disseminated to persons outside of the aerospace community; and, finally, reviewed a number of transfer case histories illustrating how the disseminated technologies are being used in non-aerospace sectors of the American economy.

Developing these transfer profiles permitted an opportunity to describe indirect benefits flowing from the nation's space program in a way that differed substantially from previous descriptions. Other descriptions of technology transfer activities tended to focus on individual, usually isolated, experiences involving secondary applications of NASA-generated technologies. The preparation of technology transfer profiles, by contrast, essentially aggregated transfer experiences according to fields of technology (e.g., contamination control, cryogenics) and described such experiences in the context of direct NASA contributions to the technical fields involved. This experimental effort produced more than a new way of identifying and describing technology transfer activities; it also generated insights into the technology transfer process. The purposes of this section are to identify issues that emerged as transfer processes in each of these five technical fields were examined, and to describe factors that were recognized as crucial in the transfer activity reported in the respective documents.

Principal Issues and Factors

This review of the principal technology transfer issues and factors that came into focus during the preparation of these profiles is arranged according to the particular technical fields in which they first became obvious to Project personnel. As each new profile was developed, beginning with plastics and concluding with cryogenics, a systematic attempt was made to pinpoint new transfer factors and to determine whether they were unique to the particular technical field or common to many fields. Knowledge of such factors is important primarily because
it enables managers of technology transfer activities to better identify the forces affecting the communication and application of technologies in different sectors of the national economy, while knowledge of the issues facilitates the description of the impact of technology transfer.

**Plastics.** The transfer profile related to plastics set the tone for all five profiles by treating issues and factors according to three dimensions of technology transfer: contributions, communications, and nonaerospace applications. In the area of contributions, the research conducted to produce this profile demonstrated that Space Agency inventions and innovations extend completely across the spectrum of the plastics field; they include dozens of materials formulations and hundreds of new processing and design applications. Those contributions were found to vary in terms of the extent to which they advanced the technology in polymer chemistry and plastics, ranging from fundamental advances to relatively minor improvements. Interestingly, important basic advances in the plastics field (e.g., new very high temperature polymers) have not yet found widespread use in nonaerospace sectors because at this stage in the transfer process, the new materials are only now being considered as more than substitutes for currently used materials in existing applications.

An issue of central importance in technology transfer concerns the manner in which transfer activities are analyzed and described. Until the development of the plastics profile, most descriptions tended to treat such activities in an either-or fashion: either transfer occurred or it did not. Even though transfer analysts have known for some time that adaptation of a technology usually is required before it can be adopted in a nonoriginating sector, nonetheless little or no attention was given to the complex and essential activities preceding adoption. To deal with this issue in the plastics presentation, a decision was made to identify different transfer stages leading up to adoption. Four transfer stages finally were identified: preliminary understanding; engineering evaluation; in-house use or prototype testing; and full-scale marketing. Once these stages were defined, it became possible to draw a profile of transfer activity showing just how far hundreds of different nonaerospace firms had proceeded in adapting and applying NASA-developed plastics-related technologies in their work.

Development of this profile clarified another transfer issue: while NASA has been able to initiate the transfer cycle and help nonaerospace firms progress through the initial transfer stages, no
actions by the Agency can create the market demand that leads to widespread adoption of a new or improved technology. In situations where NASA has generated a demand for a particular technology (e.g., high temperature polymers), that demand in itself is not a sufficient condition to insure subsequent secondary utilization of innovations created through that demand.

**Lubrication.** While the need for effective communication was demonstrated as a necessary factor in the transfer process during the preparation of the plastics presentation, the central importance of communications as a transfer issue did not come into clear focus until the profile related to lubrication technology was developed. This presentation afforded an opportunity to explore the ways in which the professional communication activities of NASA scientists and engineers complement the organized transfer program established by the Space Agency. Through their participation in professional society activities and in their interpersonal contacts, these specialists have found literally hundreds of opportunities to communicate with lubrication engineers in nonaerospace sectors of the economy concerning the results of their research and development work. Such professional activities appear to be highly effective mechanisms for communicating technological advances, although they have received little analytical attention as channels for moving NASA-generated technology. Documentation of professional communications is quite difficult, not only because such communications are pervasive, but also because many professionals consider the creation of documentation to be somehow potentially harmful to the communication process itself.

This presentation also introduced the contract mechanism as a means of stimulating technological diffusion. This mechanism capitalizes on residual effects derived from the performance of advanced research and development by contracting organizations who are participating in nonaerospace sectors also using lubrication technology. Those organizations have the distinct advantage of a market perspective in addition to their refined appreciation of particular technical developments. The special ability of contractors to weld technological discovery in the aerospace sector with market opportunity in a nonaerospace sector is, of course, the result of circumstances rather than planned transfer effort.

The systematic documentation and publication efforts by NASA lubrication specialists suggested another factor influencing the communication process: special audiences exist that could be associated
with different types of technical contributions to the lubrication field. By examining how the types of contributions relate to specific communication activities, it became possible to associate a professional engineering audience specifically with basic contributions to the lubrication field and a more general audience (including professionals) with applied contributions. For example, ion plating of solid lubricants was found to be a basic contribution of interest to a limited professional audience; by contrast, a method for evaluating high temperature liquid lubricants was an applied contribution of interest to a larger audience of professional, managerial and marketing personnel. The importance of this distinction is that it emphasizes important functions intermediaries or brokers serve in the technology transfer process. Intermediaries can, and often do, interpret basic advances in such a way that widespread adoption becomes feasible.

To a large extent, the design engineer was found to act as a technological broker when transfers of basic contributions to the lubrication field were examined. The designer acts as a link between smaller professional and larger technical audiences by transforming basic contributions into an applied form consistent with adoption constraints. The degree of actual transformation affects the extent to which the designer must be interpretive. Often a designer is able to use only an element of an innovation, particularly if the technical contribution involved is fundamental or basic. The transfer of an applied contribution, however, usually makes smaller demands on the design engineer as an intermediary because of the essential similarity of the aerospace and nonaerospace applications.

Contamination Control. In the preparation of this profile, NASA mission requirements were found to have necessitated the creation of technical innovations specifically related to the control of contamination. Such problems as constructing extraordinarily complex systems with a high degree of reliability and supporting men in space in completely closed systems have been solved during the course of NASA mission operations. Space Agency contributions to the contamination control field, however, were found to extend far beyond the development of specialized hardware and techniques. In part because of the unique nature of its mission and in part because it recognized the need, NASA helped to provide a technical integration of the entire contamination control field. It accomplished this by generating a conceptual framework which integrated all of the various dimensions of the field. This basic contribution to the contamination control field occurred during the
preparation of two documents by the Sandia Corporation under contract to NASA's Office of Technology Utilization. Those documents have figured prominently in the transfer of contamination control technology in nonaerospace applications.

By supplying a large part of the initial market for the highly sophisticated technology that was involved, NASA also facilitated the rapid growth and consolidation of the industry to the point where it could readily couple into other sectors of the economy. Such coupling clearly has enabled the contamination control industry to meet the needs of an ever-growing number of other industries through the combined stimuli of technological integration and first market.

Fire Safety. How differences in communication mechanisms affect transfer became a factor in the preparation of the fire safety profile. Two communications mechanisms, a NASA-sponsored national fire safety conference and the Agency's Tech Brief program, were examined closely to bring this factor into focus. To determine how NASA-generated fire safety technology communicated through these mechanisms has been used by persons outside of the space program, several hundred engineers and scientists who indicated an interest in that technology were contacted in two different surveys. One survey was directed toward persons who participated in the "NASA Conference on Materials for Improved Fire Safety" at the Manned Spacecraft Center in Houston, Texas on May 6-7, 1970. The other survey involved persons requesting Technical Support Packages associated with Tech Briefs reporting new fire safety technology.

Both surveys produced strikingly similar results: unfavorable markets, technological lags, or high costs were found to act as barriers to transfer regardless of the communication mechanism. These similarities appear to be far more important than the proportionate numbers of people found in the various transfer stages: three-fifths of the conference participants were in the preliminary transfer stage as compared with four-fifths of the people using Technical Support Packages. The fact that the awareness stage dominated, however, is a strong confirmation of a basic issue in technology transfer. Once a technology generator like NASA forges a link of communication with a potential user, then the transfer process begins. How far the process proceeds depends upon the industrial or commercial benefits and constraints influencing the user.
Cryogenics. The fundamental difference between technical information and the hardware embodying such information became clearer in the preparation of this transfer profile. This distinction bears directly on the question of how cryogenics technology generated in the space program transfers to nonaerospace sectors of the American economy. Because of the highly specialized propulsion, life support, and electrical power generation requirements of the space program, the specific very low temperature systems developed to meet those needs have found little application in nonaerospace situations. Technical information and engineering data concerning the behaviors of cryogens and materials brought into contact with cryogens, however, have been found to be very useful in designing and developing nonaerospace cryogenic applications. Preparation of this profile provided the first encounter with a technology in which aerospace and nonaerospace applications are quite different; technical information, rather than the embodiments of that information, becomes the common denominator for transfer.

Another important factor affecting transfers of NASA contributions to the cryogenics field was discovered in this investigation. It involves the unique ways one federal government agency can assist another in generating and disseminating technical information. NASA and the National Bureau of Standards (NBS) have worked closely for several years to create technical information concerning the behaviors of several liquefied gases and the materials used in conjunction with them. Following the generation of such information, NBS Data Center personnel have employed a variety of familiar communication techniques to disseminate information that has been utilized by cryogenics specialists throughout the world. This example of interagency cooperation illustrates the pervasiveness of transfer activity, activity not usually so distinguishable in other fields.

Conclusions

The description of transfer issues and factors discussed in this section are limited in that they were derived from an analysis of transfer in just five fields of technology. The description is based on the fact that NASA contributions to several fields extend completely across the spectrum of the respective technologies involved; that those contributions vary in terms of the extent to which they advance the technological basis of those fields; that special audiences and particular communications media can be associated with different types of technical contributions; that one of NASA's principal challenges in facilitating transfer lies in
continuing refinement of the media and mechanisms used to achieve communication; that cooperation among federal agencies can stimulate and facilitate transfer processes; that the Space Agency cannot control the industrial or commercial benefits and constraints that operate to inhibit or facilitate the diffusion of a technology; that technical information (data) often can be more useful to nonaerospace engineers than the hardware embodying such information; that oftentimes only the technical information elements of hardware systems survive the transfer process; that it is quite useful to treat transfer activities as though they progress through identifiable stages rather than to assume that transfer either does or does not occur; and finally, that it is preferable to treat transfer examples in such a way that they illustrate the observed technological change in the nation's socio-economic system rather than to treat such examples as being significant in and of themselves.

While the development of these technology transfer profiles has been useful in identifying and clarifying the factors affecting these transfer issues, much work must still be done before these factors can be unified in a statement having practical utility for managing transfer systems. Current PATT research includes the preparation of transfer profiles on nondestructive testing, visual display systems, and structural design. In each of these profiles, unique and important factors affecting transfer issues are taking shape. At this stage of profile construction, it is sufficient to note that studying each field of technology has led to the recognition and clarification of significant transfer issues.
SECTION III. TECHNOLOGY UTILIZATION COMPILATIONS

This section will discuss a recent change NASA’s Office of Technology Utilization has made in the publication and distribution of a class of documents known as TU Compilations. More specifically, the section focuses attention on the initial impacts on nonaerospace readers of a decision to include both reader service cards and formerly published Tech Briefs in new TU Compilations.

Background

TU Compilations provide readers with a collection of many related technical ideas in a single publication dealing with one technological topic area. These collections provide workbook-type information in the form of brief and illustrated statements of innovations of practical utility in specific fields. TU Compilations are published as part of the NASA Special Publications Series (see Table 3-1).

<table>
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<tr>
<th>PUBLICATION</th>
<th>SCOPE</th>
<th>PREPARED BY</th>
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<tr>
<td>SPECIAL PUBLICATIONS (SP)</td>
<td>Publications of widespread interest &amp; importance; Histories &amp; Chronologies; Management, Evaluation, &amp; Analysis Standards; Compilations; Charts &amp; Tables; Bibliographies, &amp; Other Reference Works</td>
<td>NASA and contractor authors</td>
</tr>
<tr>
<td>CONTRACTOR REPORTS (CR)</td>
<td>Generated under NASA contract or grant that resulted in a significant contribution to a field of knowledge</td>
<td>Contractor or grantee author</td>
</tr>
<tr>
<td>TECHNICAL REPORTS (TR)</td>
<td>Contains important, complete, &amp; lasting additions to available knowledge</td>
<td>NASA authors primarily in Centers, also Headquarters</td>
</tr>
<tr>
<td>TECHNICAL TRANSLATIONS (TT-T)</td>
<td>Information first published in another language deemed worthy of distribution in English by NASA</td>
<td>Commercial translation contractors</td>
</tr>
<tr>
<td>TECH BRIEFS AND TECHNICAL SUPPORT PACKAGES (TSP’S)</td>
<td>Most commonly used channel for announcing an innovation and explaining its basic concepts and principles</td>
<td>NASA and contractor authors</td>
</tr>
<tr>
<td>TECHNICAL MEMORANDUMS (TM-X)</td>
<td>Given limited distribution because data are preliminary, or not widely available by decision of Center or Headquarters</td>
<td>NASA authors primarily in Centers, also Headquarters</td>
</tr>
<tr>
<td>TECHNICAL NOTES (TN)</td>
<td>Less broad in scope than TR but nevertheless valuable</td>
<td>NASA authors primarily in Centers, also Headquarters</td>
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</table>

NATIONAL AERONAUTICS

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The primary function of Compilations is to make available technical information that generally is not documented in other publications. Compilations thus provide a mechanism for disseminating developments in materials, products, and processing techniques that, when aggregated, have high potential for use in industry.

Forty individual Compilations have been published since this particular class of documents was developed in 1967; seven of the 40 have been updated in more recent editions. Exhibit I in Appendix C presents a complete list of the Compilations published to date.

Late in 1970, the Office of Technology Utilization made two basic changes in the format of Compilations. First, reader service cards were included in each new compilation; such cards enable interested readers to order any needed additional information. Second, new Compilations were modified to include information on certain innovations announced previously in individually published NASA Tech Briefs; republication of particular Tech Briefs provides an opportunity to create a handbook of ideas, a method of disseminating technical information which has been found to be particularly effective.

In June 1971, PATT initiated a study of the effects of these changes on nonaerospace readers. Although the changes appear to be relatively minor, they triggered a substantial increase in the volume of technical information being requested from NASA.

Reader Service Cards

Many Compilation items have additional supporting material available on request. To facilitate the task of helping interested readers obtain such material, removable reader service cards have been added. Exhibit II in Appendix C presents a complete list of Compilations containing such cards.

Reader service cards provide readers with a set of numbers corresponding to the individual numbers assigned to particular items in Compilations. Once these self-addressed cards are marked and detached, they are mailed postage free to the NASA Scientific and Technical Information Facility (STIF) in College Park, Maryland. STIF forwards the cards to the various NASA field centers which are responsible for servicing the request for additional information.
Request frequency data for four of the new Compilations were tabulated to determine requester behavior over the six-month period following publication. Not surprisingly, the vast majority (87 percent) of the requests for additional material were made within the first two months after the documents were published (Figure 3-1).

![Figure 3-1. Cumulative Total of Reader Service Cards Involving Four New Compilations: January - June 1971](image)

Although Figure 3-1 presents data concerning only four of the revised Compilations, it does serve to illustrate an important point. The individual innovations, presented in a context relevant to a single technical subject area, appear to stimulate an interest in acquiring information concerning items whose usefulness is apparently not recognized without the context provided by the Compilation. The ease
with which an individual can secure additional information, through
the use of cards, should enhance the transfer process. Readers
apparently grasp this opportunity to simply complete the "awareness"
requirement which is crucial to initiation of the transfer process.

**Tech Brief Republication**

In the spring of 1970, PATT completed a substantial analysis of
NASA's Tech Brief program. A major recommendation flowing from
that study was the need to republish Tech Briefs which had generated
considerable nonaerospace interest. The assumptions behind the
recommendation were that certain technical problems recur and that
adequate solutions to such problems should be redisseminated as newcomers face those problems.

Implementing this recommendation could take one of two forms:
either republishing selected Tech Briefs as individual documents, or
republishing them in some aggregated form such as Compilations.

Partially as a result of this thinking, and for other reasons as
well, the Office of Technology Utilization decided to alter the format
of Compilations to include some Tech Brief materials. Prior to that
decision, Compilations were used almost exclusively to announce
innovations of industrial interest that were not judged sufficiently
significant to be published as individual Tech Briefs. Such minor
innovations appeared to be worth publishing, however, provided they
were aggregated into a collection of ideas related to a specific topic.

Analysis of six new Compilations (randomly selected) revealed
that not all new Compilations include innovations documented previously
as Tech Briefs. The number of former Tech Brief items in the Com-
pirations examined ranged from zero to 14 (see Table 3-2).

It also was noted in this analysis that those items representing
former Tech Briefs received as many, and usually more, requests as
those items not previously documented. The following example illustrates
this point. SP-5908(03), entitled Hand Tools, presented 24 individual
items with support materials available on request through the use of
the reader service card. Only one of those items was published
previously as a Tech Brief; it received 33 requests. The average
number of requests for all of the items was 19.
TABLE 3-2. TECHNOLOGY UTILIZATION COMPILATIONS CONTAINING TECHNOLOGIES PREVIOUSLY DOCUMENTED IN TECH BRIEFS

<table>
<thead>
<tr>
<th>TU Compilations</th>
<th>No. of Items Offering Additional Information</th>
<th>No. of Former Tech Brief Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP-5908(03) Hand Tools</td>
<td>24</td>
<td>1</td>
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<tr>
<td>SP-5910(03) Machine Tools and Fixtures</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>SP-5918(01) Welding Technology</td>
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<td>0</td>
</tr>
<tr>
<td>SP-5926(01) Measurement Technology</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>SP-5927(01) Valve Technology</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>SP-5931(01) Testing Methods and Techniques</td>
<td>25</td>
<td>4</td>
</tr>
</tbody>
</table>

By republishing innovations that had been previously documented in the Tech Brief program, the Compilation provided a second channel for communicating interesting technologies. A question was raised as to how requests for additional information (TSP's) through the Compilation reader service cards compared with requests generated through the Tech Brief program. Information from the PATT data bank was compared with the reader service cards, and three factors were observed:

- If the TSP had a substantial number of requests through the Tech Brief program, it also had a high request frequency through the Compilation.

- If the TSP had a low request history through the Tech Brief program, this was not necessarily true of Compilation-generated requests.

- If the TSP had a low request rate through the Compilation, it showed the same behavior in the Tech Brief program.

NASA SP-5910(03), entitled Machine Tools and Fixtures, can be used to illustrate this relationship between the two channels. The Compilation offers additional information for 16 of the items presented in the document, 14 of which were originally published through the
Tech Brief program. Table 3-3 shows, by item number, the total number of requests from the reader service cards versus those recorded in the PATT data bank as of June 30, 1971.

TABLE 3-3. TECH BRIEF ITEMS PRESENTED IN SP-5910(03): READER SERVICE CARD REQUESTS VERSUS TECH BRIEF PROGRAM REQUESTS

<table>
<thead>
<tr>
<th>Item Number</th>
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<th>Total Number of Requests Through the Tech Brief Program**</th>
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<tr>
<td>16</td>
<td>32</td>
<td>32</td>
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</tbody>
</table>

* The number shown in this column represents requests during the first six months of 1971 only (first request received in February 1971).

** The number shown in this column represents the total number of requests received since the Tech Brief was issued.

Conclusion

This preliminary review of two recent changes in the format of TU Compilations indicates that both changes (the inclusion of service cards and the republication of Tech Brief items) have increased the importance of Compilations as a dissemination mechanism, particularly as they act in concert with the Tech Brief program.
APPENDIX A

Summaries of Technology Transfer Activities Involving NASA-Generated Fire Safety Technology
### APPENDIX A

**SUMMARIES OF TECHNOLOGY TRANSFER REPORTS INVOLVING NASA-GENERATED FIRE SAFETY TECHNOLOGY**

<table>
<thead>
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<th>TRANSFER EXAMPLE</th>
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<td><strong>2</strong></td>
<td>40610</td>
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<tr>
<td>FIRE RETARDANT FOAMS</td>
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<td>20015</td>
<td>42935</td>
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<td>46613</td>
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<td>46652</td>
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<td><strong>POLYURETHANE FILTER FOR BURN TREATMENT</strong></td>
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*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.
BURN-RATE TESTING APPARATUS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

An important part of NASA's fire safety research is testing the flammability of materials. Tests and testing apparatus have been designed by NASA scientists to simulate combustion conditions which exist in spacecraft. The test data have been indispensable for material selection and flammability specifications for material. The data did not exist prior to NASA tests because no similar specifications had been required previously.

The burn-rate testing apparatus invented at the Manned Spacecraft Center is capable of testing a variety of combustion parameters. By using the apparatus, engineers are able to control atmospheric conditions, fuel/oxygen mixtures, the igniting flame mechanisms, and test sample orientation. A thin rectangular piece of material is used for the test sample. The apparatus incorporates several sensors including a calibration thermocouple for the igniting flame temperature and three photocells to detect flame at three different points: where flame is applied to the sample, at a point exactly opposite to where the flame is applied, and at a given distance from this point on the same side as the second photocell. Data from the first and second photocells indicate the burn-rate through the sample. Data from the second and third photocells indicate the burn-rate along the sample surface.

Ferro Corporation in Los Angeles, California (39644) has reviewed and filed the Technical Support Package describing the apparatus. The company ordered the NASA literature after a potential customer referred to the apparatus. A company spokesman said he expects new flammability specifications will be required by 1974, and the apparatus will probably be used then for testing the company's fiber glass products.

Simulation tests of the apparatus were conducted at General Motors Corporation in Warren, Michigan (40610). It was being considered for flammability testing of the cloth used in the company's polishing buffs for steel. The apparatus is considered too sophisticated in its present form for this type of test. Some of its features, however, may be included in a simpler device which is in the conceptual stage at this time.
U.S. Industrial Chemicals Company in Tuscola, Illinois (41186) plans to install a similar apparatus for testing its polyethylene products. A company spokesman said this will be done when an anticipated new ASTM flammability test is published and customers start requesting the new flammability specifications.

Control Numbers
Tech Brief Numbers: 69-10740
NASA Center: Manned Spacecraft Center
PATT Case Numbers: 39644, 40610, 41186
TEF Number: 348
Date of Latest Information Used: January 4, 1971
FIRE RETARDANT FOAMS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

NASA research in the chemistry of ablation for protection of spacecraft during atmospheric reentry led to the development of fire retardant foams at the Ames Research Center. As described in a 1968 Tech Brief (68-10358), the material is a semirigid or rigid polyurethane foam having uniformly dispersed in it a halogenated polymer capable of splitting off hydrogen halide upon heating and charring of the polyurethane. The char layer and released gases help quench the flame. The density of the foam can be varied from two to fifty 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.

Approximately 100 inquiries have been received concerning the foam. Avco Corporation in Wilmington, Massachusetts (42935) was awarded a NASA contract in 1969 to investigate processing methods, application techniques, and properties of the foam as they relate to fire safety in aircraft. The company received a nonexclusive NASA license in 1970 to use the invention and is ready to produce the foam commercially. Market studies related to aircraft application are underway.

Abt Associates, Incorporated in Cambridge, Massachusetts (46622) is working under NASA sponsorship with the Department of Housing and Urban Development to transfer some of the technology described at the NASA Fire Safety Conference to the area of urban construction. Their efforts led to prototype testing of fire retardant foams by the National Association of Home Builders and the New York Urban Development Corporation. Following the tests, an economic evaluation will be initiated. The National Bureau of Standards also plans to conduct fire tests of the foam for housing applications.

Rubber Specialties Company in Minneapolis, Minnesota (26468) received the TSP from another local firm to answer questions raised in a discussion of possible insulation materials for a project under consideration. Rubber Specialties was contemplating entry into the business of making prefabricated plastic panels for room dividers in modular-constructed buildings. The foam was considered for sound-proofing and fire retardant insulation. The company decided against entering the new field, however, and has not yet found other uses for the technology.
Dow Chemical Company in Golden, Colorado (46621) is using fire retardant urethane foam to fireproof and insulate radioactive waste containers. A company spokesman said that, prior to the NASA Fire Safety Conference, Dow had not applied fire safety techniques in its uses of the containers. Finally, Coastal States Gas Producing Company in Corpus Christi, Texas (20015) is considering the technology for potential fire suppression applications in gas processing plants.

Control Numbers

Tech Brief Number: 68-10358
NASA Center: Ames Research Center
PATT Case Numbers: 20015, 26468, 42935, 46621, 46622
TEF Number: 17
Date of Latest Information Used: January 11, 1971
Some of NASA's most significant work in recent years has been directly concerned with the control or elimination of fire hazards. Recognizing that maximum benefit can be obtained from space research only when its discoveries are widely shared, the Space Agency sponsored the "NASA Conference on Materials for Improved Fire Safety" at the Manned Spacecraft Center on May 6-7, 1970. The wide variety of NASA-generated technology on fire safety was presented to approximately 500 persons from industrial firms, government agencies including NASA, research institutes and universities. Twenty-five presentations were made which focused on the technology, its use in the space program, and its potential applications on earth.

Questionnaires were mailed to 182 non-NASA conferees in October 1970 to determine how they had been able to use or planned to use the information presented at the conference. To date, 113 (62 percent) of the conferees have returned the questionnaires. Twenty-two persons who returned the questionnaires subsequently were interviewed by telephone, primarily because they had indicated substantial progress in attempts to apply fire safety technologies presented at the conference.

Several nonflammable materials were described which conferees found particularly interesting. Two of these, and the transfer activities related to them, are described in the "Fire Retardant Foams" and "Nonflammable Materials" Technology Transfer Example Summaries presented elsewhere in this attachment.

Other materials which were of interest included nonflammable potting compounds and nonflammable fibers (e.g., Beta fiber, Polybenzimidazole (PBI), Durette, Frypo and Nomex). Each of the application activities described below was initiated by a company representative who attended the conference.

Desoto, Incorporated, a paint company in Des Plaines, Illinois (46617), will use fiber additives to develop nonflammable paints. The company plans to utilize some of the NASA flammability tests in its research.
Martin-Marietta Corporation in Denver, Colorado (46620) has used suggestions made at the conference to include new applications of PBI in a contract proposal. The company also is using one of the new flammability tests described in Houston.

General Dynamics in Fort Worth, Texas (46613) is conducting laboratory tests on nonflammable polyimides and potting compounds. These materials have been included in two recent contract proposals made by the company.

Battelle Northwest, a private research institute in Richland, Washington (46611), has received a contract to develop protective clothing for persons handling liquid sodium. The proposed clothing materials were selected on the basis of NASA research described at the conference.

The chief coal mine inspector for United States Steel Corporation in Pittsburgh, Pennsylvania (46655) established personal contact with Ames Research Center scientists at the conference. The contact has evolved into a cooperative effort to develop improved flame safety lamps and suitable fire resistant coatings for mine timbers.

Travelers Insurance Company in Dallas, Texas (46625) is using information obtained at the conference to recommend improved fire safety procedures to its industrial fire policy holders. The information also is used as part of the basis for determining hazards and premiums for industrial fire policies.

In addition to the transfer cases identified above through the questionnaire survey, the following additional transfer activities have been identified. Durette and Nomex are being investigated for application in fire fighting clothing by the Federal Aviation Administration, Airline Pilots Association, National Fire Protection Association, International Association of Fire Fighters, National Bureau of Standards, Glove Fire Suits Company, the Houston Fire Department and Humble Oil Company. Scientists from Kennedy Space Center and Manned Spacecraft Center are cooperating in this research. Prototype tests of Durette, Nomex, and fluorocarbons in aircraft applications are being conducted by Laminate Division of Tri-Wall Container Corporation, Cannon Electrical Company, Sargent Industries, United Airlines, Oklahoma City Downtown Airpark and the U.S. Air Force. Manned Spacecraft Center is cooperating in these investigations. Tests of
intumescent paints and fire retardant foams in aircraft applications are being conducted by Avco Corporation, Cannon Electrical Company, General Electric, and the U.S. Navy in cooperation with Ames Research Center. The University of Texas, the University of Pennsylvania, and General Electric Company have contracted with Welson and Company to manufacture fabrics from Durette for underwater and decompression chambers.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Numbers: 46611, 46613, 46617, 46620, 46625, 46655
TEF Number: 347
Date of Latest Information Used: December 17, 1970
HYDROGEN SAFETY
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Hydrogen is an indispensable component of rocket fuel and spacecraft energy cells. The presence of hydrogen, however, constitutes the greatest single fire hazard in the space program. The hazard is caused by the fact that this odorless gas is ten times more flammable than gasoline; in addition, hydrogen fires are colorless. NASA engineers have developed extensive safety procedures for storing, handling and using hydrogen. The Advisory Panel on Experimental Fluids and Gases at Lewis Research Center has written the Hydrogen Safety Manual (NASA TM X-52454) which presents a unified statement of these procedures. The manual describes the characteristics and nature of hydrogen, design principles for hydrogen systems, protection of personnel and equipment, and operating and emergency procedures. It is an operating manual which sets forth acceptable standards and practices for minimum safety requirements at the Lewis Research Center. Because of its relevance to increasingly common nonaerospace scientific and industrial uses, NASA issued Tech Brief 68-10323 in August 1968 to announce publication of the manual.

Dow Chemical Company in Midland, Michigan and Fenwal Electronics, Incorporated in Framingham, Massachusetts reviewed the Tech Brief and ordered the manual. Dow (22064) has used data from the manual in conducting a study of gas cloud explosions and is still using the manual as a reference for designing equipment and facilities, Fenwal (28946) has used the manual to establish safety methods and procedures for a hydrogen atmosphere chamber included in the company's manufacturing process. The company president estimated that, to date, tangible savings of $2,000 have resulted from Fenwal's use of the manual.

Control Numbers

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<td>NASA Center: Lewis Research Center</td>
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<td>PATT Case Numbers: 22064, 28946</td>
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<td>TEF Number: 258</td>
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<td>Date of Latest Information Used: December 31, 1969</td>
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The environment in space imposes great burdens on external coatings for space vehicles. The most important function of a coating in space is to assist in maintaining spacecraft temperatures within specified limits. While the temperatures are somewhat affected by conditions internal to a spacecraft (e.g., heat generated by systems operation, body heat of astronauts), the more significant temperature effects are caused by direct solar radiation, solar radiation reflected from the earth, and infrared emissions from the earth. The thermal absorption and emittance properties of a coating thus assume crucial importance, since the temperature of the spacecraft is determined by the ability of its external surface to exchange heat with the space environment. A coating also must remain stable over long periods in a hostile environment, maintaining adhesion under various mechanical stresses and temperature extremes.

Chemical coatings are widely used on spacecraft because of their low cost and ease of application, and because so much is known about them from their historically common usage. Knowledge is probably most extensive concerning organic-constituent coatings, but they are not generally suitable for space uses because the constituents outgas in space and leave harmful deposits on optical surfaces. Inorganic constituents do not have the outgassing property and are preferable to organic coatings on this ground. This inorganic coatings used in space commonly consist of silicone and silicate binders and zinc oxide pigments, which form a highly stable system in the vacuum of space.

Building upon a large amount of NASA research on inorganic coatings, Dr. John Schutt of Goddard Space Flight Center formulated a number of inorganic coatings with attributes of nonflammability, durability and ease of application. In 1965, NASA used Tech Brief 65-10156 to announce the discovery of the formulations and prepared a Technical Support Package which provided details concerning ingredients, mixing, curing and other data. NASA subsequently received a patent on the formulations in July 1969.

To date, more than 400 potential industrial users of the inorganic paint have requested copies of the TSP. A few examples of application activities associated with the technology demonstrate the specific nature of nonaerospace uses to which the inorganic paint can be put.
Several TSP users stated they are attempting to develop inorganic paints with the fireproof and high temperature characteristics of the NASA formulations. The Lithoid Corporation in Lima, Pennsylvania (672), for example, is experimenting to develop a base coat for "ceramic teflon" products which are subjected to extremely high temperatures. The Bradley-Van Holm Chemical Corporation in Brattleboro, Vermont (750) will soon resume its efforts to develop a fireproof paint for hotels and motels. J. W. Mortell Company in Kankakee, Illinois (2425) was reported in 1969 to have developed a line of fireproof coatings for sale to builders, contractors and industrial buyers. By 1971, a Mortell spokesman reported that the paint was not being sold, but that efforts to diversify product lines into fire retardant coatings would stimulate new interest in the NASA paints. The Sperex Corporation in Los Angeles, California (4535) used the TSP to perfect its own formulations for heat resistant paints for racing cars. The firm's second year sales of the paint reportedly were 40 percent above the initial year's sales, with customers using the product for truck exhaust systems, oven liners, fire walls, brake drums, engine manifolds, mufflers, furnaces and electrical applications.

Several organizations reported using the TSP to develop coatings for outdoor structural and building applications for which fireproof characteristics are important. The General Services Administration (669) is evaluating the TSP for the purpose of drawing up Federal procurement specifications. Five small paint manufacturers (656, 694, 709, 782, 8610) are working on exterior coatings, and three firms (734, 757, 761) terminated experimental evaluations of the TSP without developing an exterior paint.

Ten firms mentioned durability and anti-corrosion properties as the most important goal of their development efforts. Wisconsin Protective Coatings in Green Bay, Wisconsin (47957), for example, earned $100,000 in 1970 from sales of its inorganic paint for lining railroad tank cars carrying ethylene oxide. The company is now developing a solvent base inorganic paint for kilns and smokestacks. Another firm, the Advanced Research Corporation in Atlanta, Georgia (2433) uses its inorganic paint to coat containers for lithium compounds.

The inorganic paints are apparently quite useful for marine applications. An Eastern firm (763) sells its product for exterior coating of tanker steam lines, in which the inside temperature is 275°F and the seawater washing over the lines may be 40°F. Deck plates and super-structures coated with the paint are quite resistant to salt.
water corrosion, and the firm sells the paint for off-shore oil rigs, as well. The Kiesel Machinery Company in Jennings, Louisiana (654) is also developing an inorganic paint for off-shore rigs, and a small company in Pennsylvania (476) is working with the TSP to make an exterior paint for seashore locales.

Finally, nine other persons using the TSP reported conducting research on "specialty" coatings, not specifying the nature of intended application. Some of these doubtlessly will be sold for their fireproof properties when development is completed.

Most of the respondents still experimenting with the paint have reported experiencing difficulties with poor adherence and durability. The principal reason for this appears to have been the omission of an ingredient from the formulation given in the TSP. The final paint described in the patent contains 18 percent latex paint and 82 percent inorganic paint. The TSP neglected to mention the latex which provides the adherence and durability mentioned in the Tech Brief. Respondents cited above as having developed commercial inorganic paint products indicated they are using latex/inorganic mixtures based on either their own discovery or a copy of the NASA patent.

Control Numbers
Tech Brief Number: 65-10156
NASA Center: Goddard Space Flight Center
PATT Case Numbers: 476, 654, 656, 669, 672, 694, 709, 734, 750, 757, 761, 763, 782, 2425, 2433, 4535, 8610, 47957
TEF Number: 34
Date of Latest Information Used: January 4, 1971
NONFLAMMABLE MATERIALS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

After the tragic Apollo 204 fire at Cape Kennedy in January 1967, NASA fire safety research was greatly accelerated. The silicone elastomers which had been used extensively in spacecraft were found to be quite flammable in pure oxygen atmospheres. Research efforts to develop nonflammable silicone elastomers have yielded few results. Carboxy nitroso rubber was investigated as a nonflammable substitute for silicone, but its high cost and rapid decomposition when heated to 500 °F have prevented widespread use of the material. A successful program was initiated to develop nonflammable elastomers from copolymers of vinylidene fluoride and hexafluoropropene which have been available for many years under the trade names Viton (Du Pont) and Fluorel (3M Company). As normally produced, both elastomers are flammable in oxygen. The two companies conducted independent research programs which resulted in nonflammable versions of the fluorocarbon elastomers with a wide range of physical properties. Manned Spacecraft Center scientists cooperated with company researchers since the research was prompted by NASA fire safety requirements.

The new fluorocarbon elastomers have replaced silicone and other materials in many spacecraft components, and their importance to the space program was described at the NASA Conference on Materials for Improved Fire Safety in May 1970. NASA has used these elastomers in a variety of forms: elastomeric foams have been used for shoulder pads and spacers; they have been molded into boot soles and headrests; extruded stock has been used for oxygen and smoke-mask hoses, and sheet stock for gaskets; and coating compounds have been employed to protect flammable substrates. The fluoroelastomeric coatings are of special interest in that they provide adequate protection for flammable substrates in minimal applied thicknesses.

A spokesman for 3M Company in Chambles, Georgia (46608) reported that most of the Fluorel produced at 3M is sold as raw material to companies which fabricate spacecraft components and coating compounds for NASA from it. As a result of the conference, 3M has received numerous inquiries concerning Fluorel, and several potential users have purchased quantities for prototype testing of commercial applications in shipping, air transportation, fire fighting garments and residential housing.
Mosites Rubber Company in Fort Worth, Texas (43001) has manufactured a variety of finished products, mainly for NASA, from Fluorel produced by 3M. A company spokesman reported that sales of Fluorel products have increased and a broader market has developed since the NASA conference.

Raybestos-Manhattan, Incorporated in Charleston, South Carolina (43002) is another manufacturer of finished products from 3M's Fluorel. The company uses the brand name Refset for its coating compound. To date, NASA has been the primary customer for these products; however, Raybestos is now conducting a vigorous sales campaign to broaden its market. Aircraft, submarines, and other oxygen-rich environments are promising new application areas where safety considerations outweigh cost factors.

The nonflammable fluorocarbon elastomers are being investigated for application in wire insulation (46612, 46619, 46627), fabrics and clothing (46607, 46614, 46653, 46854), commercial aircraft interiors (46610, 46623, 46628), housing (46615), and ships (46609, 46618, 46652).

All of the investigations resulted from the NASA Fire Safety Conference and personal contacts with NASA scientists.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Numbers: 43001, 43002, 46607, 46608, 46609, 46610, 46612, 46614, 46615, 46618, 46619, 46623, 46627, 46628, 46652, 46653, 46854
TEF Number: 324
Date of Latest Information Used: December 18, 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 former NASA employee, 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
APPENDIX B

Summaries of Technology Transfer Activities Involving NASA-Generated Cryogenics Technology
## APPENDIX B

### SUMMARIES OF TECHNOLOGY TRANSFER ACTIVITIES INVOLVING NASA-GENERATED CRYOGENIC TECHNOLOGY

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* 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.
A BIAXIAL WELD STRENGTH PREDICTION METHOD
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Douglas Aircraft Company, under contract to Marshall Space Flight Center, has developed a method for design of structures which are subjected to multiaxial loading due to internal pressure. This method, described in Tech Brief 69-10471, is especially applicable to the design of liquid propellant tanks. It permits the prediction of a structure's biaxial strength by using a slightly modified uniaxial formula. For welded structures in which the uniaxial and biaxial properties are essentially the same for the weld and parent metal, an equation is given for calculating the biaxial strengths directly from the uniaxial strength. Because aluminum alloys usually have welds with different mechanical properties than those of the parent metal, a graphic method for modifying this equation also is given.

A design engineer with Eastman Kodak's chemical plant in Kingsport, Tennessee (41946), who used the prediction method, has been able to improve significantly plant safety conditions at relatively little cost to his company. Specifically, he redesigned pipes which had been rupturing by using information derived from the weld strength prediction method. Since he found the method satisfactory in solving that problem, he intends to use it again as the need arises.

Control Numbers
Tech Brief Number: 69-10471
NASA Center: Marshall Space Flight Center
PATT Case Number: 41946
TEF Number: 359
Date of Latest Information Used: March 1, 1971
Among possible materials for construction of cryogenic pressure vessels, filament-wound fiber glass composites have been acclaimed because of their high strength-to-weight ratios. Problems have occurred in efforts to use these materials, notably the tendency of the composites to become permeable after stress-induced straining. Such permeability reduces the capacity of a vessel to contain a cryogenic fluid during desired pressurization cycles. An obvious solution is the use of a nonpermeable, thin metal liner for the vessel; however, this solution would require the application of a special bonding agent to hold the liner in order to prevent buckling during depressurization. The adhesive must strain with the composite without losing adhesion to either surface or failing internally.

Under contract to NASA's Lewis Research Center, the McDonnell-Douglas Corporation developed an appropriate adhesive. As described in a March 1969 Tech Brief, the adhesive consists of adducts of urethane and epoxy resins that exhibit the best properties of both substances. The high strength and modulus of the epoxy is obtained without the brittleness of epoxy, and the strain capabilities and peel resistance of the urethanes are added without the common soft rubber appearance of the urethanes.

Epoxylite Corporation in South El Monte, California (30895) has used information presented in the NASA Technical Support Package to make proprietary improvements in one of its products and to suggest new applications for one of its adhesive materials. Samples of the improved adhesive are being evaluated by selected customers, with full-scale production and marketing planned for 1972.

Aquanomics in Santa Fe Springs, California (35382) tested prototype samples of the NASA-developed adhesive in the desalination units it produces. Although initial test results were not satisfactory, Aquanomics is still interested in developing a modified version of the adhesive in order to improve its products and reduce production costs.

The Electronics Corporation of America in Cambridge, Massachusetts (50864) has been able to improve one of its products by using the urethane/epoxy adhesive. The product, an infrared detector
system with a cryogenic subsystem, now has a longer and more reliable operating lifetime. Other ECA products also may be improved in the future through applications of this adhesive material.

Control Numbers
Tech Brief Number: 69-10074
NASA Center: Lewis Research Center
PATT Case Numbers: 30895, 35382, 50864
TEF Number: 307
Date of Latest Information Used: March 21, 1971
DIELECTRIC PROPERTIES OF PROMISING MATERIALS FOR CRYOGENIC CAPACITORS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The peripheral components required to construct a cryogenic capacitor system are well developed. The principal unknown, however, concerns the complexity of the development task to perfect the dielectric system itself. Experimental investigations were conducted at the General Electric Company, under contract to Marshall Space Flight Center, in an effort to determine dielectric properties of promising materials for cryogenic capacitors to be used in energy storage and pulse applications. Dielectric data were obtained on promising materials through screening tests, tests in liquid nitrogen, and techniques for winding or stacking small test capacitors.

GE researchers investigated three classes of materials in this study: inorganic bonded ferroelectric materials, anodic coatings on metal foils, and polar low temperature liquids. The investigation produced several possible approaches to developing cryogenic capacitors with improved mechanical characteristics. By using the dielectric parameters developed during their investigation, GE researchers provided estimates of the sizes, weights, and losses for cryogenic capacitor systems. In general, the data indicate that relatively compact capacitor systems are possible.

The vice president for research and development at Bishop Manufacturing Corporation in Cedar Grove, New Jersey (3941) requested additional information from NASA after reading a Tech Brief announcing the results of this investigation. He used the documentation to obtain current data on the development of cryogenic capacitors. Although the Bishop Company has no related projects at the present time, the development of these capacitors may lead to potential applications by the firm.

A researcher at Corning Glass Works in Corning, New York (9115) read an article describing the technology in Industrial Research magazine and requested additional information. Corning researchers had developed some new glass ceramics which were observed to have very high dielectric constants at cryogenic temperatures. After comparison with the dielectric data reported in the NASA document, Corning researchers realized the importance of these new ceramics for cryogenic capacitor applications. The company is currently investigating the commercial potential of the materials, using the TSP as a reference for cryogenic capacitors.
A Stanford University physicist (50223) obtained the NASA document as a result of the literature search conducted for him by the National Bureau of Standards' Cryogenic Data Center. He is using the document as a reference source during the course of his research on the dielectric losses of energy in superconducting cavities. This research is part of a superconducting project which is expected to produce basic results and practical applications. The physicist described the NASA document as being his primary source of data on dielectric properties at cryogenic temperatures.

Control Numbers

Tech Brief Number: 67-10366
NASA Center: Marshall Space Flight Center
PATT Case Numbers: 3941, 9115, 50223
TEF Number: 363
Date of Latest Information Used: March 19, 1971
HANDBOOK OF CRYOGENIC DATA
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

As part of a project to design high-pressure vessels for storing gases, a Boeing Company engineer developed a cryogenic data handbook. The primary reason for creating the handbook was to present in a single volume and a useful format cryogenic data previously available only in widely scattered sources. One of the main tasks in preparing the handbook involved the creation of simplified graph formats to make the data more useful to cryogenic engineers and scientists. The handbook includes such information as the boiling heat transfer rate from copper to liquid nitrogen; temperature-enthalpy functions for liquid nitrogen; saturated liquid/gas relations; linear contractions of teflon, stainless steel, and other materials of construction; and gaseous air density and compressibility factors versus pressure. It concentrates extensive data on common materials of construction and properties of fluids frequently encountered in designing cryogenic systems.

American Atomics Corporation in Tucson, Arizona (8784), which produces self-luminous light sources, used the data presented in the handbook to improve the performance and predictability of a cryogenic system employed in its manufacturing processes. The firm's supervisor of research and development stated that having the data compiled in a single document helped him save at least 30 hours of research time. American Atomics will continue to use the handbook as a reference tool.

A consulting engineer in St. Louis, Missouri (9548) is using cryogenic data presented in the NASA handbook to verify the adequacy of equipment being used in a new process to liquefy natural gas. If the overall process is adopted, field operation costs could be reduced by as much as $50 million per field site. The engineer indicated that the design of the new process could not have been successfully completed without the NASA information.

The process design group at Hooker Chemical Corporation in Niagara Falls, New York (9554) is concerned with predicting the thermodynamics of chemical processes and manufacturing operations. The NASA handbook provided the group with enthalpy data for analyzing thermodynamic problems, which then led to the design of improved equipment and processing techniques. Two improved methods resulting from their use of handbook data involved chemical processing and pollution control. The firm's process design manager stated that the availability of the NASA information enabled the firm to save research time.
Consulting engineers at Mason & Hanger-Silas Mason Company, Incorporated in Lexington, Kentucky (9562) have used data from the handbook to design four liquefied natural gas storage facilities and to redesign a refrigeration system used to freeze runny ground for excavation. The refrigeration system is being used in a major sewage system project in New York City. Mason & Hanger consultants were asked to redesign the previous system which was subject to several very expensive problems. Data in the NASA handbook provided approximately 50 percent of the input to redesigning the system. The new system reportedly works very well. The firm also has used the handbook to determine design specifications and materials for low temperature equipment in plants which Mason & Hanger operate for the government. The handbook was described as being a very important and timesaving reference tool for the company's low temperature consulting jobs.

A U.S. Civil Engineering Laboratory in Port Hueneme, California (9587) used the handbook as a primary reference source in its investigation and evaluation of a commercial underwater power module. The module incorporated a liquid nitrogen system to provide nitrogen gas which ran pneumatic tools. The project engineer reported that without the handbook the evaluation of the modules' cryogenic system would have been incomplete. He indicated that the handbook is still used as a basic reference tool at the laboratory for evaluating cryogenic equipment.

Control Numbers
Tech Brief Number: 67-10610
NASA Center: Kennedy Space Center
PATT Case Numbers: 8784, 9548, 9554, 9562, 9587
TEF Number: 248
Date of Latest Information Used: March 26, 1971
HYDROGEN SAFETY MANUAL
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Hydrogen, in both liquid and gaseous states, is an indispensable component of rocket fuel and spacecraft energy cells. The presence of hydrogen, however, constitutes one of the greatest single fire hazards in the space program. This hazard is caused by the fact that this odorless gas is ten times more flammable than gasoline; in addition, hydrogen fires are colorless. NASA engineers have developed extensive safety procedures for storing, handling and using hydrogen. The Advisory Panel on Experimental Fluids and Gases at Lewis Research Center has written the Hydrogen Safety Manual (NASA TM X-52454) which presents a unified statement of these procedures. The manual describes the characteristics and nature of hydrogen, design principles for hydrogen systems, protection of personnel and equipment, and operating and emergency procedures. It is an operating manual which sets forth acceptable standards and practices for minimum safety requirements at the Lewis Research Center. Because of its relevance to increasingly common nonaerospace scientific and industrial uses, NASA issued Tech Brief 68-10323 in August 1968 to announce publication of the manual.

Dow Chemical Company in Midland, Michigan (22064) reviewed the Tech Brief and ordered the manual. Dow engineers have used data from the manual in conducting a study of gas cloud explosions and are still using the manual as a reference for designing equipment and facilities for the company's chemical processing plants.

Control Numbers

Tech Brief Number: 68-10323
NASA Center: Lewis Research Center
PATT Case Number: 22064
TEF Number: 258
Date of Latest Information Used: June 6, 1971
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A comprehensive compilation of technical data on Aluminum Alloy 6061 has been presented in a handbook prepared by the Syracuse University Research Institute under contract to Marshall Space Flight Center. The handbook includes data on the properties of the alloy at cryogenic, ambient, and elevated temperatures, as well as other pertinent engineering information required for the design and fabrication of components and equipment utilizing the alloy. In particular, it contains information on procurement, production and manufacturing practices, static and dynamic properties, corrosion resistance and protection, surface treatments, and joining techniques. In March 1969 NASA published a Tech Brief announcing the availability of the handbook.

Two divisions of Honeywell, Incorporated have used the TSP for reference purposes. The Aerospace Division in St. Petersburg, Florida (29435) improved manufacturing processes in-house by using the data on Alloy 6061. Information contained in the handbook on the alloy's forming characteristics is used in the production of chassis and containers made from the alloy. Subsequent improvements have saved the division both time and money. An in-house materials consultant with the Industrial Division in Fort Washington, Pennsylvania (30073) also reports he has saved time in providing information on the alloy to production engineers and sales personnel in his division. Both divisions will continue to use the TSP as a reference tool.

Electro-Tec, a division of KDI Corporation in Blacksburg, Virginia (30206), has saved research time by using the handbook as a reference tool. The company produces electronic components in which Aluminum Alloy 6061 is used extensively. The handbook is one primary source of information which Electro-Tec design engineers use when working with this alloy.

Control Numbers

Tech Brief Number: 69-10065  
NASA Center: Marshall Space Flight Center  
PATT Case Numbers: 29435, 30073, 30206  
TEF Number: 358  
Date of Latest Information Used: March 9, 1971
MATERIALS DATA HANDBOOK, ALUMINUM ALLOY 7075
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A comprehensive compilation of technical data on Aluminum Alloy 7075 was prepared by the Syracuse University Research Institute under contract to Marshall Space Flight Center. Published by NASA in 1967, the handbook includes data on properties of the alloy at cryogenic, ambient, and high temperatures, as well as other information required for the design and fabrication of components and equipment using this alloy.

Beckman Instruments, Incorporated in Palo Alto, California (7493) used the handbook as a reference text in a recent study of low cycle fatigue characteristics of Alloy 7075. The alloy was evaluated for use in high speed ultracentrifuges made by the company. Upon completion of the study, the firm adopted Alloy 7075 for several components of its ultracentrifuge. The NASA handbook was deemed valuable for its suggestion of the probable outcome of the study, assistance in designing the research, and for verification of test results.

Robbins and Myers, Incorporated, a machinery manufacturer in Springfield, Ohio (4511), regularly uses the NASA document describing Alloy 7075 as a general reference book during the early stages of new product development programs. According to a company spokesman, Robbins and Myers' engineers have been able to make small, but important, changes in a variety of mass production processing techniques.

Control Numbers
Tech Brief Number: 67-10301
NASA Center: Marshall Space Flight Center
PATT Case Numbers: 4511, 7493
TEF Number: 243
Date of Latest Information Used: March 26, 1971
NYLON-FILLED EPOXY POLYAMINE

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.

LUSOL Company in El Monte, California (27958) is engaged in custom compounding of epoxy resins, silicones, and polyurethanes for high and low temperature uses. The company used 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 company estimated that the document saved 40 to 50 hours of research time during preparation of 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
THERMAL EXPANSION PROPERTIES HANDBOOK
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A NASA Tech Brief published in March 1969 announced the availability of a new handbook concerning thermal expansion properties of materials used in aerospace systems. Compiled by E. F. Green of North American Rockwell Corporation under contract to Marshall Space Flight Center, the handbook consists of charts and tables for data on thermal expansion properties at cryogenic temperatures (to -423°F) and at high temperatures (to 2,000°F). The data were derived from experimental measurements and supplemented by information from various literature sources.

Pyromet Industries in San Carlos, California (30398) has used data in the handbook to help improve the design of its production fixtures and quality control procedures. According to a company spokesman, the firm's custom production of specialized metal parts and brazing and heat treatment services has been improved during the first months of application. He estimates that Pyromet will save approximately 100 man-hours annually by using the handbook.

Engineers employed by Eastman Kodak in Kingsport, Tennessee (32416) have used the NASA information to save approximately 25 percent of the design cost and a considerable amount of construction cost for a new support facility recently built at the Tennessee plant. The facility, designed for producing hydrogen gas, is estimated to have cost between $500,000 and $1,000,000. Kodak's engineers are continuing to improve existing production equipment by using the NASA technology.

Control Numbers

Tech Brief Number: 69-10055
NASA Center: Marshall Space Flight Center
PATT Case Numbers: 30398, 32416
TEF Number: 321
Date of Latest Information Used: March 22, 1971
FIBER GLASS/POLYURETHANE FOAM INSULATION ON CRYOGENIC VESSELS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Polyurethane foam applied as insulation on metal cryogenic vessels tends to separate from the metal surfaces as the result of differential shrinkage when the vessel is cooled to cryogenic temperatures. Voids between the separated polyurethane insulation and the metal surfaces become filled with moisture and air and cause excessive cracking of the insulation. Under contract to Marshall Space Flight Center, McDonnell-Douglas Corporation engineers recently found a solution to this problem. The shrinkage is eliminated by interposing a layer of fiber glass insulation between the polyurethane foam and the outer surfaces of cryogenic lines and tanks. The fiber glass material retains its resilience at cryogenic temperatures and provides an expansion layer between the metal surfaces and the polyurethane foam. A Tech Brief describing the technology was issued in 1968.

Rovanco, Incorporated in Joliet, Illinois (49055) developed a new method of preinsulating metal pipe sections which uses the fiber glass and polyurethane foam technology developed for NASA. Rovanco subsequently applied for a patent on the method. Several prototypes are in the process of being field tested by potential customers. The company president reports that initial reactions to the preinsulated pipe have been favorable. He indicated that a large potential market for the pipe exists in the liquefied natural gas industry.

Control Numbers
Tech Brief Number: 68-10406
NASA Center: Marshall Space Flight Center
PATT Case Number: 49055
TEF Number: 350
Date of Latest Information Used: February 18, 1971
FROST AS AN INSULATOR
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Frost is generally considered to be an undesirable, inert, homogeneous, crystalline structure that must be eliminated to enhance the heat transfer of cooling coils. When frost forms under other conditions, however, such as on the outside of cryogenic lines, its qualities can be used advantageously. It possesses an insulating capacity which compares favorably with some common low efficiency insulation materials such as shredded bark, insulating brick, asbestos and leather.

Basic insights on the insulating quality of frost and mechanisms for using frost in specific applications have been derived from recent tests and studies at the Los Alamos Scientific Laboratory under contract to the Space Nuclear Systems Office. Frost is an ice layer formed by condensed crystals of liquid air. If the liquid air is allowed to escape, the frost layer cracks, sloughs off, shifts position, and repairs itself with consequent changes in insulating value and thermal conductivity. However, by maintaining relative humidity above set values and blowing the moist air past cryogenic lines at certain velocities, frost can be formed to set thicknesses and densities which can be sustained. Once this occurs liquid air run-off is eliminated, and the frost layer becomes a uniform insulator. This technique could be applied in operations where it is difficult to wrap or attach standard insulating materials. Conditions can also exist where space constraints or lack of access impedes the placing of insulation. With an available supply of moist air, frost possesses the inherent advantage of easy insulation of cryogenic lines which otherwise might not be protected.

Chicago Bridge and Iron Company (CB&I) in Plainfield, Illinois (50869) learned of this development through the results of a literature search conducted for the company by the National Bureau of Standards' Cryogenic Data Center. After executing tests on frost to verify the Los Alamos results, CB&I engineers used the technology in designing a liquefied natural gas transfer system to be used by a customer. The customer has installed this system in a slightly modified form, using some insulation with the frost. CB&I reportedly
saved approximately $10,000 in research costs by using the data. A CB&I engineer says the company will use the technology in future cryogenic system design work.

Control Numbers

Tech Brief Number: 70-10593
NASA Center: Space Nuclear Systems Office
PATT Case Number: 50869
TEF Number: 365
Date of Latest Information Used: March 30, 1971
INSULATION

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The use of high energy cryogenic fluids to boost large payloads into space and to furnish power during space missions has required the development of cryogenic insulating materials which will adequately protect highly volatile fluids during ground storage, launch, and mission operation. As principal contractor to NASA for the Apollo command and service modules and the S-II second stage of the Saturn V launch vehicle, the Space and Information Systems Division (S&ID) of North American Aviation, Incorporated in Seal Beach, California (50221) has devoted a large share of its engineering and manufacturing resources to the development and use of cryogenic technology. In addition to testing and evaluating numerous cryogenic materials, S&ID's cryogenic technology program has involved the origination of various composite materials, design of structures for minimum heat transfer, development of advanced insulation systems, and refinement of unique fabrication and bonding techniques.

S&ID obtained a contract from Marshall Space Flight Center for the S-II. To meet the insulating requirements for the S-II fuel tanks, S&ID engineers designed sandwich-type cryogenic insulation panels which could be adhesive-bonded to the outer wall of the fuel tank. Special adhesives and advanced bonding techniques were developed to ensure a bond which would withstand the temperature extremes and other stresses imposed upon the insulation. The insulation panel consists of a polyurethane foam-filled phenolic-glass honeycombed core, to which a laminated skin is bonded. The skin is composed of polyvinylfluoride film and nylon fabric impregnated with phenolic resin. The 33-foot diameter S-II is joined to the Saturn S-1C stage by an interstage skirt. An important requirement is cryogenic insulation for the bolting ring at the juncture of this skirt and the S-II's liquid hydrogen and liquid oxygen propellant tanks. To facilitate insulation of the bolting ring's complex surface, S&ID developed a closed-cell polyurethane foam which, unlike open-cell foams, requires no external seal membrane and is able to withstand thermal shock without cracking. An effective insulator in cryogenic environments to -423°F, closed-cell foam can be used without surface treatment for warm-side temperatures to 500°F.

To foam-spray the complex surface of the S-II bolting ring, S&ID developed special techniques, including a holding fixture which permits the spray gun to be adjusted for movements on all three axes.
S&ID's cryogenic test facilities are used to demonstrate the reaction of cryogenic materials to actual mission profiles. In addition to being exposed to temperatures in the -423°F to 500°F range, materials proposed as cryogenic insulators are tested for thermal shock; helium permeability; tensile, compression, and shear strength; elongation; and coefficient of expansion.

S&ID has distributed an advertising brochure which states:

In accepting the contracts for the Apollo spacecraft and the Saturn S-II booster, the Space and Information Systems Division committed itself to producing equipment of the highest efficiency and reliability. The facilities and experienced personnel acquired to meet this challenge, as well as the manufacturing processes developed during five years of spacecraft manufacture, are now available to meet the unique development or production requirements of other organizations.

The company's advertising and sales campaign subsequently produced between $500,000 and $1,000,000 in contracted, nonaerospace insulating business in 1970. Current or completed insulation applications include large liquid methane tankers and a tuna boat. S&ID also has entered into a license agreement with a division of Wanner-Isofi, a world-wide, French-based insulation and tank company, to supply the insulation system designs, materials testing, polyurethane foam application equipment, and technical representatives for Wanner-Isofi's liquefied natural gas installations in North Africa, Asia and Europe.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 50221
TEF Number: 361
Date of Latest Information Used: March 16, 1971
SUPERINSULATING MATERIALS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The National Research Corporation (NRC) developed an aluminized film, NRC-1, in the mid-1950's, and announced as early as 1957 that sales were being made to the military and to industry for insulation applications. In 1958, the firm expanded its work to include cryogenic insulation modifications of the material. By 1962 the firm had secured a patent on NRC-2, a crinkled, aluminized .0025-inch plastic film (MYLAR). The material possessed the highest insulating efficiency per pound of any known material.

In 1962, National Research Corporation (37434) began to execute a variety of NRC-2 application contracts with NASA, mainly with the Lewis Research Center. NRC-2 eventually was used as the outer skin of the Echo I satellite, in components storing cryogenic liquids, and in suits worn by astronauts. These were the first applications of NRC-2. The company also granted licenses to two manufacturers for use in cryogenic vessels, some of which were used to store and transport cryogenic fluids for the space program.

Norton Company bought control of NRC in early 1965, shortly after NRC had introduced the first consumer product from NRC-2: a .005-inch, uncrinkled film for use as a disposable rescue blanket. This product was not successful, and a reusable blanket was announced in late 1965. Although it was a stronger, grommeted lamination of polyethylene and NRC-2, the material did not "breathe," could not be stitched, and was not very durable. In 1968, NRC developed a method for coating fabrics with NRC-2 by using vacuum deposition. This technique provided the solution to the three previous problems.

NRC became the Metallized Products Division of Norton Company in 1969, and a sales campaign based on the new coating method was initiated. Early in 1969, the new Norton division contracted with McGregor-Doniger, Incorporated to apply the coating to McGregor's fabrics which were then used to produce sportswear. Norton's annual business for this coating service has leveled off at about $2,000,000, with McGregor continuing to be the major customer. Norton also introduced several newer versions of the "space blanket," as the rescue blankets are now called, which incorporated the same coating process on several different fabrics. Since then approximately one million of the blankets have been produced annually. They have suggested retail prices ranging from $2.00 to $7.95.
In March 1971, the Norton division was sold to King-Seeley Thermos Company. Thermos has a national sales network for its line of camping equipment, and the consumer-oriented applications of NRC-2 are being integrated into this product line.

Control Numbers

Tech Brief Number: None
NASA Center: Lewis Research Center
PATT Case Number: 37434
TEF Number: 160
Date of Latest Information Used: June 8, 1971
THERMAL INSULATION SYSTEMS
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

NASA contributions to the development of advanced thermal insulation technology have been directed primarily to applications in cryogenic systems. That technology, however, also has influenced the development of thermal insulations for use at higher temperatures. Different materials must be selected to withstand higher temperatures, but similar principles of heat transfer apply. The thermal insulations available today fall into two major categories: those which are gas filled, and those in which gases have been evacuated to achieve a required low pressure. Although multilayer insulations are considered by many to be the most striking of the important new developments, space program research in this area also has produced improvements in the effectiveness of foam, evacuated powder and fibrous insulations. Information on thermal insulations developed in the course of space research programs has been made available to scientists and engineers through contractor reports and technical articles in professional journals. Until recently, however, this information has not been applied outside of the space program, primarily because relevant concepts and applications have been difficult to extract.

To facilitate the transfer of this technology, Arthur D. Little, Incorporated conducted a survey of NASA work in the development of thermal insulation systems. The results of that survey subsequently were published in a NASA Special Publication, entitled Thermal Insulation Systems. The document includes an extensive discussion of the principles of thermal protection systems, the insulation components for such systems, and their integration, installation, and performance in typical applications.

Stanford University (50224) recently installed cryogenic storage vessels to support cryogenics research work in its physics laboratory. Stanford personnel were able to design the necessary insulation systems by using the NASA document. Scientists and engineers described the
handbook as their primary reference tool in designing insulation systems for cryogenic research equipment.

Control Numbers

Special Publication Number: SP-5027
NASA Center: NASA Headquarters
PATT Case Number: 50224
TEF Number: 362
Date of Latest Information Used: March 19, 1971
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; however, the very low temperatures cause plastics to become brittle, shrink, and lose resilience with the result that a seal using these materials does not perform well.

An engineer employed by North American Rockwell's Rocketdyne Division, under contract to Marshall Space Flight Center, 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 "superfinishing" 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 of 1967, a waiver was granted to North American. The Seals Division of Shamban Corporation in Los Angeles, California (4574) then received a license from North American 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
CONNECTOR SEALS FLUID LINES AT CRYOGENIC TEMPERATURES AND HIGH VACUUM

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In 1964, engineers at NASA's Goddard Space Flight Center invented a fluid line connector to meet rigid, low pressure, and low temperature sealing specifications. The invention incorporates a metal disk gasket which is compressed between a set of concentric serrations on each of the connector halves. Compression on the disk is applied by uniform tightening of the flange bolts. Uniform compression on both sealing surfaces is ensured by the spring action of the disk. Any difference in the coefficient of thermal expansion between the disk and flange, which is normally very slight, is offset by the spring action of the disk. The connector serves as a positive seal for fluids at temperatures ranging from near absolute zero to 300°F; it also is suitable for use in vacuum systems at pressures down to 10⁻⁸ mm of mercury. The connectors can be installed or removed quickly. Installation does not require soldering or welding within vacuum chambers and, hence, reduces the possibility of chamber contamination. A Tech Brief describing the invention was issued in December 1964.

Cryolab, Incorporated in Los Osos, California (49067) is currently producing the NASA-developed connector in several sizes. The decision to include the connector in Cryolab's product line of cryogenic and vacuum components was made shortly after the company received the Tech Brief. Cryolab subsequently received a license to manufacture the NASA invention in August 1965. Since that time, the company has had total sales of approximately $20,000 for this product.

Control Numbers
Tech Brief Number: 64-10327
NASA Center: Goddard Space Flight Center
PATT Case Number: 49067
TEF Number: 354
Date of Latest Information Used: February 17, 1971
HAND-TIGHTENED, HIGH-PRESSURE SEAL
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A need existed in the space program to provide flared tubing and hose connections for high-pressure (10,000 psi) cryogenic service that could be assembled without the use of tools. North American Rockwell Corporation engineers, under contract to Marshall Space Flight Center, modified existing high-pressure fittings to provide hand-tightened, leak-proof connections. Two types of fittings were modified to receive a special, double-truncated, cone-shaped Kel-F washer. The use of this type of hand-tightened seal on cryogenic lines to -320°F is limited to seal diameters of 0.75-inch and less. There is no apparent limit to the size of this seal design when it is used at ambient temperatures. A Tech Brief describing the invention was issued in December 1968. Two magazines, New Products Newsletter and Machine Design, subsequently published articles describing the invention. In each example cited below, the individual involved requested a copy of the Tech Brief and license information for the invention as a result of the publicity given the technology in the magazines.

An engineer with the National Division of Ritter Engineering Company in Pittsburgh, Pennsylvania (49059) has developed prototypes of the NASA connector in a slightly modified form. Tests conducted at National have shown that the prototypes provide improved tubing connections in hydraulic systems produced by the company. Present economic factors are being evaluated prior to initiating full-scale commercialization of the seals.

The manager of Webster Machine Products, Incorporated in Webster, Massachusetts (49057) considered the modified metal fittings described in the Tech Brief for possible adoption as new products. He subsequently decided that the fittings were too far afield from the company's product line, and terminated all adaptation activities. He indicated that he plans no further use of the seal technology at this time.

Control Numbers
Tech Brief Number: 68-10417
NASA Center: Marshall Space Flight Center
PATT Case Numbers: 49057, 49059
TEF Number: 357
Date of Latest Information Used: February 18, 1971
COOLDOWN OF CRYOGENIC TRANSFER SYSTEMS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The fluid flow and heat transfer characteristics of cryogenic cooling systems during the start-up of NASA's nuclear rocket engines have been the subject of extensive research at Los Alamos Scientific Laboratory, under contracts with the Space Nuclear Systems Office and the Lewis Research Center. The published results constitute the principal body of available knowledge on the cooldown of cryogenic transfer lines. These publications provide experimental results and analytic models for predicting the transient flow, thermal stress, and heat transfer characteristics of warm pipelines when they are cooled to operating temperature by either a small, steady flow of liquid cryogen or a flow of chilled gas from the cryogen. If the cooldown flow-rate is too low, then the resulting two-phase, stratified flow produces undesirable effects. On the other hand, if the flow-rate is too high, then large thermal stresses are produced in flanges and valve bodies on the pipeline.

In March 1970, the National Bureau of Standards' Cryogenic Data Center conducted a literature search for the Chicago Bridge and Iron Company (CB&I) in Plainfield, Illinois (50868). CB&I subsequently made extensive use of the publications identified in that search during the preparation of a successful $5,000,000 contract proposal to design and install a liquefied natural gas (LNG) transfer system. The contract has subsequently been expanded to $7,000,000, based on excellent preliminary results. The new system will use 24-inch diameter transfer pipelines to carry LNG from huge ocean tankers into shore storage tanks. The company, under a contract with Distrigas Corporation, will make the initial installation of the LNG transfer system in Boston, Massachusetts. CB&I is also building the shore storage tanks for this installation, which is scheduled for operation in the fall of 1971.

CB&I's director of cryogenic research reported that the company had no previous experience with ship-to-shore transfer systems, and had never worked with LNG transfer pipes larger than 10 inches in diameter. He also indicated that, without the NASA documents, CB&I probably would not have received a contract of this type. He said the documents were very important to his engineers in writing the proposal, establishing their expertise, and designing the system which is now under construction. In terms of future benefits to the firm, the newly
developed system has become a very significant development for the company. Additional installations of similar ship-to-shore transfer systems will probably be made by CB&I and its licensees in England, Europe, and Japan as the rate of importing LNG increases in each country.

Control Numbers

Tech Brief Number: None
NASA Centers: Lewis Research Center and Space Nuclear Systems Office
PATT Case Number: 50868
TEF Number: 364
Date of Latest Information Used: March 30, 1971
CRYOGENIC FLUID FLOW INSTABILITIES IN HEAT EXCHANGERS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

An experimental investigation was conducted at the General Electric Company, under contract to Marshall Space Flight Center, to determine the nature of oscillations and instabilities that occur in the flow of two-phase cryogenic fluids at both subcritical and supercritical pressures in heat exchangers. The objective was to obtain a fundamental understanding of the phenomena, without regard to the design parameters of a particular heat exchanger configuration.

The major experimental work was conducted with liquid nitrogen at subcritical pressures in an apparatus designed to provide data on the nature and rate of fluid flow, heat transfer rates and pressure drops. The results of the tests with varying system parameters suggest certain design approaches with regard to heat exchanger geometry which should increase system stability.

The president of Frumerman Associates, Incorporated, a consulting engineering firm in Pittsburgh, Pennsylvania (34684), requested additional information on the technology after reading a Tech Brief which described it. He studied the NASA document and plans to use it in his consulting work as the need arises.

A researcher with the Shell Development Company, the research branch of Shell Oil Company, in Houston, Texas (35176), recently used the NASA document during a low temperature research project. Although that project was completed successfully, there are no immediate plans to utilize the results in Shell's production facilities. The TSP is credited with allowing the Shell researchers to save valuable time on the project.

Union Carbide's Linde Division in Tonawanda, New York (39954) has improved one of its products by using this technology developed for NASA. The product, a cryogenic vaporizer, was subject to pressure surging. While surging presented only minor difficulties in most applications, it was potentially quite dangerous in others. The problem
has since been eliminated by modifying the product. Linde engineers plan to conduct a more complete analysis of the problem by using the mathematical model described in the NASA document sometime in the near future.

Control Numbers

Tech Brief Number: 69-10541
NASA Center: Marshall Space Flight Center
PATT Case Numbers: 34684, 35176, 39954
TEF Number: 356
Date of Latest Information Used: March 11, 1971
HEAT TRANSFER COEFFICIENTS FOR LIQUID HYDROGEN TURBOPUMPS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Numerous complex modes of heat transfer occur during transient start-up operation of liquid hydrogen turbopumps. A Marshall Space Flight Center contract with North American Rockwell Corporation resulted in documentation of empirical equations that establish appropriate heat transfer coefficients for operation of these turbopumps. As written by W. R. Wagner and W. R. Bissel of North American, the equations are expressed as functions of temperature drops and heat transfer rates for a wide range of convective and boiling conditions at different locations in the pump.

Engineers at the Convair Division of General Dynamics Corporation in San Diego, California (26264) used the NASA publication presenting these equations to improve prediction of chill-down time for liquid hydrogen turbopumps on Centaur engines. Ground chill-down is accomplished with liquid helium, but subsequent in-flight starts require propellant dumping to achieve chill-down. The improved ability to predict chill-down time permits reduction of the amount of in-flight propellant dump required for chill-down, which allows an increased payload capability.

Control Numbers
Tech Brief Number: 68-10517
NASA Center: Marshall Space Flight Center
PATT Case Number: 26264
TEF Number: 268
Date of Latest Information Used: December 16, 1969
AIRCRAFT GALLEY AND CARGO REFRIGERATION SYSTEM

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The AiResearch Manufacturing Division of the Garrett Corporation in Los Angeles, California (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 of 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.

Since 1968, 55 aircraft have been equipped with the galley refrigeration unit. 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: June 9, 1971
SPECIALIZED MICROWAVE EQUIPMENT  
TECHNOLOGY TRANSFER EXAMPLE SUMMARY  

Two new products have been developed by Maury Microwave Corporation in Cucamonga, California (900Z) as the result of contractual work performed for NASA's Jet Propulsion Laboratory (JPL). Since 1962, the firm has held contracts with JPL to develop and manufacture various pieces of microwave equipment. The first contract was for a cryogenic termination, also known as a "cold noise source," which provides an integrated noise-temperature input for calibrating and measuring the performance of microwave equipment. Following completion of this particular NASA contract, the firm continued its own internal development of the instrument. According to a company spokesman, the resulting instrument is superior to other such devices because of its greater accuracy.

Maury Microwave's development of the cryogenic termination led to a second product, which in itself requires a test instrument for calibration. Based on inventions originating at JPL and protected by NASA-owned patents, the firm developed for commercial use an instrument known as the "Insertion Loss Test Set." This instrument provides precise measurement of losses caused by insertion of a microwave component into a circuit, and is used for calibrating the cryogenic termination. The instrument's development began in 1963 and was completed in August of 1964. Since 1964, 107 cryogenic terminations have been sold at an average price of $3,600 each and 26 test sets for an average $3,200 each. Total sales since 1964 have been approximately $468,400.

The president of Maury foresees additional product developments arising from its NASA contract work. He indicated, for example, that an antenna monitor receiver developed for use in the space program is being adapted to a commercial product. In addition, the firm has the capability to make very precise measurements and calibrations of microwave equipment, a service previously available only from the National Bureau of Standards.

Control Numbers  
Tech Brief Number: None  
NASA Center: Jet Propulsion Laboratory  
PATT Case Number: 9002  
TEF Number: 136  
Date of Latest Information Used: June 8, 1971
CONTROL FOR LEVEL OF A CRYOGENIC LIQUID

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

When a cryogenic liquid is used to cool a cold trap in a vacuum system, the liquid level of the operating vessel must be kept fairly constant to ensure effective operation of the trap. The supply of this liquid as it vaporizes and boils off to the atmosphere must be replenished constantly. An intricate glassware device was invented at the Jet Propulsion Laboratory, under contract to the NASA Pasadena Office, to maintain the liquid level automatically. The device, powered by the build-up of gas vapor pressure from boil-off, pumps in more liquid from a storage vessel to replace the amount which has vaporized. The device is actuated by changes in the volume of a second gas, such as methane, produced by temperature variations associated with boil-off in the operating vessel.

The president of Cryogenic Service Corporation in Glendale, California (49069) read a Tech Brief which described the level control device. He subsequently received a nonexclusive, royalty-free license to produce the NASA invention. In December 1970, the company hired an expert glass blower and began manufacturing the device. The new product is almost identical to the NASA invention. It is being advertised in Cryogenic Technology, and more than a dozen have been sold to research laboratories for $300 each. The company president reported that the product has good market potential.

Control Numbers

Tech Brief Number: 69-10573
NASA Center: NASA Pasadena Office
PATT Case Number: 49069
TEF Number: 351
Date of Latest Information Used: February 18, 1971
SUPERCONDUCTIVE THIN FILM AS A LIQUID HELIUM LEVEL SENSOR

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A convenient sensor was invented at NASA's Langley Research Center for measuring the level of liquid helium in a Dewar flask. It consists of a superconductive film mounted on a dipstick. The sensor is made by depositing a thin film of niobium metal to a thickness of approximately 2,000 angstroms on a quartz substrate, which is then mounted on a graduated dipstick.

To use the sensor as a gage for measuring the level of liquid helium, the niobium film is connected in series with a 1.5-volt battery, an indicating lamp, and a normally open pushbutton switch. With the pushbutton closed, the top of the dipstick is held with thermally insulated gloves and the sensor is slowly and cautiously lowered into the Dewar until the indicator lamp glows. At this point, contact of the sensor with the liquid helium surface reduces the temperature of the sensor to that of the liquid helium and the resistance of the sensor suddenly falls to zero, permitting sufficient current from the battery to light the lamp. The reading on the dipstick then corresponds to the liquid level. The level or depth of the liquid helium may be measured to an accuracy of ±0.25-inch.

Andonian Associates, Incorporated in Waltham, Massachusetts (49066) is planning to develop a new product similar to the NASA-developed sensor. The company already produces a semicontinuous level sensor and other cryogenic equipment. The new product will satisfy the anticipated requirements of Andonian customers for continuous sensing capabilities.

Control Numbers
Tech Brief Number: 68-10341
NASA Center: Langley Research Center
PATT Case Number: 49066
TEF Number: 355
Date of Latest Information Used: February 16, 1971
APPENDIX C

Exhibit I. Technology Utilization Compilations
Exhibit II. Technology Utilization Compilations Containing Reader Service Cards
## APPENDIX C

### EXHIBIT I. TECHNOLOGY UTILIZATION COMPILATIONS

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### APPENDIX C

**EXHIBIT II. TECHNOLOGY UTILIZATION COMPILATIONS CONTAINING READER SERVICE CARDS**

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