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PROCEEDINGS OF COLLOQUIUM/WORKSHOP ON COMPOSITE MATERIALS AND STRUCTURES

STANDARDIZATION, QUALIFICATION, CERTIFICATION

AD-A149 039

Stanley L. Channon, *Editor*

July 1984

Held at
NATIONAL ACADEMY OF SCIENCES BUILDING
2100 Constitution Avenue
Washington, D.C.
May 8-10, 1984

Prepared for
Office of the Under Secretary of Defense for Research and Engineering

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A Colloquium/Workshop on Composite Materials - Standardization, Qualification and Certification was organized and held at the National Academy of Sciences Building, Washington, D.C. on May 8-10, 1984. Announcements were made in various technical and trade publications and letters of invitation were sent to individuals in Government, industry and academia. Attendance was limited to U.S. citizens only.

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1. Fibers and Reinforcements,
2. Matrix Materials,
3. Intermediate Products, and
4. Components and Structures,

On the third day, summaries of the working group discussions and recommendations were presented in a general session, followed by a period of open discussion.

This document contains the presentations by individual speakers and the summary reports by the Working Group Chairmen. These sessions were taped and the oral presentations have been included in the document with minor editing to assist the reader in the interpretation of the charts and tables.

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1801 N. Beauregard Street
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PREFACE

On the basis of previous studies by the Institute for Defense Analyses, a Colloquium/Workshop on Composite Materials - Standardization, Qualification and Certification was organized and held at the National Academy of Sciences Building, Washington, D.C. on May 8-10, 1984. Announcements were made in various technical and trade publications and letters of invitation were sent to individuals in Government, industry and academia. Attendance was limited to U.S. citizens only.

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EXECUTIVE SUMMARY

The recommendations and suggestions made by the individual speakers and the results of the working group deliberations have been combined into this brief overall executive summary prepared by the editor. The major topics are discussed separately and recommendations for actions or options are included. These items are arranged in an approximate order of priority or need.

1. Composites Industry Association

Each of the working groups and several of the speakers recommended that the industry form an Association to provide a single voice in dealing with the problems of the industry and in communications with the Government agencies. The charter of this Association was not defined but the Aluminum Association was often mentioned as an example of the type of organization which may be appropriate. It was generally felt that the Association should be limited to the materials suppliers and should not include end users such as the aircraft manufacturers, although some thought that the end users were the beneficiaries and perhaps should be included. Although there were some doubts about the advantages of an Association in this relatively small and specialized segment of the overall reinforced plastics industry, sufficient interest was shown that preliminary arrangements were made to survey the industry. (Shortly after the colloquium, DuPont sent letters to the composites suppliers in the U.S. and abroad inviting them to attend a formative meeting in San Francisco on July 26-27, 1984, if the responses were sufficient.)

2. Test Methods Standardization

Although the A.S.T.M. test methods for composites have been and are still being developed as standards for the industry, there was repeated concern over the mis-use or non-use of these standards by various suppliers and users. There is also a tendency for individual organizations to develop their own methods but refer to ASTM standard methods when and if the data are reported.

The acceptance and use of standardized test methods was strongly urged by many speakers and all working groups. This is considered to be an essential prerequisite to the development of standardized specifications as well as qualification tests and criteria.

It is recognized that the voluntary consensus method used by ASTM to develop standard test methods is slow and relies on the enthusiasm of the committee members. Recommendations were made that ASTM consider what steps can be taken to accelerate the establishment of these methods. It was also suggested that the industry provide A.S.T.M. with recommendations and priorities for the tests that are needed.

DoD may also explore the possibility of providing support to ASTM in order to emphasize the development of certain types of tests.

In the interim, it was recommended that the industry adopt the current ASTM test methods to provide a more standardized set of test data which can be transferred between end users more readily.

3. Materials Specifications

The industry has developed around a set of individual materials bearing trade names or alpha-numeric designations which identify proprietary materials. Although it was generally recognized that some degree of standardization and the use of generic descriptions would be desirable in specifying the materials, there is some concern about trying to establish specifications which are too rigid while the industry is still in a period of frequent change. Provision must be made to encourage and accommodate the development of improved materials.

One solution which was suggested by several participants is to provide a series of stratified specifications which describe different levels of the properties required. It was also suggested that suppliers be included early in the cycle for the development of these materials specifications. The development of a series of standard specifications was also considered to be important in programs requiring international cooperation.

The Society for Automotive Engineers, Aeronautical Material Specifications (AMS) activity has a voluntary specifications committee for composites. In keeping with the Government trend toward the use of commercial specifications wherever possible, this committee is endeavoring to compile AMS specifications for the composite materials which will be standardized to the maximum extent. It was recommended that AMS take a leading role in reviewing and recommending standardized specifications. This will require the participation of industry and, perhaps, some Government organizations. It is also recommended that DoD follow the present NASA program on the development of specifications for toughened matrix materials being conducted by the three principal commercial transport aircraft. This program may provide a basis for similar DoD action in military applications.

4. Standardized Data Base (MIL-Handbook 17)

Much of the data base on advanced composite materials has been generated by industry as part of development or production programs and is not generally available for wide dissemination. Mil-Handbook 17 is the only recognized source of data but its progress has been hampered by the unavailability of data from defense contractors and a low level of funding for the development of data by the responsible organization, the Army Materials and Mechanics Research Center (AMMRC). At the present rate of progress, a statistically reliable data base on a single material will not be available before the material has become obsolete.

It was strongly recommended that DoD explore ways to accelerate the Mil-Handbook 17 program and that steps be taken to require that contractors provide data for inclusion in the Handbook. The participation of FAA in providing data from commercial programs was also recommended.

5. Certified Testing Laboratory

One of the major problems in the composites industry (especially for military aerospace applications) is the high cost of qualification, which can vary from $20,000 for a few simple tests on a material to several million dollars for full scale flight demonstration. The first supplier to become qualified is usually supported financially by the contractor; subsequent suppliers find it economically difficult or impossible to get their materials qualified since they must often bear the full cost of qualification (including materials and testing wherever it may be conducted). In many cases, the same type of material must be qualified by several fabricators, resulting in replication of the test program without the benefit of data sharing.

It was suggested that an initial qualification test matrix could be completed at a certified testing laboratory and these data used to "qualify" the material one time only. Additional testing would still be conducted by the individual end users because of certain design requirements and structural configurations. Although the concept of a certified testing laboratory was viewed with favor, it was recognized that there are many options which need to be explored to determine the type of facility, its location, cost, etc. A study of these options was recommended.

6. Qualification Test Matrix

Wide differences in the tests used for qualification exist among various programs in both the military and commercial fields. The FAA provides a standardized set of qualification tests which are fairly uniform, but the military programs differ among the Services. This is particularly troublesome to the suppliers who are now obliged to provide a variety of data in accordance with each end-user's specifications.

It was recommended that DoD undertake a study to explore the possibility of providing a standardized qualification test matrix which would be acceptable to both DoD and industry. This would require the participation of industry, also.

7. Introduction of New Technology and Materials into Production Systems

Comments from suppliers and from Government representatives emphasized the difficulties in introducing new and improved materials into a production system, especially in the military programs. The commercial aircraft industry appears to be more receptive to materials improvements. While DoD supports the development of new materials in its research and development programs, it is also reluctant to accept these materials into an on-going production program. It was suggested that materials suppliers would have a greater incentive to develop new products if there was some assurance that an opportunity to use them in production would materialize within a reasonable time period.

It was recommended that DoD explore procedures which would provide for the orderly introduction of new materials and technology into production programs.

8. Requirements for Composite Materials

Industry representatives expressed the need for information from DoD and the Services on the requirements for various types and forms of materials in the different applications for which they are intended. This information is needed for the planning of future R & D studies in industry as well as for the establishment of facilities to accommodate these needs. A suggestion was made that DoD should have a focal point for reviewing the multiple and conflicting requirements of the Services.

It was recommended that DoD explore the feasibility of determining these requirements and providing periodic feedback to the industry.

9. Contractual Requirements

a. Dual Sourcing

Many materials and/or processes relating to composite structures are provided by sole sources and, in some cases, by foreign sole sources. It was recognized that multiple sources are desirable but are not always economically viable. It was recommended that, if DoD requires dual sources, this should become a contractual requirement at the time of procurement of the weapon system rather than creating artificial second sources.

b. Pricing

There was concern by some suppliers that the Government did not fully appreciate the extent of the investment required to produce some of the composite materials. It was suggested that a DoD review of the pricing regulations might be in order.

c. Data Base

A suggestion was made that the provision to DoD of the material data base be made a contractual requirement on production programs involving composites. This would enable DoD to share the data base with other DoD contractors, where appropriate.

10. Export/Import Regulations

It was felt, by some suppliers, especially those associated with metal matrix composites and carbon-carbon, that the U.S. industry is being handicapped by the current regulations on the export control of composite materials and technology. It was suggested that the technology of composites has become international and it is necessary to recognize that fact in the export regulations. It was pointed out that opportunities abroad are being lost as a result of these regulations. Restrictions on the import of composite materials from abroad are minimal.

A recommendation was made that DoD again review the export control regulations covering composites to assess their impact on the U.S. composites industry as a whole. A uniform approach to co-production programs with foreign countries was also recommended.

11. Development of Instrumentation Methods

It was concluded that instrumentation methods for determining the characteristics of composites were generally inadequate. It was therefore recommended that steps be taken by DoD and industry to support the development of acceptable instrumentation.

12. <u>Hybrid Composites</u>

It was recommended that DoD explore approaches for the utilization of hybrid composites (carbon, Kevlar and glass) to improve composite component supportability in the military maintenance environment. This involves the development of toughened resin systems as well as the design of damage tolerant structures with built-in repairability.

13. <u>Analysis Methods and Test Validation</u>

Analytical procedures are extensively used in the certification of aerospace structures in lieu of full scale testing of large structures. There is a need for the development of analysis methods and test validation on sub-scale structures to verify the performance of the structure in post-buckling, impact, bolted joints and transverse failure modes. The development of accept/reject criteria is also necessary. Although much work is being done by DoD and NASA in these areas, it was recommended that DoD support a program to collect these data and make them available to the industry.

INTRODUCTION

Ken Foster
Department of Defense

Since the Department of Defense plans to spend $80 billion for weapon systems which will use composites in one form or another over the next five years with increasing use of composites planned, this colloquium is timely and necessary. We are fortunate to have as our keynote speaker, Mr. John A. Mittino. He joined the office of Secretary of Defense in 1972 and is currently the Assistant Deputy Under Secretary for Production Support. In this capacity, he is responsible for Department of Defense policy development in several important areas including the defense standardization program, the defense productivity, reliability and quality assurance. His other Pentagon experience included four years as director of standardization, acquisition support and, prior to that, he reviewed major defense systems from the production and logistics aspects. He has a BS in electrical engineering from the Missouri School of Mines and a Master of Business Administration from the University of Arizona. Please help me welcome Mr. John Mittino.

KEYNOTE ADDRESS

John Mittino

Department of Defense

Good morning, it's nice to be here. I appreciate the opportunity and the invitation to be here. I come out of an office that is concerned with the industrial base and its relative health and vitality and revitalization and its condition for readiness and for sustaining some kind of emergency. Having said that, I think I can put in perspective the interest we have in something like the whole area of composites. I know nothing about composites, yet I have a keen interest in them because I can already see that, in the normal sequence of new technology and commodities that find their way, first, into weapons systems and defense materiel and, later, are more prolific in the commercial sector, there is a great need for exchange of information and community development of technology (industry and government, etc.) with little assistance or participation by the government, DoD. I always try to make that point clear. That may sound strange to you, but our rule of thumb as far as overall policy approach to anything is that we try to keep out of it if we can. The best way to have things happen is in the private sector (we thought that even before this administration came into being) and, as all of you know who pay attention to those things, the policy of the Administration is just that. It says that we are a claimant; we are a customer of the industrial base and we mean to keep it that way. Where necessary, we will engage in some artificial moves to provide seed money for new technology if that be the case, but at least we will be a good customer. And God forbid that, if there should come an emergency where we need to use some of this deterrent we have built over the years, we will be ready for that, not only in terms of the force structure, but in terms of the so called defense industrial base. This is not really a defense base at all but it is the

U.S. basic industry we are talking about, of which we are a claimant just like any other customer.

As I talked with Mr. Foster yesterday, I became interested in the situation in composites. I wouldn't presume to tell you anything about composites except that there are some generalities that became apparent to me. I have seen this situation before in other commodities. It's happening in 2 or 3 other areas where we are concerned now with a management approach in trying to facilitate the whole area of standardization, and especially qualification, of the technology or commodities. Fiber optics - does that sound familiar to you? We have a person in the audience who is working very diligently to help find a way to insert into the system for productive purposes, the necessary documentation and so forth that our acquisition community can use in the building of the force structure.

I was also interested to note that our foreign friends have, in various ways, been interested in composites and that we would have to watch ourselves, in my estimation, to make sure that we retain the necessary minimum U.S. domestic capacity in this area. It gets pretty difficult sometimes because, throughout the 1981-82 period when the economy was down, I would hate to tell you how many times well known corporations would come in to see us and advise us that business was down to the point where they felt relatively threatened by what was happening in the market place. When you combine this with the complexities of foreign military sales and the whole offset approach, we find it is necessary to pay particular attention to the kind of U.S. basic industry retention of a commodity area that we will try to achieve.

The idea of this conference is just fabulous because it is here that we can trade the information and try to understand the trends for the next several years. We will play a role in this in DoD but we want that role to be sensible and sane and we don't want it to encumber an otherwise rapidly moving expansion of a new area. I would also like to point out that, as a matter of interest, we have people in the Pentagon, such as Dr. Richard DeLauer, and formerly with Paul Thayer as Deputy Secretary and other Secretaries and Deputy Secretaries, whose attention can be gained very quickly when you talk about something like composites because they all have a stake in them. Almost as a class of people, their attention wanes to zero when you talk about other bureaucratic things - no interest. So, its just delightful to find out that, when we broach this subject with Dr. DeLauer, all of a sudden we get a great deal of attention. So you do have a great deal of attention in this area, and you can fully expect all the support that we can provide. I believe that, with your advice and consultation, we can position ourselves to be a partner and a help rather than a hindrance which all too often happens when we get our nose into things. That's really about the message I have - it will be one of the shortest keynotes you have had. I wish you all the luck in the world and, if you need something from us, all you need to do is let us know and you will have it. Good luck on your conference here.

REVIEW OF IDA STUDIES

Stanley L. Channon
Consultant

REVIEW OF IDA STUDIES

Stanley L. Channon
Consultant

During the past five years, IDA has undertaken several studies related to composite materials, strategic and critical materials and industrial base issues. These studies served as background for this conference and, in fact, prompted the recommendation that such a conference be held. A brief summary of the studies is shown in this chart.*

Under the sponsorship of Mr. Jerome Persh, Staff Specialist for Materials and Structures, the International technological status of composite materials was assessed from 1979 to 1981 and recommendations made regarding the export control of composite materials and technology. An Industry/Government workshop was held in 1981 to review these recommendations, using a format similar to the format for this conference.

As part of a review of the DoD needs for strategic and critical materials in 1981, carbon fiber was included because of the potential for substitution of some critical and strategic metals with composites containing carbon fibers. This, coupled with the anticipated large increase in the use of composites in military systems, prompted a more detailed analysis of the DoD needs and the ability of the U.S. composite industry to satisfy these needs for the next ten-year period. This study revealed several areas which were expected to have a limiting effect on the expansion of the U.S. industrial base in emergencies, and perhaps in peacetime, as well.

In the 1982-83 period, two complementary studies were undertaken, one involving an assessment of the foreign industrial base for production of composites rather than technology and the other involving a survey of alternate sources, qualification practices, standards and specifications

*p. 19.

for composite materials in both the U.S. and abroad. This study formed the basis for the present conference.

As part of another exercise on logistics and supportability, there have been recent studies on the repair and maintainability aspects of composites. The present conference is timely in the sense that standards and specifications also play an important role in the repair and maintainability practices.

In order to put this conference in perspective, I would like to indicate those items which might be thought to comprise the industrial base for composites. This chart* shows most of the key elements which make up the industrial base. A weakness in any one or more of these segments of the industry can have a limiting effect on the industrial base on which DoD is dependent for its hardware needs. Although the U.S. has capability in all of these areas, it is strongest in some areas, especially those associated with the design and fabrication of materials into final products. It is also a major source of prepreg materials for many U.S. and foreign fabricators but this situation is changing as other foreign suppliers are becoming qualified as prepreg suppliers. Except for aramid fibers which are, at present, primarily of U.S. origin, many of the raw materials or semi-processed materials are obtained from foreign suppliers.

The U.S. composites industry is generally characterized by having several separate steps, each being performed by specialty companies. Each segment of the industry provides some sort of criteria by which the materials are accepted by the next step in the fabrication cycle. In some cases, material certifications are provided by the supplier which confirms that the shipment has certain characteristics. Specifications are generally written around available materials and are more often placed on the intermediate product (prepreg) supplier rather than the fiber or resin

*p. 20.

supplier. Qualification involves testing against a set of criteria developed by the end user. Once a material has been qualified, it is customary to disallow any changes in the material or process. This restriction frequently extends all the way back to the starting material.

It is the purpose of this conference to examine the problems associated with qualification, specifications and standards at each stage of fabrication, including the requirements for certification of full-scale hardware.

Some of the factors which tend to limit the U.S. Industrial Base for Composites are listed in this slide*

From the standpoint of national security, it is important to realize that many defense programs using composite materials are dependent on foreign sources or sole domestic sources for some materials.

Many organic base composite materials are proprietary formulations of resins which are unique to each formulating company and could not be readily supplied by another producer in an emergency. Lack of material uniformity in the intermediate products and the shortage of reliable data on certain forms of the material also tend to limit the use of composites. Likewise, the lack of standardization is also believed to be a deterrent to more extensive use.

The overriding impediment to expansion of the composites base seems to be the high cost of qualification. Current practices seem to favor the continued use of previously qualified materials because confidence has been established in the qualified material and it is too expensive to qualify new or alternate materials. Several suppliers have indicated that this cost is a determining factor in the economic viability of the industry. Even though composites are being used in increasing amounts, the total volume of business is still relatively small and must be divided among many suppliers,

*p. 21.

at present. If business conditions are not favorable, some suppliers may have difficulty remaining active which would require that alternate materials would have to be qualified.

All segments of the industry indicated that trained manpower would be a serious limitation in the event that scaled-up production was needed to supply DoD needs. Since many of the operations require skilled labor which must be trained on-the-job, production could not be expanded in proportion to the additional facilities without allowing time for the training of new personnel. In fact, it was pointed out that the addition of new manpower may actually result in a slight decrease in production initially due to higher scrap rates.

Several cases of limitations in production due to the environmental regulations have been reported. This subject has not been thoroughly reviewed to determine the future impact on composites production. New fibers and resins are being developed which may require special controls.

Some key examples of U.S. dependence on foreign sources are listed in this chart* It is well known, by now, that polyacrylonitrile precursor fiber used in the manufacture of carbon fiber is essentially imported from Japan. Almost 100 percent of the qualified materials used in DoD programs rely on Japanese precursor, some of which is converted to carbon in the U.S. and some is imported as carbon fibers from Japan and the U.K. We will hear more about these fibers from speakers from Union Carbide and Hercules this afternoon. At this time, however, I would like to point out that each of the carbon fiber producers in Japan, the U.S., and the U.K. use somewhat different processes for the production of precursor and conversion of PAN to carbon. The interchangeability of these fibers has not been established. In the working group discussions, I expect that this subject will receive considerable attention.

*p. 22.

This chart* shows world production of carbon fiber produced from PAN precursor, the carbon fiber production by company, and a cumulative total for each country. It also shows the origin of the precursor. Red indicates a Japanese precursor, blue is a U.K. precursor and green is the U.S. precursor (based on Japanese technology applied to domestic acrylic starting material), and yellow is the French precursor. It will be noted that the Japanese production is nearly double that of the U.S. and about 70 percent of the U.S. production depends on the use of Japanese precursor. British production of fiber has been recently more than doubled by the addition of a new fiber line at Grafil and start up of a line by R.K. Fibers. The SOFICAR venture by Toray and Elf-Aquitaine will provide further European capacity in the next year or so. A similar venture by Hercules and Pecheney has been discontinued and it is now understood from press releases that Pecheney may be buying into the SOFICAR venture.

Two other significant foreign sources include diaminodiphenylsulfone (D.D.S) which is used as a curing agent in most resin systems employed in DoD composites applications. There is no production of DDS in the U.S. even though this material had its origin in the U.S. The French pharmaceutical company, Roussel, has been the sole supplier of this material to the U.S. Ironically, DDS is not used extensively in Europe as a curing agent. The establishment of a domestic source of DDS or the availability of an alternate curing agent would result in an extensive requalification program, if the past philosophy of qualification is adopted.

High purity quartz fibers used in some special military applications are also 100 percent imported from France. There is no U.S. production facility in operation for this material and the amount of material needed is small. Several years ago, sufficient material was procured and stockpiled for the life of the program.

High strength glass (R Glass), a product of France, is competitive with S Glass produced in the U.S. and is

*This chart is reproduced here in black and white in four parts (pp. 23-26).

receiving attention among some of the military departments in the U.S. If adopted for production applications, this would result in dependence on another foreign source, as well as requiring qualification of this material for these applications. Silicon carbide continuous fiber produced by Nippon Carbon Company in Japan is also gaining interest in the U.S. and would represent another imported material, if used extensively.

It was mentioned earlier that there are many U.S. domestic sole sources for materials used in composite fabrication. Some examples are shown in this chart.* In some respects, each supplier of prepreg may be viewed as a sole source because these materials are often qualified by their proprietary name rather than by generic type. Sole sources are not necessarily a serious limitation to the industrial base unless the product is so special that the production volume is insufficient to provide a return on the investment and the supplier discontinues production. This occurred in the case of rayon precursor in the late 1960's. It is understood that Owens-Corning discontinued the availability of S-glass in 1983 and now provides only S-2 glass. Attempts to establish second sources of materials may not be appropriate if the market is not sufficient to sustain two suppliers, under normal circumstances. Under emergency conditions, the sole source suppliers may have to expand production by diverting other production or adding facilities. In either case, requalification may be required. One of the questions which this conference should address is the acceptable amount and type of testing required to qualify products from the expanded sources or alternate sources.

On the subject of alternate sources, and specifically domestic alternate sources, part of the IDA study was aimed at determining the interest of U.S. companies in becoming suppliers of some key materials needed for DoD production programs. The responses were very disappointing in terms of the number of responses received. Some offered

*p. 27.

encouragement that some materials would be domestically produced in the near future. Announcement of any such actions will have to come from the companies themselves. This survey indicated that all U.S. acrylic fiber producers could be potential suppliers of PAN precursor fiber if the consumption was sufficient for them to enter the market. It is interesting to note that the Japanese and U.K. carbon fiber producers are essentially in the textile business and only 2 percent of their polyacrylonitrile production finds its way into carbon fibers. No U.S. textile company is engaged in the production of carbon fibers.

Several resin producers could supply the resins required for DoD use. It is understood that two former specialty resin producers may reenter this market in the near future. Similarly, DDS could be produced by several companies and alternate curing agents could be developed and qualified.

In the case of quartz fiber, it is more likely that the volume of material needed is so small that no commercial company would be willing to set up and operate a facility for a single product with limited consumption.

In the consideration of sources of supply and qualification, it is well to keep in mind the fact that the composites business has already become international in a very complex manner, partly due to the manner in which the industry has developed (fabrication in the U.S. and Europe, fibers in Japan and the U.K. as well as some in U.S.) and the expanding involvement of foreign countries in the fabrication of composites hardware for U.S. programs. Examples are Boeing's association with Aeritalia and Japanese aerospace companies, European associations between countries and U.S. military co-production programs. This means that standards and specifications must be developed which can be applied in various countries and products must be interchangeable, to a certain extent.

This chart* shows the complicated interrelationship between producers of PAN and PAN-base carbon fibers in the geographical areas of the free world in which composites are being used. There are also indications that the prepreg phase of the industry is pursuing a similar course. This chart emphasizes the fact that business ventures are generally established between companies in different countries to protect their competitive position. The establishment of domestic sources must take into account these existing relationships. It should also be realized that some foreign countries are also leaning toward self-sufficiency and, in some cases, insist on domestically available material being used. The U.K. is already in this position, with respect to carbon-epoxy composites. The Japanese are heading in that direction rapidly.

Developments on pitch-base carbon fibers have been advancing rapidly in Japan during the last couple of years with claims being made of fibers being produced with properties similar to PAN base fibers and cost projections which indicate that lower prices may be achievable. If successful in production, a lower cost pitch-base fiber would be an attractive replacement for the PAN base fiber and would, of course, require a new round of qualification tests.

Finally, a few words about the cost of qualification. In the questionnaires sent to all segments of the composites industry throughout the U.S., a number of questions concerning qualification testing and costs was asked. The costs were found to vary rapidly with the stage at which testing is performed and the criticality of the end product. Examples of typical costs are shown in this slide.** The figure of $9K for basic tests represents the least cost involved. More typical costs for evaluating an alternate precursor fiber range from $20-30K just for fiber testing. The cost for complete replacement of an alternate precursor fiber in a helicopter rotor blade application amounted to $750K.

*p. 29.
**p. 30.

Qualification of a prepreg costs $20-50K per customer. However, the development of a design data package can cost $500K-1.5M. The most expensive qualification programs appears to be those involving nozzle ablative performance in which costs of $1-2M can be incurred. The costs are assumed by the customer (which would be the Government for DoD programs) for the first material to be qualified. As a general rule, subsequent suppliers may have to share the costs in some manner, either by supplying material free of charge, conducting or paying for the testing involved, or both. Additional prospective suppliers frequently must absorb all costs or be denied the opportunity to qualify.

The purpose of this conference is to recommend options for expanding the U.S. industrial base for composite materials in the interests of national security. The items to be addressed in the next few days include means for establishing domestic sources for materials which are now of foreign origin, qualification of alternate materials and sources, including methods of streamlining the procedures; standardization of materials, test methods and specifications, establishment of a data base and means for acquiring and exchanging data, expansion of training programs and a definition of the roles which might be played by Government and industry.

In these few minutes, it is impossible to cover all of the ramifications of qualification, supply, specifications, and standards. Examples of some industry views provided during the survey are included as appendices in the executive summary provided to you. It is hoped that this report and the discussions which follow today will stimulate your thoughts and suggestions on those subjects.

Thank you for your attention.

COMPOSITE MATERIALS — INDUSTRIAL BASE AND QUALIFICATION

Presented
at
Colloquium/Workshop
on
Composite Materials and Structures —
Standardization, Qualification, Certification

at
National Academy of Sciences
Washington, D.C.
May 8-10, 1984

Stanley L. Channon
Consultant to
Institute for Defense Analyses

4-23-84-6

IDA STUDIES ON COMPOSITE MATERIALS

1979-81	INTERNATIONAL TECHNOLOGICAL STATUS AND EXPORT CONTROL OF COMPOSITE MATERIALS AND TECHNOLOGY
1980-81	STRATEGIC AND CRITICAL MATERIALS (INCLUDED CARBON FIBERS)
1981-82	U.S. INDUSTRIAL BASE AND D.O.D. NEEDS FOR COMPOSITES
1982-83	FOREIGN INDUSTRIAL BASE FOR COMPOSITES
1982-83	ALTERNATE SOURCES AND QUALIFICATION OF SOME COMPOSITE MATERIALS
1983-84	STANDARDIZATION, QUALIFICATION AND CERTIFICATION OF COMPOSITES
1983-84	REPAIR AND MAINTAINABILITY OF COMPOSITES

4-23-84-7

INDUSTRIAL BASE FOR COMPOSITES

COMPRISES

- RAW MATERIALS
- CONVERSION FACILITIES AND TECHNOLOGY
- WEAVING CAPABILITIES, 2D ------ nD
- MATRIX FORMULATION AND COATING FACILITIES AND TECHNOLOGY
- FABRICATION FACILITIES AND TECHNOLOGY
- DESIGN DATA BASE AND DESIGN TECHNOLOGY
- TESTING AND INSPECTION METHODS AND CRITERIA
- SPECIFICATIONS AND STANDARDS

4-23-84-8

LIMITATIONS ON U.S. INDUSTRIAL BASE FOR COMPOSITES

- DEPENDENCE ON FOREIGN SOURCES
- RELIANCE ON FEW SOLE SOURCES
- PROPRIETARY MATERIALS
- LACK OF MATERIAL UNIFORMITY
- LACK OF MATERIAL INTERCHANGEABILITY
- DATA BASE LIMITATIONS
- LACK OF STANDARDIZATION
- HIGH COST OF QUALIFICATION AND CERTIFICATION
- ECONOMIC INFLUENCE ON INDUSTRY PARTICIPATION
- TRAINED MANPOWER
- ENVIRONMENTAL REGULATIONS

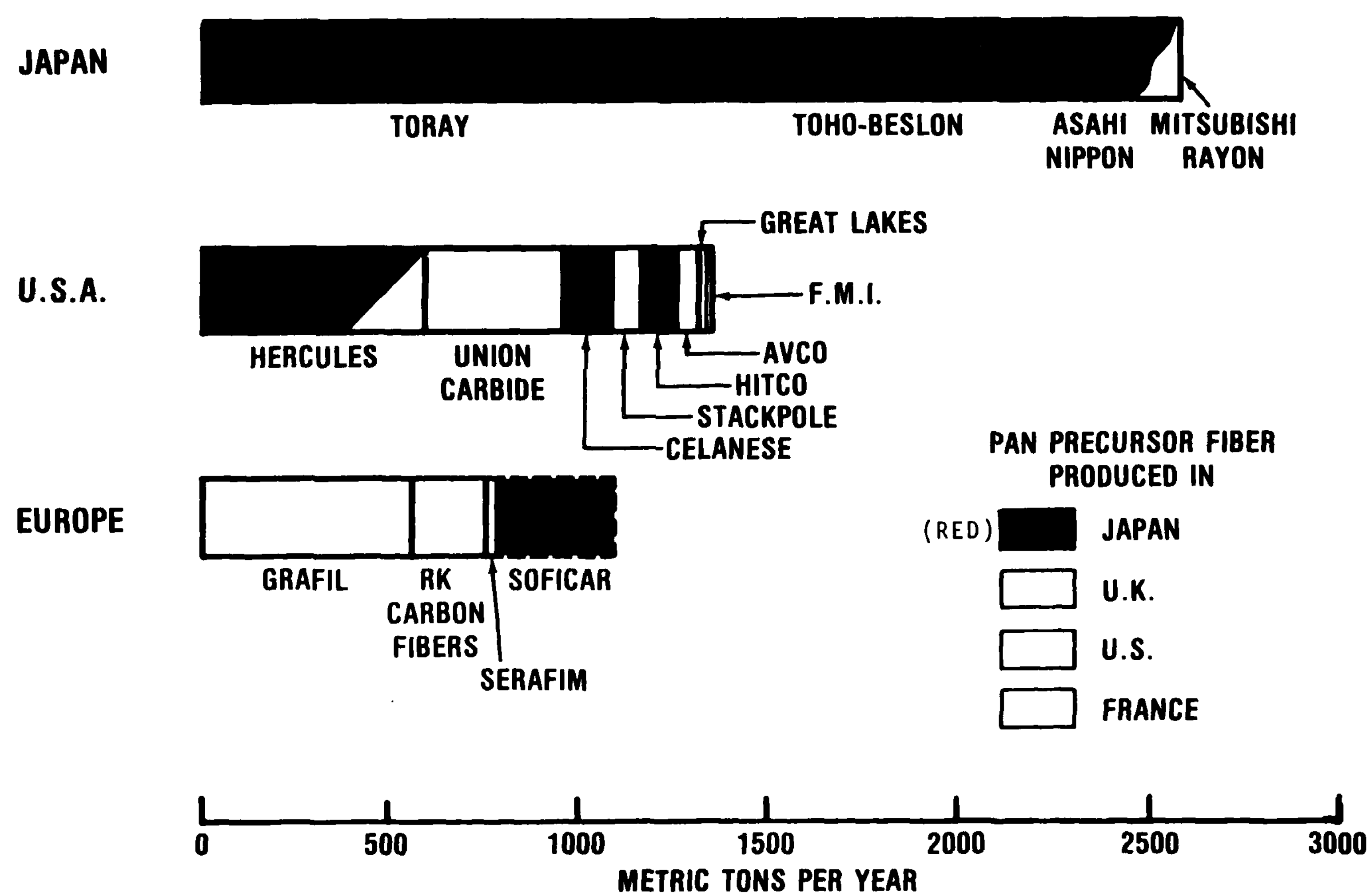
4-23-84-11

U.S. DEPENDENCY ON FOREIGN SOURCES

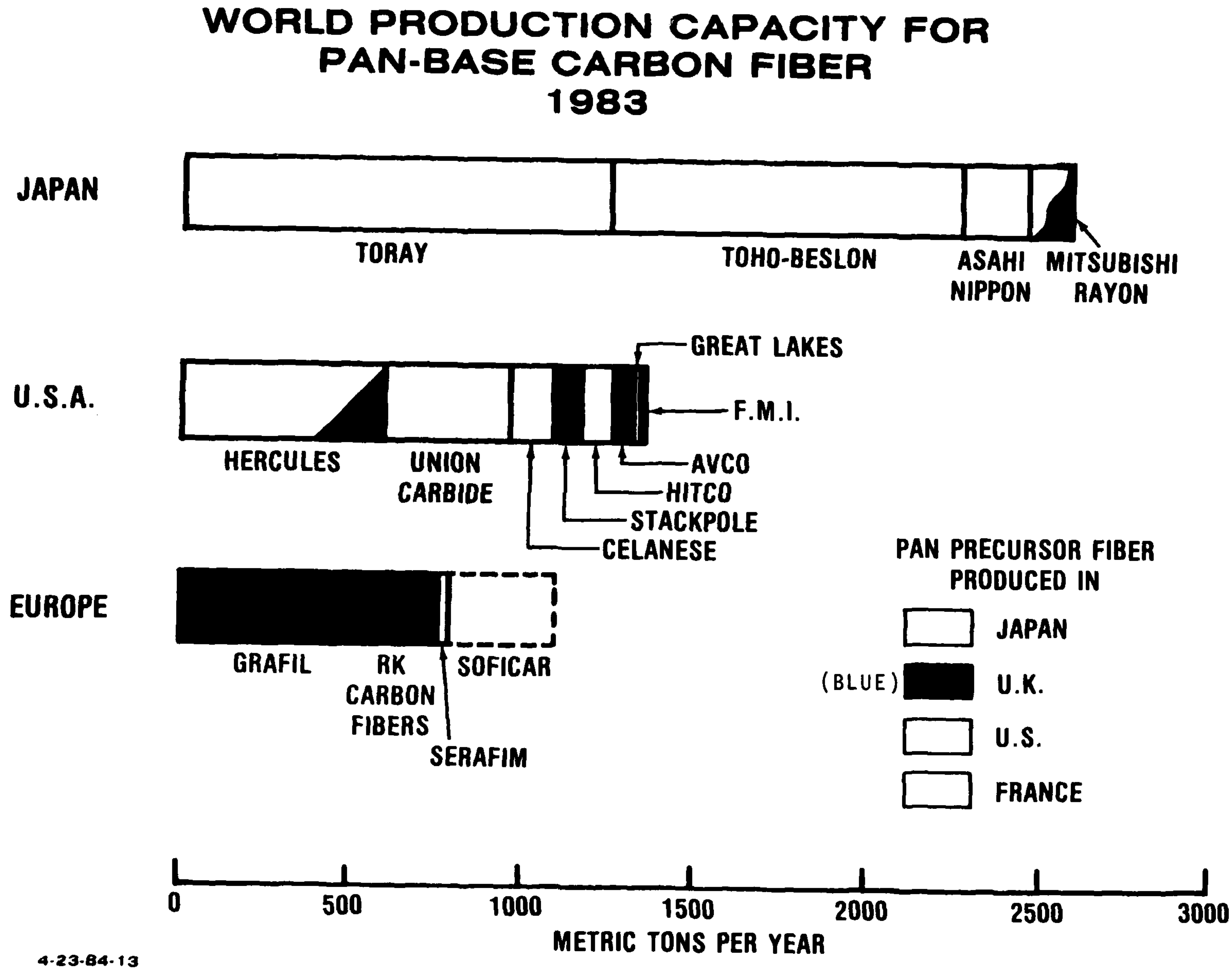
	SOURCE	PERCENT FOR DoD NEEDS
PAN PRECURSOR FIBER	JAPAN	70-100
PAN-BASE CARBON FIBER	JAPAN, UK	15-30
DIAMINODIPHENYLSULFONE (DDS)	FRANCE	100
HIGH PURITY QUARTZ FIBER	FRANCE	100
HIGH STRENGTH "R" GLASS FIBER	FRANCE	SMALL, BUT LIKELY TO INCREASE
SILICON CARBIDE CONT. FIBER	JAPAN	SMALL

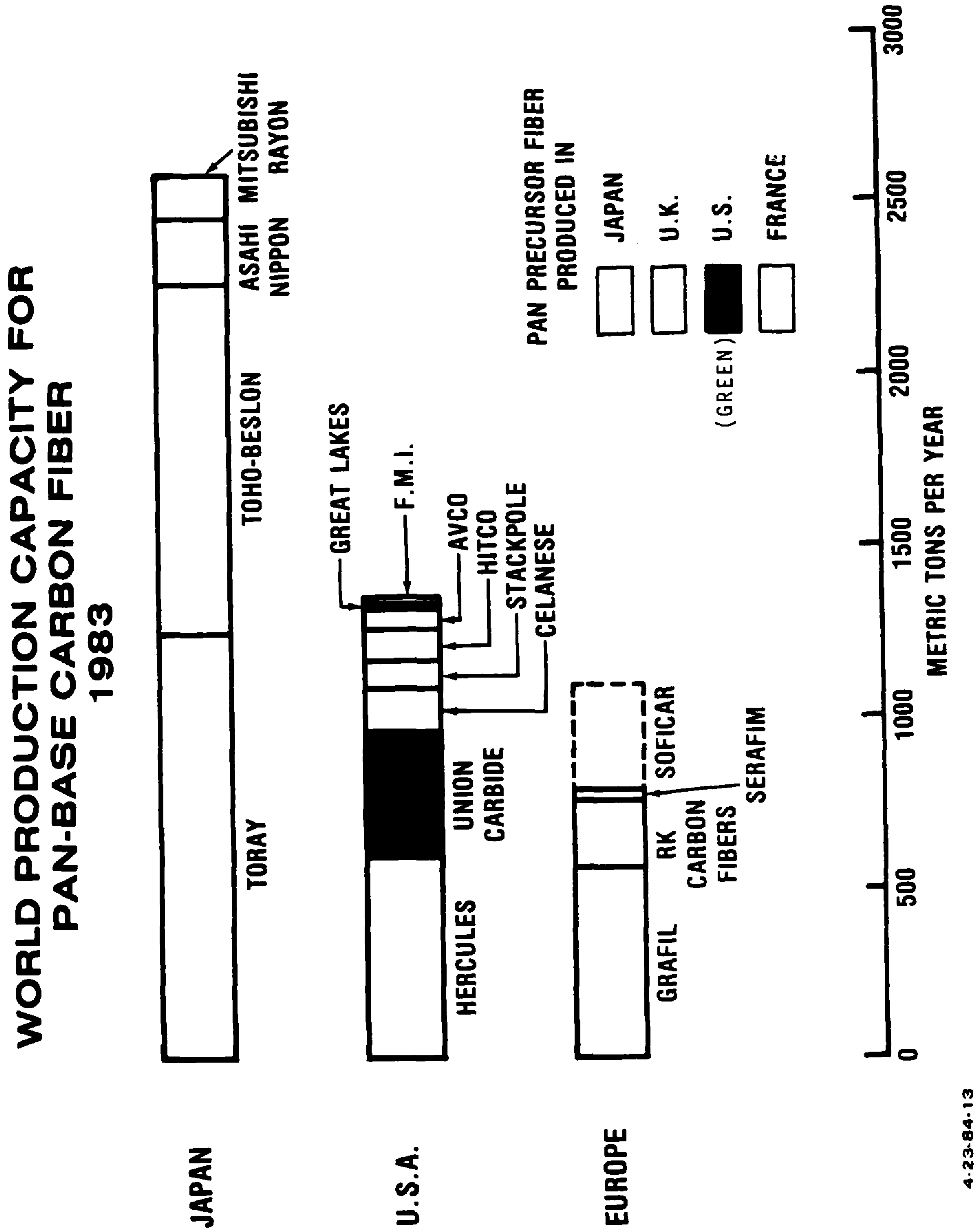
4-23-84-12

WORLD PRODUCTION CAPACITY FOR PAN-BASE CARBON FIBER 1983



4-23-84-13


WORLD PRODUCTION CAPACITY FOR
PAN-BASE CARBON FIBER
1983
JAPAN
TORAY
TOHO-BESLON
ASAHI NIPPON
MITSUBISHI RAYON
U.S.A.
HERCULES
UNION CARBIDE
CELANESE
STACKPOLE
HITCO
AVCO
F.M.I.
GREAT LAKES
EUROPE
GRAFIL
RK CARBON FIBERS
SERAFIM
SOFICAR
PAN PRECURSOR FIBER PRODUCED IN
JAPAN
(BLUE) U.K.
U.S.
FRANCE
0
500
1000
1500
2000
2500
3000
METRIC TONS PER YEAR
4-23-84-13



WORLD PRODUCTION CAPACITY FOR PAN-BASE CARBON FIBER 1983
JAPAN
TORAY
TOHO-BESLON
ASAHI NIPPON
MITSUBISHI RAYON
U.S.A.
HERCULES
UNION CARBIDE
CELANESE
STACKPOLE
HITCO
AVCO
F.M.I.
GREAT LAKES
EUROPE
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RK CARBON FIBERS
SERAFIM
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PAN PRECURSOR FIBER PRODUCED IN
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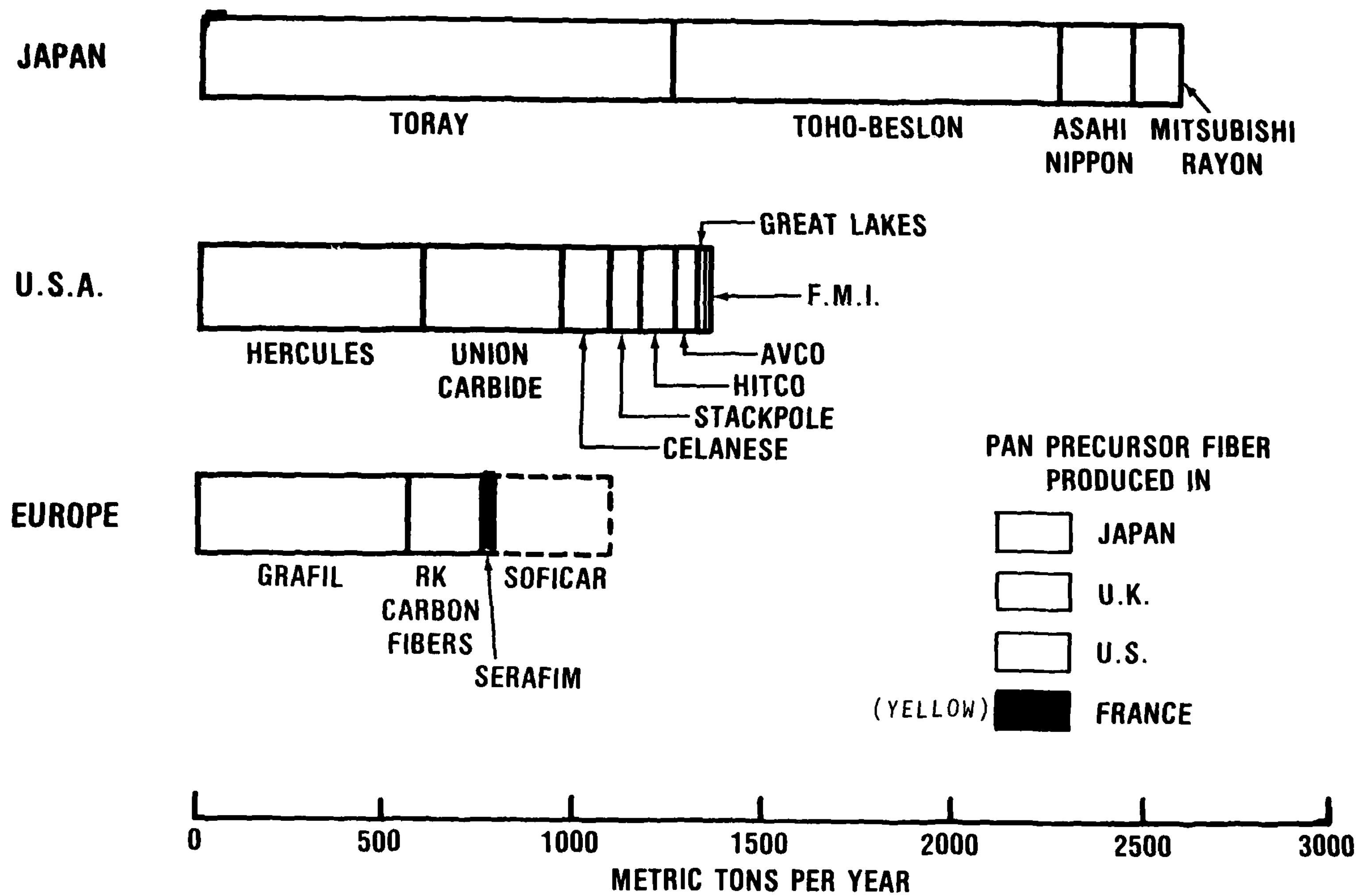
METRIC TONS PER YEAR
4-23-84-13

WORLD PRODUCTION CAPACITY FOR PAN-BASE CARBON FIBER 1983



4-23-84-13

EXAMPLES OF SOLE SOURCES IN U.S.

RAYON PRECURSOR FIBER	AVTEX
PAN PRECURSOR FIBER (CARBONIZABLE TO HIGH STRENGTH CARBON)	UNION CARBIDE
PITCH BASE GRAPHITE FIBER	UNION CARBIDE
S-GLASS FIBER	OWENS CORNING
ARAMID FIBER (KEVLAR)	DUPONT
ALUMINA FIBER	DUPONT
SILICON CARBIDE WHISKERS	ARCO
EPOXY RESIN MY720	CIBA-GEIGY
PROPRIETARY PREPREG FORMULATIONS	EACH SUPPLIER

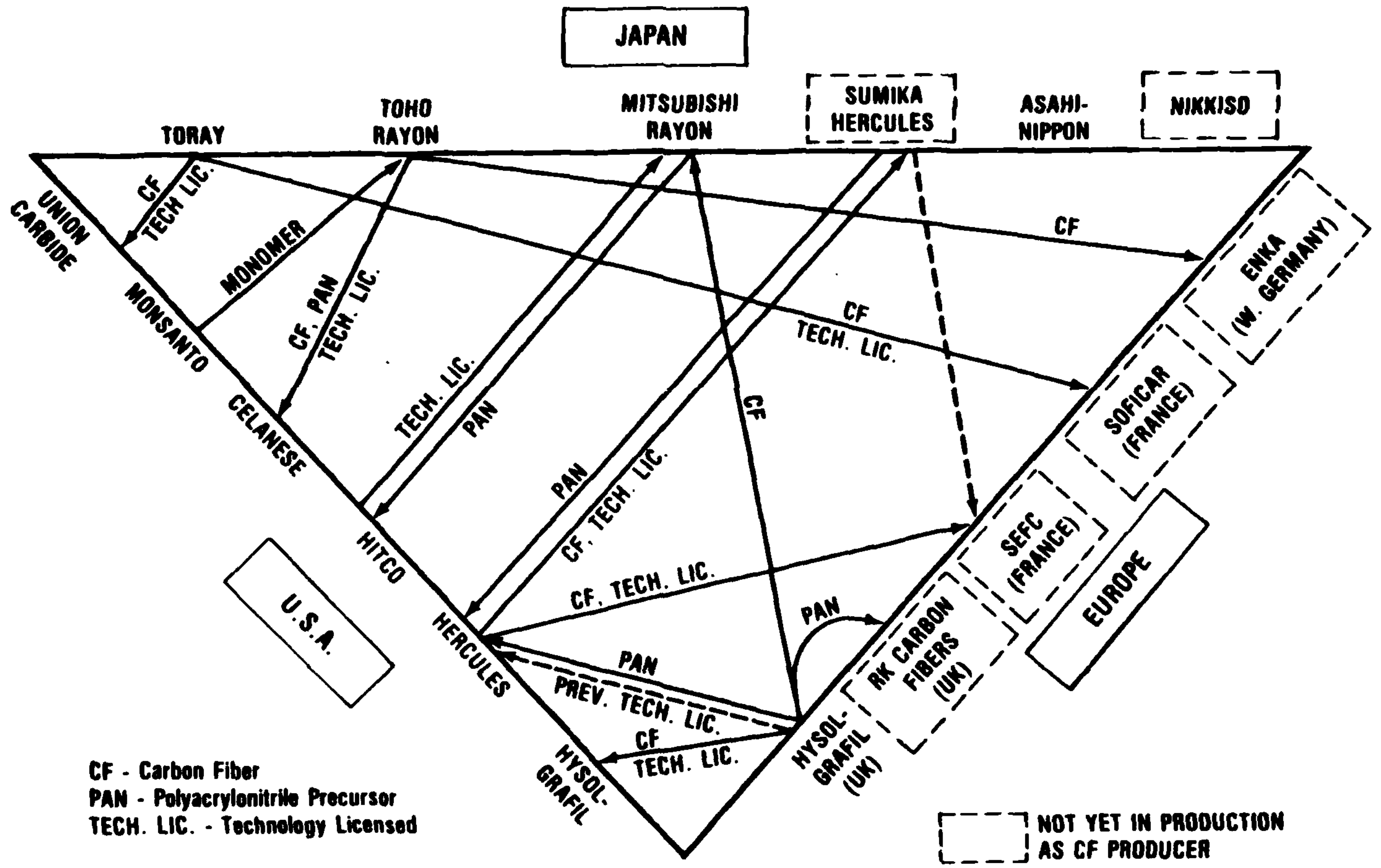
4-23-84-16

ALTERNATE SOURCES/MATERIALS

- PAN PRECURSOR
  - ALL ACRYLIC FIBER PRODUCERS ARE POTENTIAL SOURCES
- RESINS
  - SEVERAL POTENTIAL SUPPLIERS, BUT PRODUCTS NOT AVAILABLE
- D.D.S.
  - SEVERAL POTENTIAL SUPPLIERS
  - ALTERNATE MATERIALS NEED TO BE QUALIFIED
- QUARTZ FIBER
  - NO OPERATING FACILITY IN U.S.

4-23-84-17

PAN-BASE CARBON FIBER ORGANIZATIONS



CF - Carbon Fiber
PAN - Polyacrylonitrile Precursor
TECH. LIC. - Technology Licensed

4-23-84-14

COST OF QUALIFICATION

• RANGE	DOLLARS
BASIC MECHANICAL AND PHYSICAL TESTS	9 K
ALTERNATE PRECURSOR FOR CARBON FIBER	
— FIBER TESTING	20 - 30 K
— REQUALIFICATION OF HELICOPTER ROTOR BLADE	750 K
BASIC PREPREG QUALIFICATION	20 - 50 K
DESIGN DATA	500 K - 1.5 M
FULL SCALE FIRING TESTS ON NOZZLE	1 - 2 M

• WHO PAYS ?

FIRST MATERIAL QUALIFIED	— CUSTOMER (OR GOVERNMENT)
SECOND MATERIAL QUALIFIED	— SUPPLIER OR SHARED
OTHER SOURCES	— SUPPLIER

4-23-84-19

EXPANSION OF U.S. INDUSTRIAL BASE FOR NATIONAL SECURITY

- ESTABLISH DOMESTIC SOURCES
- QUALIFY ALTERNATE MATERIALS AND SOURCES
  - STREAMLINE QUALIFICATION PROCEDURES
- STANDARDIZATION
  - MATERIALS
  - TEST METHODS
  - SPECIFICATIONS
- ESTABLISH DATA BASE
  - INTERCHANGE OF DATA
- EXPAND TRAINING PROGRAMS
- DEFINE ROLES OF GOVERNMENT AND INDUSTRY

4-23-84-20

U.S. ARMY QUALIFICATION PRACTICES

Edward Lenoe
Army Materials & Mechanics Research Center

U.S. ARMY QUALIFICATION PRACTICES

Edward Lenoe

Army Materials & Mechanics Research Center

Good morning, I'm pleased to be here to speak with you. I'm sure the next three days will be very productive. What I'm going to try to do this morning is to briefly try to identify the range of DARCOM or Army activities related to composites, talk a little about the philosophy of qualification, but I'd also like to raise a number of issues for the working groups to consider, and then I'd like to conclude with some personal concerns.

With regard to DARCOM activities, they cover the full spectrum of materials R & D, preliminary design and analyses, prototype systems and also the development of advanced characterization techniques. We manage the DoD Specification and Standardization program as well, which I will describe in a little detail. I'd like to say that our orientation, at least in the composites community, is around airframe structures. We hear a lot about the future use of composites being at the level of around 40-50 percent in air-frames; however, one of the things I'd like to emphasize in my presentation is the increased utilization in all types of military hardware. Regardless of the application, the range of concern includes the production capability, the actual certification of repairs (this is another issue which should receive increasing attention) and finally the vulner-ability and survivability and the increased enhancement of these qualities using the unique properties of composites for a number of advanced weapons threats.

With regard to Army applications in the aircraft, most of us are familiar with helicopters. The Army approach has been evolutionary, starting with a number of major components, moving into secondary structures, various flight controls and, most recently, strong efforts toward an all-composite helicopter. In general, the Army helicopter experience has been excellent. While one main rotor blade design has been expensive to maintain, we have several components that have accumulated quite an impressive log of hours. The oldest component has been in service for 13 years with over 7000 hours on one blade. Some specific problems have been erosion strips and leading edges. The certification procedures for rotor blades are fairly well pinned down, but as you heard from Mr. Channon, they are quite expensive. This document, the Engineering Design Handbook on Helicopter Engineering,* is representative of an Army approach to qualification in a variety of systems. We deal largely through program manager offices. We have a number of documents of this type which outline general procedures. The contractor maintains a great deal of responsibility in the full definition of the certification. I believe that this is sensible in general; however, it does lead to a proliferation of certification and qualification procedures, and I hope the working group will address the issue of how to introduce more uniformity in general qualification approaches.

I'd next like to refer to a chart** that Dick Hadcock put together at Grumman. It is interesting because it brings to mind the historical perspective that we have to have. What we have here is a demonstration of weight savings in a chronological order. This one curve essentially indicates the first time structures were built and tested - essentially the prototype demonstration of a variety of components. You can see that there is a fairly large time lag between the introduction in the prototype sense and in the application sense. This ranges from 10 to 15 to 20 years and, obviously, this whole cycle is a learning experience. It involves iterative design, analysis and testing. If you look at the history of advanced composites, you see the learning curve in a production capability, you see the improvements in design and quite often, these design improvements can be a factor of two.

*p. 44.
**not included in proceedings.

I'd like to keep this as a perspective in looking at the whole range of Army applications where we have done either design or prototype testing. It covers not only the more familiar aircraft applications, but it ranges over armor, various kinds of body armor, tank liners, new initiatives in the design of advanced artillery gun barrels, howitzer trail arms, looking at composites in munitions and bridging. We did extensive work on flywheels a number of years ago, work on rocket motor cases as in the Viper system, and so on. You can appreciate the fact that ground vehicles, as opposed to aircraft or electronic shelters for chemical/ biological warfare, each have to be approached in a different way. It is obvious that an advanced Pershing structural adapter or a nose cone is a different situation than a man-rated anti-tank weapon system such as the Viper system. The Viper system cost, last year at its preliminary production, something like $700 per unit. The actual inspection cost was, I believe, a fraction of a dollar, and that involved real time proof testing of the case. Another interesting facet of the Viper was that the presence of small holes which would be cause for rejection of a lot of aircraft components had absolutely no bearing on the performance of these launch tubes. The certification procedure was essentially field ruggedness, e.g. whether a soldier would sit on it in an extended position. Another kind of a situation is in the 5-ton truck. We've built the entire cab area out of composites with a 45 percent weight savings. We've manufactured truck wheel hubs and the actual truck frame.

One thing I'd like you to consider. I think our emphasis has been on high reliability, relatively low volume aerospace type production. The Army also deals with high volume and cheap items in which we are willing to accept low reliability. I think the philosophy of design allowables "A" and "B" is fine for the high reliability items but we should also leave room for an approach which considers a wide range in materials properties so that we can achieve appropriate reliability.

Another thing I'd like to remind the working groups to consider are the opportunities for light weight materials for specific weapons threats, e.g. laser resistance or ballistic tolerance. So much for the philosophy related to the wide range of applications for composites.

Next, I'd like to talk about the Defense Standardization and Specification program. The mission of this activity is to achieve the highest degree of standardization. It includes preparation, revision, amendment and cancellation of specifications. Within the co-called DODISs, there are 46,000 standardization documents, more than 500 dealing with threaded screws. It is obvious that we have a long way to go in this business. Of the approximately 46,000 standardization documents, 4500 are related to materials and these are administered in our laboratory, the Army Materials and Mechanics Research Center. We have automated that data base which will be hooked up to 8 interactive terminals so that we can get a real time playback of at least these materials specifications. We have a lower degree of computerization of the 46,000 documents. An examination of this data base indicates that there are currently 450 Federal Supply Class documents that relate to plastics fabrication. One of our primary activities relates to MIL Handbook 17 about which you will hear from one of the other speakers. In a general sense, we produce about 233 updated revised specifications in a year and we have a look at over-aged documents every 5 years. So, in principle, nothing in this automated data base is older than 5 years. That means that some respected organization in DoD has given its blessing that it is still an acceptable document.

I do want to emphasize that the Defense Standardization program actually implements consensus specifications to a high degree. I have an example of that with regard to work over the last 20 years or so. This is the total number of documents that have been adopted from ASTM, ASM and other industry type standards. You see that they begin to approach 2400. With regard to composites, we have adopted 60 test methods from ASTM and most recently a number of specifications related to armor, body armor, aircraft seats, transparent armor and Frank Traceski is here to answer any details on that. I'd like to say that we have 5 participants and if there are any questions on any of the subjects that I have briefly discussed, I will be happy to put you in touch with the appropriate individuals.

Next, I'd like to talk in a philosophical vein. I'd like to go back to Stan Channon's chart which he used earlier and look at this from a somewhat different perspective. We heard recently that 2 or 3 new pitch base fibers have been announced by Japanese producers and apparently 8 to 10 manufacturers are involved in that enterprise. You've heard the story about PAN base fibers. It looks as if there is an aggressive entry into the pitch base fibers as well.

The other thing I'd like people to give some consideration to is uniform approaches to co-production. If you look at military sales, we are doing co-production with Turkey, Spain, Italy, France, etc. On the civilian side, we are doing co-production on very high performance aircraft as well. I think we've got to be very protective of that and adopt some uniform approaches as well. Stan's document essentially concluded that the U.S. is not only strongly dependent on foreign materials but, encouragingly, it has the largest fabrication base. We have some truly unique facilities. We are currently the largest consumer of composites. I think we shouldn't give up this position, but we should try to enhance our national capabilities in a variety of areas. These intersecting three circles are a useful way to approach the situation. We are talking in terms of the supplier, the manufacturer and the user. In terms of international collaboration, I believe it certainly makes sense to collaborate as fully as we can with regard to qualification and certification of raw materials. At the user end, I think this is the arena where we have to be extremely careful.

Lastly, I'd like to allude to a personal problem that we have. We have been approached by a number of overseas authorities who are interested in adopting the structural certification procedures, in particular, recently, the U.K. They are interested in our activities on MIL Handbook 17. They have some good perspectives - one of their questions is whether we use a fracture mechanics approach or an equivalent overload approach. I just wanted to lay that on the table since we are currently wrestling with how to approach that. In conclusion, I want to remind you that my major concern is that other certification activities be initiated with regard to non-aircraft structures as well.

OVERVIEW OF DARCOM ACTIVITIES

IN

STANDARDIZATION, QUALIFICATION & CERTIFICATION

OF

COMPOSITE MATERIALS & STRUCTURES

E. M. LENOE

PREPARED FOR

COLLOQUIUM/WORKSHOP

COMPOSITE MATERIALS AND STRUCTURES

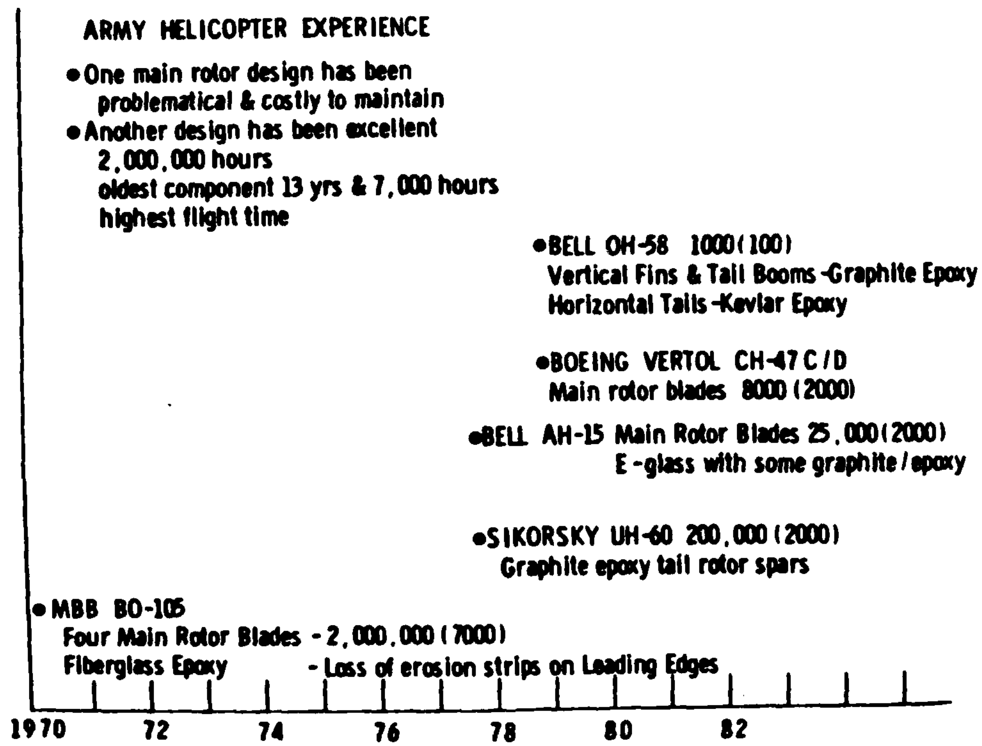
STANDARDIZATION, QUALIFICATION, CERTIFICATION

NATIONAL ACADEMY OF SCIENCES

MAY 8 - 10, 1984

ARMY ACTIVITIES - COMPOSITE MATERIALS AND STRUCTURES

- MATERIALS RESEARCH & DEVELOPMENT
- PRELIMINARY DESIGN & ANALYSIS
- PROTOTYPING OF SYSTEMS
- ADVANCED CHARACTERIZATION & TESTING TECHNIQUES
- STANDARDS, SPECIFICATIONS, HANDBOOKS


ARMY HELICOPTER EXPERIENCE
• One main rotor design has been problematical & costly to maintain
• Another design has been excellent
2,000,000 hours
oldest component 13 yrs & 7,000 hours
highest flight time
• BELL OH-58 1000 (100)
Vertical Fins & Tail Booms -Graphite Epoxy
Horizontal Tails -Kevlar Epoxy
• BOEING VERTOL CH-47 C/D
Main rotor blades 8000 (2000)
• BELL AH-1S Main Rotor Blades 25,000 (2000)
E-glass with some graphite/epoxy
• SIKORSKY UH-60 200,000 (2000)
Graphite epoxy tail rotor spars
• MBB BO-105
Four Main Rotor Blades - 2,000,000 (7000)
Fiberglass Epoxy
- Loss of erosion strips on Leading Edges
1970
72
74
76
78
80
82

ENGINEERING DESIGN HANDBOOK

HELICOPTER ENGINEERING

PART THREE

QUALIFICATION ASSURANCE

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND APRIL 1972

SOME TYPICAL ARMY APPLICATIONS OF COMPOSITE MATERIALS PRELIMINARY DESIGN AND/OR PROTOTYPE

AIRCRAFT
- Rotor Blades
- Drive Shafts
- Transmissions
- Flight Controls
- Landing Gear/Skids
- Fuselage
- Tail Boom

ARMOR
- Body Armor
- Tank Liners
- Helmet Liners
- Pilot Seats

ARTILLERY
- Gun Barrel Extensions/Stiffeners
- Howitzer Trail Arms
- Munitions

BRIDGING
- Traversing Beams
- Bottom Chord
- Web Module
- Cables
- Reinforcing Kit

ENERGY
- Flywheels

MISSILES
- Rocket Motor
- Launchers
- Nose Cone
- Missile Structure
- Fins

TANKS
- Torsion Bar
- Drive Wheel
- Track Support Roller
- Track Idler Wheel
- Track Road Wheel
- Track End Connector Link

VEHICLES
- Body
- Frame
- Drive Shaft
- Suspension System
- Wheel Hubs/Rims

SHELTERS
- Tents and Portable Shelters
- Electronic Shelters

PIPING AND STORAGE CONTAINERS

ARMY MATERIALS AND MECHANICS RESEARCH CENTER

MANAGES

PART OF DEFENSE STANDARDIZATION AND SPECIFICATION PROGRAM

(DSSP)

MISSION: ACHIEVE HIGHEST PRACTICABLE DEGREE OF STANDARDIZATION

- SPECIFICATIONS
- STANDARDS
- HANDBOOKS

INCLUDES: PREPARATION, REVISION, AMENDMENT, CANCELLATION

DOD

46000 STANDARDIZATION DOCUMENTS

DEPARTMENT OF DEFENSE INDEX OF SPECIFICATIONS & STANDARDS

(DODISS)

APPROXIMATELY 4500 ARE MATERIALS RELATED AMMRC ADMINISTERED

OF THESE:

450 FEDERAL SUPPLY CLASS (FSC) 9330 - PLASTIC FABRICATION MATERIALS

BASIC STANDARDIZATION DOCUMENTS

- MILITARY - SPECIFICATIONS & STANDARDS
- FEDERAL - SPECIFICATIONS & STANDARDS
  - INDUSTRY STANDARDS
  - MILITARY HANDBOOKS

AMMRC STANDARIZATION ACTIVITES

THERMOPLASTICS

- PREPARATION OF NEW OR REVISED MIL SPEC
- ADAPTION AND PREPARATION OF NONGOVERNMENT STANDARDIZATION DOCUMENTS

1981 - AMMRC REVISED DODISS

1. MIL-N-18352A(OS)
2. MIL-M-19887A(SH)
3. MIL-M-20693B - SEVEN REPLACED BY ASTM-D 4066-82 FOR NYLON MOLDING & EXTRUSION MATERIALS
4. MIL-P-22096B
5. L-P-395C
6. MIL-P-46180(MR)
7. MIL-P-46181(MR)

THERMOSETS

THE FOLLOWING POLYIMIDE SPECIFICATIONS ARE BEING REVIEWED:

1. AMS 3616
2. AMS 3618
3. AMS 3619
4. AMS 3684
5. AMS 3845/1
6. AMS 3845/2
7. AMS 3847
8. MIL-R-83330

* AMS SPECIFICATIONS ARE PUBLISHED BY THE SOCIETY OF AUTOMOTIVE ENGINEERS.

COMPOSITES

- MILITARY HAND BOOK 17 (PART 1)

  MECHANICAL PROPERTY DATA PRIMARILY FOR AEROSPACE VEHICLES

- MILITARY SPECIFICATIONS

  MIL-A-46103C

  LIGHTWEIGHT, CERAMIC FACED ARMOR (BODY ARMOR & AIRCRAFT SEATS)

  MIL-A-46108B

  TRANSPARENT ARMOR - VISION BLOCKS, WINDSHIELDS

  MIL-A-46166 (MR)

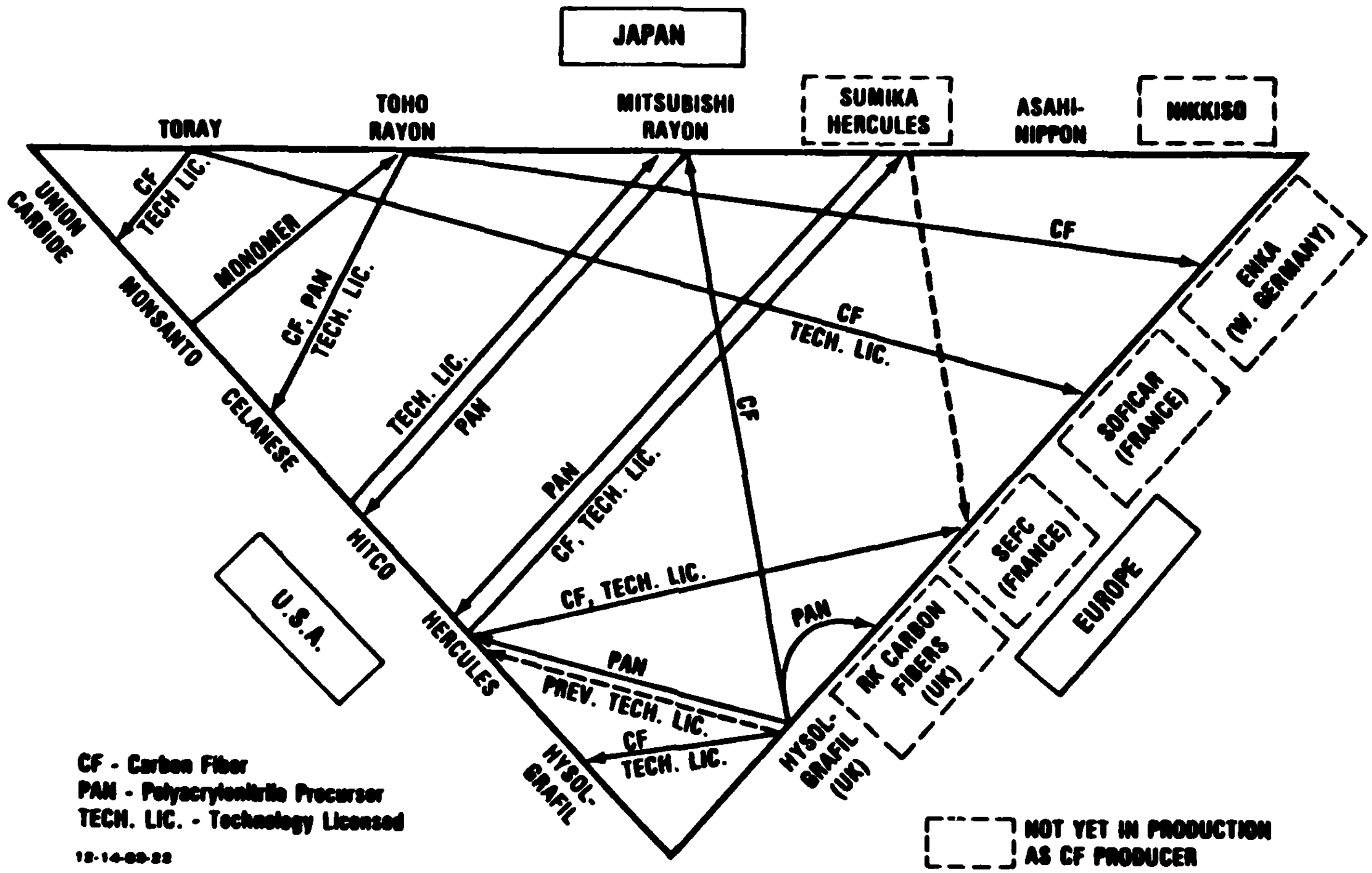
  LIGHTWEIGHT REINFORCED PLASTIC/COMPOSITES ARMOR - PILOT SEATS, SIDE AND FLOOR PANELS

<u>COMPOSITE TEST METHODS</u>

DoD ADOPTED OVER 60 ASTM TEST METHOD STANDARDS

- MECHANICAL
- THERMAL
- OPTICAL
- ELECTRICAL
- ENVIRONMENTAL
- CHEMICAL
- MISCELLANEOUS PHYSICAL

WORLDWIDE INTER-RELATIONSHIPS-PAN-BASE FIBER



SOURCE: S. L. CHANNON, IDA STUDY
MARCH 1984

PROPOSALS FOR A COMMON INTERNATIONAL APPROACH

STRUCTURAL AIRWORTHINESS CERTIFICATION

A. W. CARDRICK

RAE, FARNBOROUGH

DIFFERENCES OF UK APPROACH AND MIL-A-83444

- ABNORMAL STRUCTURE OR ABNORMAL LOADS?
- INITIAL CRACKS OR HIGHER STRESS LEVELS?
- LIFE PREDICTION?
- INSPECTION INTERVALS?

UNITED STATE STRONGLY DEPENDENT

ON

FOREIGN MATERIALS

- HAS LARGEST FABRICATON BASE
- LARGEST CONSUMER OF
  COMPOSITE MATERIALS

U.S. NAVY QUALIFICATION PRACTICES

Michael Dubberly
Naval Air Systems Command

U.S. NAVY QUALIFICATION PRACTICES

Michael Dubberly

Naval Air Systems Command

I want to cover two main topics in the time we have.- (a) how we go about selecting materials for a new aircraft program, and (b) structural certification procedure as we go through a full scale development program. Relative to the material systems there will be some discussion on the thought process that drives us to select one or the other material systems, the qualification procedures once that material is selected and some concerns that I have in the way we currently do business in the composite materials sector.

On certification issues, we'll just cover the broad view in terms of how it compares to what we would do for comparable metal structures, some of the characteristics that drive you to certain types of testing and an overview of the static and fatigue testing (full scale and small scale) as it involves a new full scale aircraft development program, the options and some words on what we have done in the past and what we are likely to do in the near future. Then, I will summarize and include some examples of current uses and immediate future uses.

Relative to selection considerations, there are two main ingredients - performance and experience. In any new aircraft, you are going to try to get the weight down. A new material system has to come in near the leaders of the pack relative to strength and stiffness. If not, it is not likely to receive much consideration. It also has to have good processing characteristics because, in a production environment, we can't afford the kind of luxuries that we can in a laboratory environment. Relative to experience, (and this certainly is a key issue) we would like to do nothing better than to adopt those new systems, but they are not quite there yet in terms of an experience base. So we play the role of pushing the technology on the one hand and, on the other hand, acting as a gatekeeper when we commit to full scale production. We consider how much material has been produced, whether the supplier appears to have a stable production base, the consistency of properties, the size of the existing data base (not that we are looking for an allowables data base, necessarily) and a warm feeling that, when you do get to the allowables data base, you are going to achieve the advertised properties, and lastly, some fabrication experience. This is more than just small specimens. We have run into a number of scale-up problems over the years in which the material went together fairly well when we were making small specimens but, when we began to make large panels, difficulties arose. All of the critical selections are either made by the Navy or subject to Navy approval. We feel that this is too important to leave to the contractor himself, so it is a joint venture.

Once we have selected a system and launch into a material qualification program, typically, as part of the full scale development program, we only have to be concerned about the qualification of the material as opposed to going into the further development of aircraft components. The allowables program consists of developing either "A" or "B" basis allowables. To date, we have been using "B" basis allowables but I don't know that that will necessarily continue to be the case. Typically, that will run in the neighborhood of 800 to 1000 specimens, will take about a year and will cost $1 - 1.5 million, depending on the extent of the usage and how much experience we have with the particular system that has been chosen. For a major program, we usually qualify only one system. This has to do with the costs and the schedule constraints, and once we've selected a system that we believe to be the best for the application, there is hardly any time or money to qualify more than one.

In terms of manufacturing experience, we would tailor the early stages of the program to acquire substantial hands-on experience prior to beginning to make something that we are going to count on either as a full test article or a flight article. That process also includes developing the process specifications, the incoming inspection testing and so forth. The latter part is crucial relative to being able to assess the quality of the materials that are received and the consistency of the materials. Some of my concerns relative to the materials systems that are in place today relate to receiving inspection. We do that quite extensively and, frankly, it is due to the lack of a verifiable composition or process control at the supplier. We are not suggesting that everybody does not do the best they can and are well intended, but there is some history of variation of products over a period of time, particularly in the early days. When those things occur, the proprietary nature of most of the products prevents complete openness by the supplier in resolving the problem, so we are often left with uncertainty about what went wrong and realize that it may happen again. Lastly, the fabrication process is fairly sensitive, much more so than with the metals. Metals have their own problems, but they aren't nearly as sensitive in the production operation as composites are.

The second subject is certification. In the broad view, the differences in certification for composites and metals depends on how far up the chain you are when you look down. At a high enough level, it looks about the same in terms of what we would do relative to the analysis, development test, major full-scale testing, floght testing and so forth. Again, from a program manager's or higher perspective, it doesn't look appreciably different; however, when we set out to design test programs, we try to design programs to interrogate the specific characteristics of the material and the failure modes. Over the years, we have developed fairly standard practices for metals, but this is the result of a lot of feedback over a period of years. Comparing composites and metals in terms of their characteristics, the composites are fairly linear and metals are ductile, the composites are statically notch-sensitive whereas the metals are not. One of the main problems with composites is the low strength through the thickness, whereas metals have a relatively low directionality. Analytically, that is difficult to deal with, because obviously we can't do three-dimensional analysis all around a large airplane. Composites exhibit an appreciable temperature and moisture sensitivity that the metals do not, at least over the short term. Composites don't corrode but they certainly experience some reduction in properties. In metals, we are typically used to watching out for the tension loaded structure in fatigue but, in composites, it is just the opposite. Both are reasonably notch sensitive. Composites have a high variability which is one of the chief problems in the qualification of a composite structure to try to obtain the same degree of confidence as you would have in a metal structure.

In terms of a certification program, (both statically and in fatigue) we try to account for those items which make composites difficult to deal with such as the environment, the variability and the fact that most of our structures nowadays are neither all composite nor all metal, but a mixture of both. Conducting a conventional ambient test and interpreting the data in the normal manner that we would do in full scale testing, is clearly inadequate. Over the last few years, we have adopted the building block approach in which we produce progressively more complex structures, starting with the allowables on simple specimens to joints, to a unique section of a wing or fuselage to a component, and maybe one or two spar boxes of a multi-spar wing. We try to get an environmental test on the largest components that are practical (say a three spar box on an F-18 wing - something about three feet wide and 6-8 feet long).

In the area of the full scale tests, there are a number of options. Most of those are going to be ambient tests. In accordance with our specifications, we compare the measured strains to the allowable strains developed during the allowables program. Just getting the structure to reach the normal 150 percent does not pass the test. We can test to a factor above 150 percent; if the design is adequate, the composites can clearly handle this whereas the metals frequently can't. We are always dealing with a mixed structure. Full scale environmental tests are generally impractical, unfortunately. So we've tested to failure and we've compared the strains all around the structure with the allowables. In other words, when you are at 150 percent, if the strain that you are measuring exceeds the design allowable, then you have failed the test whether the structure broke or not.

Relative to fatigue, the same three factors are important. We have adopted the same building block approach as before, building progressively larger and larger specimens, and then conduct conventional fatigue tests. These are similar to and usually the same as the static specimens. What is considered conventional in the Navy isn't necessarily the same as what you might see elsewhere. Our fatigue tests are generally done to severe loads relative to the expected usage. They are not intended to represent the normal expected usage. This is not a function of composites but has been the general practice over a number of years. We test to a 2 lifetime test and perhaps to three or four if nothing happens, but usually there is a lot happening. Or we can test with higher load levels in order to interrogate the composites. To some extent, what we adopt is the tailored spectra but it really doesn't end up being appreciably different than our past practice. As you begin to add more and more high loads to a spectrum, if you look at the life of the metal parts that are the ones that will fail first, (unless you erred in the composite design) then the life tends to initially get longer as you get those residuals in from the metal, and then it tends to get shorter as you get more loads and the high loads seem to dominate the life. We always try to make it a practice to be over on the far right hand side of the curve so that the high loads are dominating. Composites are very sensitive to a few high loads so, while we don't have a test procedure that gives you the same level of certification confidence in the composites as you get in the metals, it is moved in that direction as much as the metals will allow.

The last item has to do with some efforts that we have under way in the research area now. There is certainly a possibility that you can tell something about the fatigue life from the static test results if you can get to a high enough load level and you have fully quantified the fatigue characteristics of the particular composite material system.

Lastly, in summary, the conventional static and fatigue tests, all by themselves, without any modification from tailoring that I have described, just really don't tell you what you need to know. The building block approach is a key element in the certification procedure in terms of supporting the full scale test results. The full scale test options that are available are, to some extent, application sensitive, depending on the nature of the structure, the environment and the scope of development testing. In some cases, we have taken a much less than desirable approach to producing a piece of production hardware. The mixed structure is going to remain a difficult area to deal with. When we do the static tests, the bias is to get up to the high loads. In the fatigue tests, we are really interrogating the metals in full scale testing.

Lastly, I just wanted to show you a few of our primary applications to date. On the F-18, the primary areas for composites are the wing skin, the dorsal covers and the horizontal and vertical tails. The wings and the horizontals and verticals all have metal substructure and are about 10 percent graphite which works out to about 1200 pounds per aircraft. A number of doors and secondary structure are also included as well as the flaps. To date, we really have not had bad experiences with the F-18 and composite materials. We have certainly had a few difficulties, but nothing that would make us think that we might have made the wrong choice. The AV-8B is a much smaller aircraft but it has higher use of composites. It also has about 1200 pounds but the overall structural weight is only 4600 pounds compared to 10-12,000 for an F-18. The wing of the AV-8B is really the centerpiece and was the product of a long development program much preceding the full-scale development. The horizontal tail and forward fuselage are more recent applications. The wing is a full depth structure, probably one of the first of its kind in a production application. We've recently adopted a few other composite parts in hot areas, using bismaleimide and a few others, not extensively, but just where the temperature required it. Overall, composites comprise about 25% of the structural weight. Lastly, the new aircraft that we are launching is being described as the all-composite aircraft, (all means about 60%, which is a lot). The material system for this is the IM6 - 3501-6. The other two systems were either AS-1 or AS-4 fibers in the same resin system. All the primary structure in this aircraft is going to be graphite, with a few fittings of metal. The majority of the structure is composite, including the wing, fuselage, empennage, and so forth.

U.S. NAVY CERTIFICATION PROCEDURES FOR COMPOSITE AIRCRAFT STRUCTURES

- o MATERIAL SYSTEMS
  - -SELECTION CONSIDERATIONS
  - -QUALIFICATIONS PROCESS
  - -CONCERNS
- o STRUCTURAL CERTIFICATION
  - -BROAD VIEW
  - -METAL VS. COMPOSITE CHARACTERISTICS
  - -STATIC
  - -FATIGUE
  - -SUMMARY

CONSIDERATIONS IN SELECTING COMPOSITE MATERIALS SYSTEMS FOR NEW PRODUCTION AIRCRAFT

- o PERFORMANCE
  - PROPERTIES
  - PROCESSING CHARACTERISTICS
- o EXPERIENCE
  - MATERIAL PRODUCTION
  - SIZE OF EXISTING DATA BASE
  - FABRICATION EXPERIENCE

ALL CRITICAL SELECTIONS EITHER MADE BY THE NAVY OR SUBJECT TO NAVY APPROVAL.

COMPOSITE MATERIAL SYSTEM QUALIFICATION PROCEDURES FOR NEW PRODUCTION AIRCRAFT

- o ALLOWABLES PROGRAM
  - DEVELOP "A" OR "B" BASIS PROPERTIES TO BE USED FOR DESIGN
  - TYPICALLY 800/1000 SPECIMENS, 8/12 MO AND $1/1.5 M

- o MANUFACTURING EXPERIENCE PROGRAM
  - SUBSTANTIAL "HANDS-ON" FABRICATION EXPERIENCE REQUIRED PRIOR TO MAKING FIRST TEST/FLIGHT PART
  - DEVELOP PROCESS SPECIFICATION
  - INCOMING INSPECTIONS/TESTS

- o FOR A MAJOR PROGRAM WE USUALLY QUALIFY ONE MATERIAL SYSTEM

CONCERN WITH COMPOSITE MATERIAL SYSTEMS.

- LACK OF VERIFIABLE COMPOSITION OR PROCESS CONTROL AT THE SUPPLIER
- LACK OF OPENESS BY SUPPLIERS IN INVESTIGATING/RESOLVING PROBLEMS
- FABRICATION PROCESS SENSITIVITY

STRUCTURAL CERTIFICATION

- o AT BROADEST LEVEL........
  - CERTIFICATION PROCESS FOR COMPOSITE COMPARABLE TO METALS
- o ANALYSIS
- o DESIGN DEVELOPMENT TESTS
- o MAJOR STATIC AND FATIGUE TEST
- o FLIGHT TEST

SOME CHARACTERISTICS BEARING ON CERTIFICATION

COMPOSITES	METALS
o LINEAR STRAIN TO FAILURE	o DUCTILE
o STATICALLY NOTCH SENSITIVE	o NOT STATICALLY NOTCH SENSITIVE
o PLANES OF WEAKNESS NORMAL TO THICKNESS (INTERLAMINAR INFLUENCE COMPLEX FAILURE MODES)	o LOW DIRECTIONALITY
o TEMPERATURE/MOISTURE SENSITIVE	o INSENSITIVE
o FATIGUE LIFE - COMPRESSION DOMINATED	o FATIGUE LIFE- TENSION DOMINATED
o FATIGUE - NOTCH INSENSITIVE	o FATIGUE - NOTCH SENSITIVE
o HIGH VARIABILITY IN STATIC STRENGTH AND FATIGUE LIFE	o LOW TO MODERATE VARIABILITY

STATIC STRENGTH CERTIFICATION

(ACCOUNT FOR ENVIRONMENT, VARIABILITY, MIXED STRUCTURE)

- CONVENTIONAL CONDUCT AND INTERPRETATION OF AMBIENT TEST TO 150% DLL

  ....INADEQUATE CERTIFICATION DATA

- BUILDING-BLOCK APPROACH REQUIRED

  ....PROGRESSIVIELY MORE COMPLEX TEST ARTICLES

  - LOW COMPLEXITY SPECIMENS (SINGLE FAILURE MODE)
  - REPRESENTATIVE DESIGN FEATURES
  - SUBCOMPONENTS - MAINTAIN LOAD PATH AND COMPETITIVE FAILURE AND FIDELITY

- FULL-SCALE AIRCRAFT TESTS

  OPTIONS:

  1. AMBIENT TEST TO 150% DLL AND COMPARE MEASURED STRAINS TO ALLOWABLES
  2. AMBIENT TEST TO REQUIRED FACTOR ABOVE 150% DLL
  3. ENVIRONMENTAL TEST

FATIGUE CERTIFICATION FOR COMPOSITES

- o ACCOUNT FOR - o VARIABILITY
  - o ENVIRONMENT
  - o MIXED METAL AND COMPOSITES

- o OPTIONS FOR FULL SCALE TESTING (BASED ON BUILDING BLOCK)

  1. CONVENTIONAL FATIGUE TEST

  2. LONGER FATIGUE TEST (MORE SIMULATED LIFETIMES)

  3. FATIGUE TEST WITH FACTORED (HIGHER) LOAD LEVELS

  4. FATIGUE TEST WITH "TAILORED" LOAD SPECTRA (SPECTRA ALTERED TO MAXIMIZE DIFFERENCES BETWEEN COMPOSITES AND METALS RESPONSE TO HIGH LOADS)

  5. STATIC TEST RESULTS USED TO ASSESS COMPOSITES FATIGUE LIFE

TECHNICAL OBSERVATIONS.....SUMMARY

- o CONVENTIONAL STATIC AND FATIGUE TEST MAY PROVIDE REDUCED "STAND-ALONE" CERTIFICATION INFORMATION

- o BUILDING-BLOCK APPROACH REQUIRED

- o FULL SCALE TEST OPTIONS AVAILABLE BUT NO SINGLE BEST APPROACH
  ....JUDGEMENT DEPENDS ON:

  - NATURE OF STRUCTURE
  - EXPECTED ENVIRONMENTAL DEGRADATION
  - SCOPE OF DEVELOPMENTAL TESTING

- o MIXED STRUCTURE - MOST DIFFICULT CASE

- o STATIC TEST - BIAS TO COMPOSITES

- o FATIGUE TEST - BIAS TO METALS

U.S. AIR FORCE QUALIFICATION PRACTICES

John Lincoln
Aeronautical Systems Division

U.S. AIR FORCE QUALIFICATION PRACTICES

John Lincoln

Aeronautical Systems Division

I hate to start off a presentation with an apology. I don't have pictures to show you of airplanes, and the reason for that is that, 10 years ago, the Air Force was bearish on composites. They viewed composites as having a number of inhibitors. The Navy and Army pushed forward and moved into composites while the Air Force lagged behind. In the last 10 years or so, a number of these inhibitors have been removed. Government and industry programs, particularly the durability program at Northrop and the damage tolerance program at Boeing, have been very influential in removing these inhibitors. They have been conducted under contract to AFWAL. The things I'm going to show you are still pretty much in a stage of evolution. Things that we said 2 or 3 years ago were different than what I'm going to tell you today. If we had to go to press today and design an airplane out of composites, the type of things I'm going to tell you are what we would be doing.

I'll talk first about aircraft. Back around the late 1950 time period, the Air Force got tired of cracking metal airplanes and instituted the aircraft structural integrity program. This has persisted through the years and has now become quite formalized. The details of that program are covered in MIL STD 1530 which is required by Air Force Regulation 80-13. The regulation describes the details of the aircraft structural integrity program, the details of the master plan, the responsibilities of the users, the responsibilities of the Air Force Systems Command and the Air Force Logistics Command. It is really a cradle - to - grave operation composed of these five tasks - design information, design analyses and development tests, full scale testing, force management data package and force management. The last task is usually an Air Force only responsibility. The first four tasks are usually done through a contractor. I am going to talk to these first three tasks relative to composites. In those five tasks, there are 35 elements.

Task 1 has included material allowables; right now, we are thinking in terms of B basis allowables, to include the effects of temperature and moisture history as imposed on the structure. If temperature and moisture degrade the material, it will not be a very valid competitor. In terms of analyses, which are a Task 2 responsibility, things of interest there are strength, durability, damage tolerance, and they include flutter because of the modulus implications in composites. Damage tolerance considers a worst case type defect with which the structure may have to live. In terms of analyses on damage tolerance, we are asking that the damaged structure be required to survive two life times, without failure. Durability requirements are for two life times without impairment of function. Tests in Task 2, include design development tests and some damage tolerance testing. Task 3 has the full scale static tests and the full scale durability tests.

It is true that the building block approach is necessary for composites. I guess it is true for metals, too. I don't think we have emphasized the building block approach enough for metals, but it's always been there, and we put great stock in the final static and durability testing. It is mandatory in composites that you understand the composite structure through coupons, elements, subcomponents and components. If nothing more, you've got to do this, strictly on an economic basis, because you can't afford to do it in full scale. In coupons and elements, we are looking at the effects of moisture and temperature on the allowables; we evaluate the effects of high energy impacts up to 100 foot-pounds and living with that type of impact for two lifetimes. At this level, we also need to determine the potential failure modes and this examination may take more testing than you would think would be normally required in a metal structure. Lastly, in the design development tests, you need to establish the full scale test requirements.

We feel that the full scale durability tests really can be a test of the metals. Every airplane that we can conceive will be a mixture of composite and metal. The durability of composites will be established in the design development tests. We think that composites have superior durability capability. It is a problem in a sense, because we have something that is very good, but it takes an extensive amount of testing to verify that goodness. We may have to test in the early development tests for a number of lifetimes to obtain the same level of confidence that we have in metal structures. We think also that the damage tolerance of the structure will be developed in the building block process. Currently, in metal aircraft, there is an option of using the full scale article or components to validate the damage tolerance capabilities. For composites, because of the concern of shift in failure modes and the need for all of the impact testing, delamination testing, and so forth, full scale testing is probably not in the realm of reality. Right now, we are working with Boeing in setting up requirements on damage tolerance; those are being coordinated through AIA and include impact damage, delaminations, scratches, bird strike and lightning strike.

I would like to say a word about missiles and spacecraft. The general requirements for strength and rigidity of missile structures are covered in MIL-8856A. Unfortunately, that was last updated in October 1969 but does not say anything at all about composites. They do rely on the 88 series but it is hard to find specific requirements for composite structures in missiles and spacecraft. For missiles that are carried on aircraft and would affect the safety of an aircraft, we do apply the aircraft structural integrity program. For missiles that are not on the aircraft, the ASIP does not apply. So there seems to be some work needed for requirements for these types of vehicles. The qualification approach has been one of testing to fracture, based on rather rudimentary analyses. There is some evidence that the analysis techniques are improving. For exit cones and nozzles, those analyses are pretty complex.

USAF REQUIREMENTS FOR COMPOSITE STRUCTURES

BASIS FOR AIRCRAFT

- MIL-STD-1530 DEFINES THE AIRCRAFT STRUCTURAL INTEGRITY PROGRAM (ASIP) AS REQUIRED BY AFR 80-13
- FIVE TASKS OF ASIP
  - DESIGN INFORMATION
  - DESIGN ANALYSES AND DEVELOPMENT TESTS
  - FULL-SCALE TESTING
  - FORCE MANAGEMENT DATA PACKAGE
  - FORCE MANAGEMENT

KEY FEATURES OF ASIP

- MATERIAL ALLOWABLES - B-BASIS (INCLUDES EFFECTS OF TEMPERATURE AND MOISTURE HISTORY)
- ANALYSES
  - STRENGTH
  - DURABILITY
  - DAMAGE TOLERANCE
  - FLUTTER
- TESTS
  - DESIGN DEVELOPMENT TESTS
  - FULL-SCALE STATIC
  - FULL-SCALE DURABILITY
  - DAMAGE TOLERANCE

DESIGN DEVELOPMENT TESTS

- BUILDING BLOCK APPROACH
  - COUPONS
  - ELEMENTS
  - SUBCOMPONENTS
  - COMPONENTS
- EVALUATE EFFECTS OF MOISTURE AND TEMPERATURE ON ALLOWABLES
- EVALUATE EFFECTS OF LEI AND HEI
- DETERMINE POTENTIAL FAILURE MODES
- ESTABLISH FULL-SCALE TEST REQUIREMENTS

FULL-SCALE STATIC TEST

- TEST PERFORMED AT ROOM TEMPERATURE WITHOUT SPECIAL MOISTURE CONDITIONING - UNLESS THE DEVELOPMENT TESTS CANNOT ADEQUATELY DEMONSTRATE THAT THERE IS NO CHANGE OF FAILURE MODE DUE TO ENVIRONMENT
- NO INCREASE IN LOAD TO ACCOUNT FOR SCATTER IN STRENGTH PROPERTIES
- NO INCREASE IN LOAD TO ACCOUNT FOR ENVIRONMENTAL EFFECTS

FULL-SCALE DURABILITY TEST

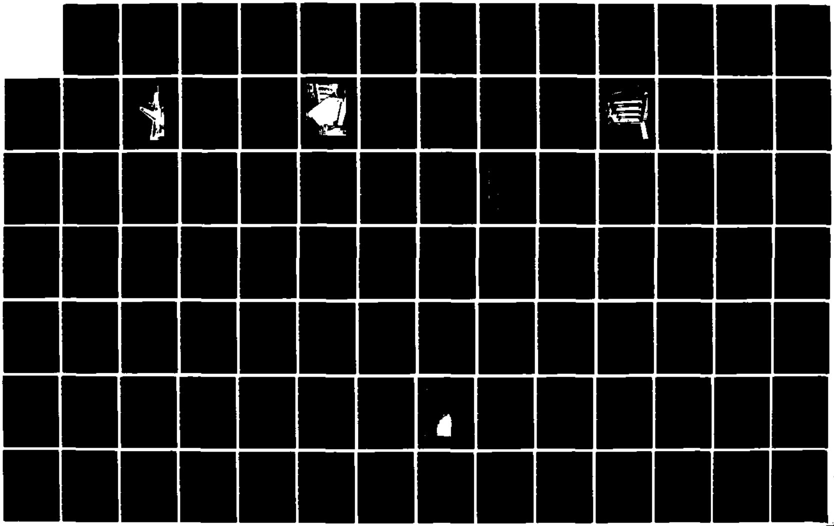
- PRIMARILY PERFORMED TO TEST METALLIC PART OF THE STRUCTURE - DURABILITY OF COMPOSITES VERIFIED IN DEVELOPMENT TESTS
- ACCOMPLISHED AT ROOM TEMPERATURE WITHOUT SPECIAL MOISTURE CONDITIONING

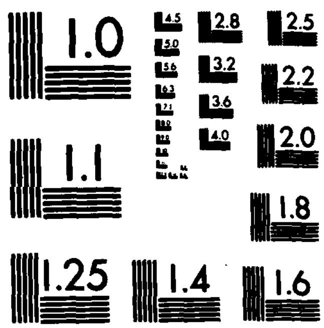
DAMAGE TOLERANCE TEST

- DAMAGE TOLERANCE CAPABILITY ESTABLISHED THROUGH BUILDING BLOCK APPROACH
- INCLUDES: DELAMINATIONS
  IMPACT DAMAGE
  SCRATCHES
  BIRD STRIKE
  LIGHTNING STRIKE

AD-A149 039 PROCEEDINGS OF COLLOQUIUM/WORKSHOP ON COMPOSITE MATERIALS AND STRUCTURES..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA S L CHANNON JUL 84 IDA-D-70 2/6

UNCLASSIFIED MDA903-84-C-0031 F/G 11/4 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

BASIS FOR MISSILES

- GENERAL REQUIREMENTS DEFINED IN MIL-M-8856A IN COMBINATION WITH MIL-A-8860 SERIES SPECS, ETC.
- NO PROGRAM FOR MISSILES EQUIVALENT TO THE ASIP FOR AIRCRAFT

N.A.S.A. QUALIFICATION PRACTICES

Louis Vosteen
N.A.S.A. Langley Research Centre

N.A.S.A. QUALIFICATION PRACTICES

Louis Vosteen

N.A.S.A. Langley Research Center

Since NASA is not a procurer of aircraft, in the sense of the military or the commercial operators, our involvement in the certification process is considerably different from that described by the other speakers. I'll try to explain to you what that process is and how we are involved. Our role in the certification process is really peripheral to the direct line of communication between the FAA and the industry, which involves the development of the certification regulations, the FARs, development of standard practices, guidelines and the certification process itself. We are involved in working with the industry, through our R & D contracts, to define the technical needs of the industry, and we in turn, in our research activities, define to the industry problems they might encounter in flying the materials. We exchange technical information with them which should enable them to develop the materials and processing to satisfy the requirements of the FAA. We work with the FAA in defining technology needs, and they define to us what their concerns are and we try to develop the information to provide them with a basis for rule-making. In some cases, we get involved in joint programs with the FAA to satisfy a particular requirement. For instance, in past years, we have worked with them in the fire safety area, evaluating materials and processes to improve the fire safety of aircraft. We are currently in a program looking at the crash safety of transport aircraft in joint programs evaluating new materials and defining the loads that the structure experiences during a survivable crash.

NASA has been involved in the certification process for various components shown here,* beginning back in 1973,

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*p. 101.

with the L1011 fairing panels up to the present day, where recently some primary structure has been placed on aircraft. For example, 737 horizontal stabilizers are being installed on aircraft and going into commercial service. All the components shown have been certificated by FAA with the exception of the CH53 cargo ramp. They are a combination of aramid fiber reinforcement materials, graphite reinforced materials and combinations of both on one component. As you can see, the number of flight hours amassed to date exceeds 3 million flight hours of components actually in service with high times of nearly 30,000 hours.* To date, there have been no unusual circumstances with these materials. There has been routine maintenance; in many cases, the maintenance has been less than that on metal parts. The certification for these components generally follows a process outlined on this slide.**

All parts have to show compliance with the airworthiness requirements of FAR 25 and the guideline circular AC 20-107 that was developed about 8 years ago. NASA was involved in the development of that circular in an advisory capacity, the principal interaction being between the FAA and the industry in developing guidelines for compliance with the regulations. In general, the approach has been to provide compliance by analysis supported by test as opposed to test with analysis as a supplement. This involves a variety of tests-component tests and full scale tests, including flight tests. In some cases, depending on the application on the aircraft, and location on the aircraft and particular conditions, there might be special requirements imposed such as those listed.***

As an example, I would like to take you through what was done on one particular component, the DC10 vertical stabilizer, which is still under development. The article is about 25 feet in length. The certification plan generally consists of a number of documents that have to be

*p. 101.
**p. 102.
***p. 102.

submitted to the FAA on how the industry proposes to satisfy the FARs. Each of these would comprise a document and each one has an objective for satisfying the requirements for certification. Generally, you start with some data base for the material, doing some analysis, developing a test program, using the building block approach as the military people described, with sub-component tests, full scale tests and proceeding on to flight tests. Sub-component tests typically would involve components like this, each one having a particular critical element in it that you want to verify at the component level. The spar shear web, for example, is a heavily loaded part near the root of the structure, where you have cut-outs, you have transitioning from a sine wave corrugated shear web to a solid laminate in the vicinity of cut-outs, and it is actually the shear load in this area which is critical. The rudder support fitting represents a point load application into the structure where you try to transfer the heavy loads from control actuators into a rib/spar junction and the skin. The combined load panel is a skin surface and, in this case, the combined load is transverse and shear loading representing rib and spar intersections and the spar root attachment transitioning from sine corrugated into a solid laminate into heavy titanium fittings which transfer all of the load on four spars into the main structure of the aircraft. This then becomes the critical area.

In this particular program, some of the requirements for satisfying environmental conditions were done with a full scale portion of the fin. This represents about the lower third of the structure. This article was built early in the program and went through environmental testing. The environmental fixture went into a large conditioning chamber in which you could control the humidity and the temperature and the article was loaded in the facility at high temperature and low temperature after moisture conditioning. Results from a test such as that are then analyzed to see whether there are any critical conditions. The cold dry condition may be the one critical condition for a stress concentration condition or fracture condition and the hot wet condition would be for stiffness effects or lower strength. As you can see* in this particular case, up to 100% limit load, all of these curves appear about the same indicating that, at that temperature (about 140°), the material did not show any significant difference in performance. This is typical of a full scale ground test program for a flight article. It would include limit load cycle on the article to begin with, then the addition of a fatigue lifetime, a test to the ultimate design load, then the article would be damaged and another fatigue lifetime placed on the article to see if the damage progresses, a limit load cycle at the end of that time to see if the article still has its original strength. The damage at that point would be repaired and then the article tested up to its failure.

Another approach to the environmental conditions was done on the L1011 vertical fin, in which a number of components were built representing some of the heavily loaded parts at the base of the fin. This is a spar section about 6 feet long, 2 feet deep at the root and a cover section about 4 feet long and 2 feet wide which is in a heavily loaded compression and shear area near the rear spar, near the root. Originally, 10 articles of each type were built and statically tested to determine the variability in the component with no conditioning of any kind. The tests indicated that these components built in a production environment had a scatter of less than 6%. Then, 12 articles of each kind were placed in environmental chambers which simulated the flight loads and flight moisture and temperature conditions over a 20 year lifetime of the

*p. 108.

part. This happens to show 6 of the spar elements in the chamber.* A typical cycle that these went through is shown.** In order to compress the testing time on these articles, at each phase of the flight, about 6.2 flight cycles of load would be added. This involved the lower temperatures which would be associated with the cruise condition on the vehicle and descent flight through the lower atmosphere. The upper humidity conditions were varied to go from a 0% RH to a very moist condition and, during the 36,000 flight loads that were put on the article during this life test, there were what you might call over-conditions in which the temperature was cycled up to 160° during 40 cycles and up to 180° during 10 cycles. Following this total testing time which simulate 20 years of flight, these articles were taken out of the facility and are now in the laboratory for residual strength testing.

In conjunction with these programs, and to try to get at the area of standardizing the materials and specifications, we are currently involved with the transport builders, Boeing, Douglas and Lockheed, to develop an industry standard specification for toughened materials. This specification deals only with a 350° curing toughened epoxy system. We are not trying to specify a particular material, but rather the kind of characteristics that the material should have. The principal purpose is to allow the aircraft developers to go to the materials suppliers with a common set of specifications so that there can be competition for the materials themselves and also a single basis which they know that the user is going to use as his basis for evaluating their materials. It specifies such things as the test procedures that will be used to determine the properties of that material, qualification procedures that will be used on various batches of materials, qualification procedures that the supplier must go through in order to prepare that material. It would include physical

*p. 111.
**p. 112.

properties on the prepreg and chemical information on the prepreg and on the fiber coating, simply to fingerprint it, i.e. to say that the material has a certain characteristic, and as later batches come along, the user can determine whether that material is changing. At this time, it is not a specification for a particular chemical structure or a particular type of material. It does include such things as processing limits. The material has to process in a certain way with a certain temperature cycle or a certain range on the temperature cycle, not being exactly specific.

The progress to date is that we have defined the scope of the specification, what it will and will not include, the test methods and requirements have been identified, and some target values that the material will have to exhibit. The draft is currently being reviewed by the industry and by NASA. Along with the testing, we have found that data bases in general have not been transferred between companies. This is partly because the FAA says that they are not sure that the material made by Company A is the same as Company B, and so on, even though they may be obtaining their raw materials from the same supplier. We feel that one of the goals in this program is to develop material transferability between programs. Along those lines, we have tried to develop a set of tests for toughened materials. The ASTM specifications are good for a lot of things in determining the physical properties of materials, but they were not really developed with the idea that we are dealing with certain kinds of materials and the kind of performance from that material.

Of course, the toughness and damage tolerance are key factors now. So we have defined 5 tests that we call standard tests for toughened resin composites. These include compression after impact test, an open hole compression test for correlation with this type of test, an open hole tension test, fracture toughness where this is an edge delamination where you select a layup which will delaminate on the edge, and a double cantilever beam. These may not produce what you would call design data but they should be a method for getting direct comparison between materials and data coming from different sources and tested in different laboratories. The specimen configurations and test procedures are both defined, so now we hope we can develop a data base which can, in a more qualitative sense, compare materials from a variety of sources. Hopefully, eventually, information gained here will enable us to go back and find out what are the physical properties you want in order to produce the particular result.

In summary, some of the key factors in the process of certification of composites involves the data base, and transferability of data from one organization to another. This will have to come from standardization of the specifications to the extent that we can. I don't think we are going to get away from proprietary materials, nor should we get away from proprietary materials because that is the stimulus to the industry to continue to improve. However, I think we can develop specifications that will specify the limits within which we can work with the material and the supplier can then know what targets he has to achieve in order to have an acceptable material to the industry. Of course, data transferability would depend upon standard tests throughout the industry so that you can know when data from one source is equivalent to data from another source.

I didn't touch on design verification, but that is another key feature in the certification process. The analysis methods must be verified. In general, a global finite element analysis is generally done on the structure and then detailed analyses done in areas where the internal loads indicate we may have a design problem. I don't think we are to the point where we can always pinpoint where these key areas might be, even though we perform the global analysis and get the internal load distribution. I don't think we know enough at this point about the real features of failure in composites to identify those areas and do the analysis before we do the test. We can predict the general behavior of the structure, but the deficiency lies in being able to pinpoint the failure and the load level at failure. Quantitative methods of NDE are needed. I say "quantitative" because I think the ultimate here is to have some means of determining the state of the article after it has been in service so that you can look at it by some means and determine the strength of the material at this point. Until we get a lot more experience with composites, I don't think we'll be able to do that.

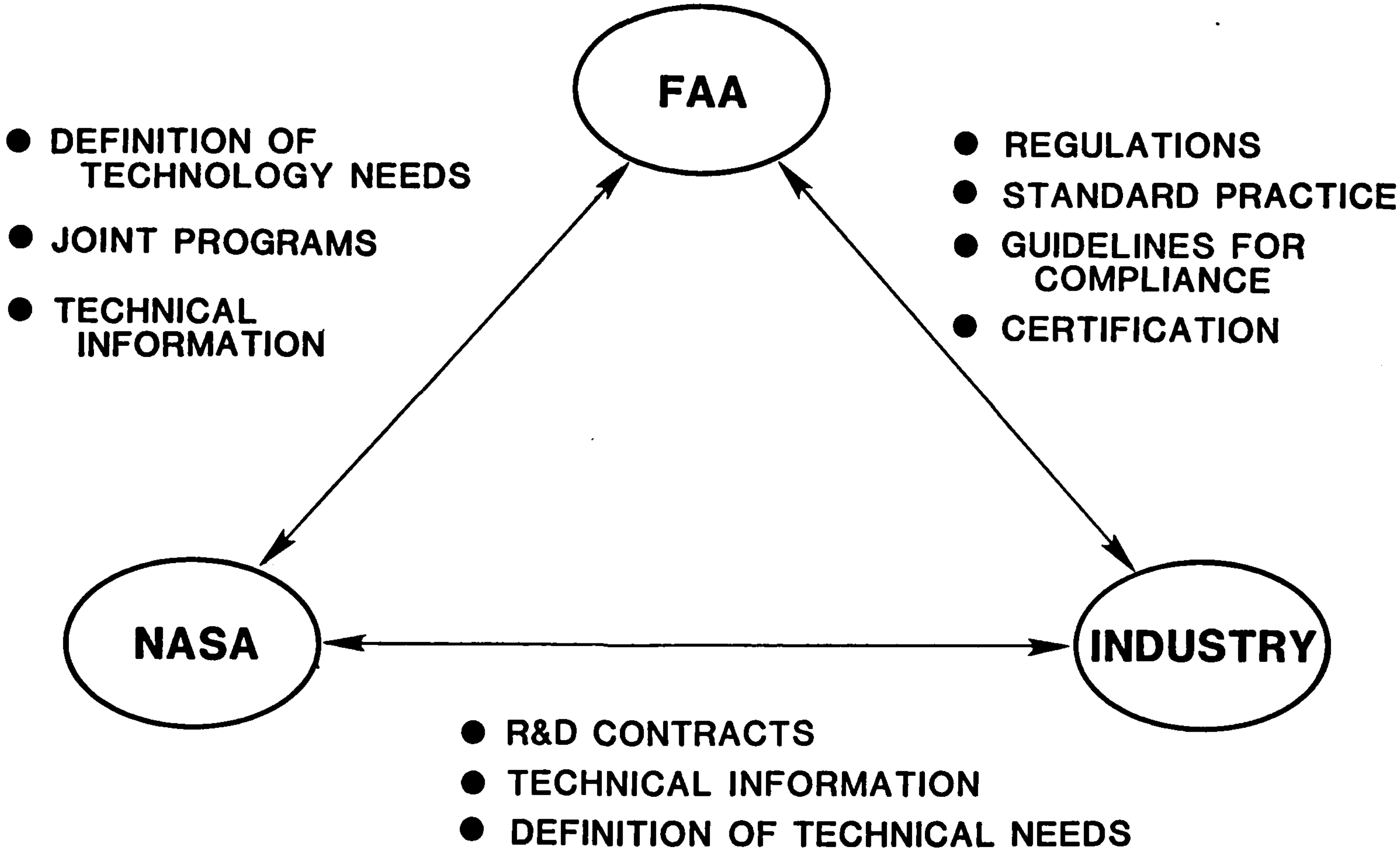
CERTIFICATION OF COMPOSITES--A NASA PERSPECTIVE

LOUIS F. VOSTEEN
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

COLLOQUIUM/WORKSHOP ON COMPOSITE MATERIALS AND STRUCTURES:
STANDARDIZATION, QUALIFICATION, CERTIFICATION

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, DC
MAY 8-10, 1984

NASA ROLE IN CERTIFICATION



NASA COMPOSITE STRUCTURES FLIGHT SERVICE SUMMARY

AIRCRAFT COMPONENT	TOTAL COMPONENTS	START OF FLIGHT SERVICE	CUMULATIVE FLIGHT HOURS	
			HIGH TIME AIRCRAFT	TOTAL COMPONENT
L-1011 FAIRING PANELS	18	JANUARY 1973	29,310	480,840
737 SPOILER	108	JULY 1973	29,430	1,996,880
C-130 CENTER WING BOX	2	OCTOBER 1974	6,700	13,300
DC-10 AFT PYLON SKIN	3	AUGUST 1975	24,700	66,700
DC-10 UPPER AFT RUDDER	14*	APRIL 1976	27,600	243,100
727 ELEVATOR	10	MARCH 1980	12,600	108,000
L-1011 AILERON	8	MARCH 1982	7,110	53,110
S-76 TAIL ROTORS AND HORIZONTAL STAB.	14	FEBRUARY 1979	4,200	41,300
206L FAIRING, DOORS, AND VERTICAL FIN	144**	MARCH 1981	3,050	176,000
CH-53 CARGO RAMP SKIN	1	MAY 1981	600	600
737 HORIZONTAL STAB.	4***	MARCH 1984	------	-------
GRAND TOTAL	326			3,179,830

APRIL 1984

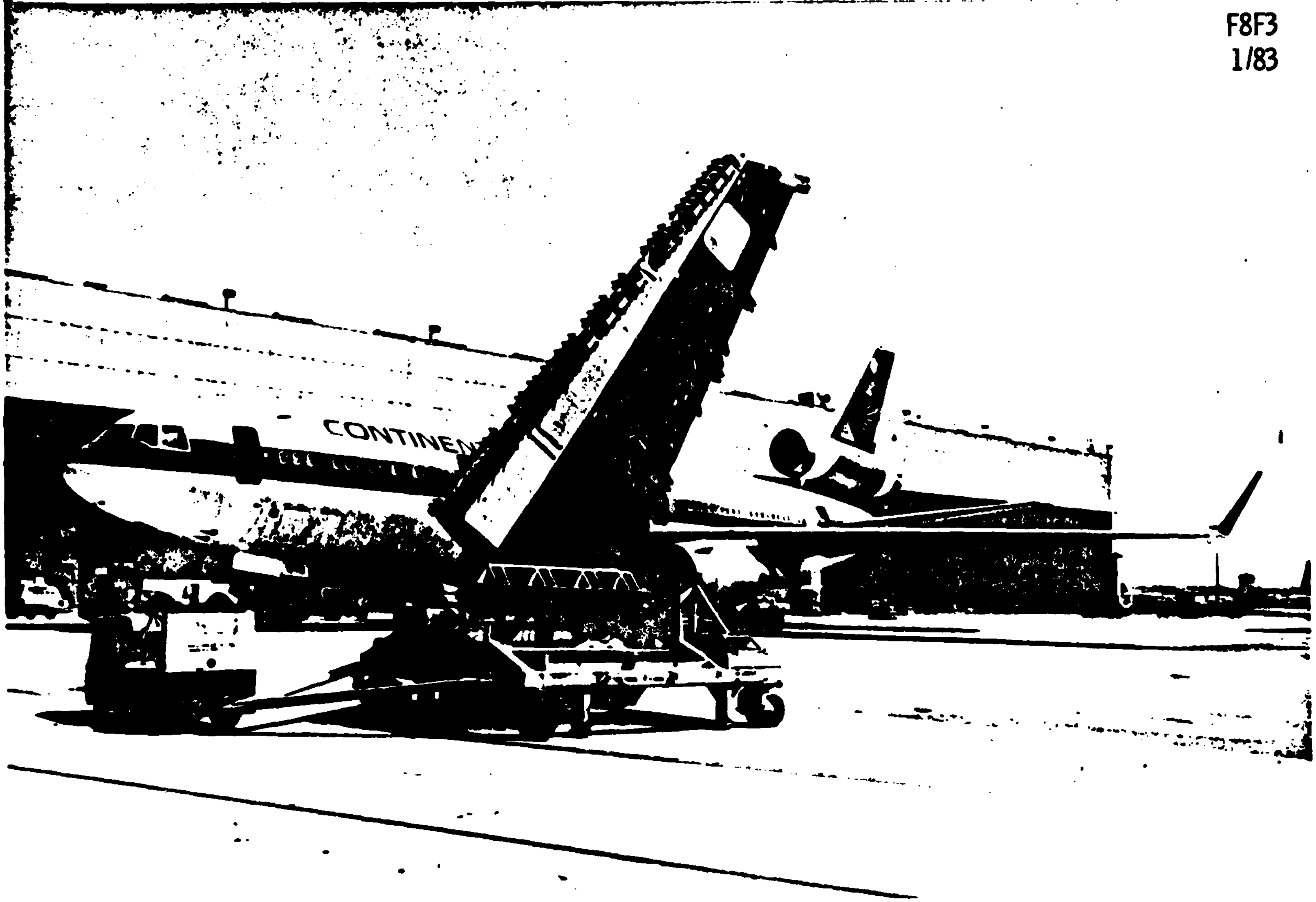
* 6 MORE RUDDERS TO BE INSTALLED
** 16 MORE COMPONENTS TO BE INSTALLED
*** 6 MORE STABILIZERS TO BE INSTALLED

CERTIFICATION OF COMPOSITE STRUCTURES

- SHOW COMPLIANCE WITH
  - FAR 25
  - COMPOSITE GUIDELINE AC 20-107
- COMPLIANCE DEMONSTRATED BY STRUCTURAL ANALYSIS AND SUPPORTING TEST DATA
  - FEM ANALYSIS - GLOBAL ANALYSIS, DETAILED ANALYSIS OF CRITICAL AREAS
  - COMPONENT TESTS
  - FULL SCALE GROUND TESTS
  - FLIGHT TESTS
- SPECIAL REQUIREMENTS
  - ENVIRONMENTAL EFFECTS
  - DURABILITY
  - DAMAGE TOLERANCE
  - FAIL SAFE
  - BIRD STRIKE
  - LIGHTNING PROTECTION

DC-10 COMPOSITE VERTICAL STABILIZER

F8F3
1/83



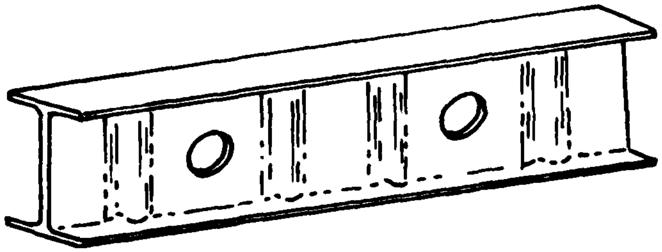
EXAMPLE OF CERTIFICATION PLAN

	PRINCIPAL OBJECTIVES
BOX BEAM SUBCOMPONENT TESTS	° LIMIT LOADS ° LIFETIME FATIGUE CYCLES ° ENVIRONMENTAL EFFECTS ° DAMAGE TOLERANCE
FULL SCALE STABILIZER GROUND TESTS	° LIMIT LOADS ° ULTIMATE LOAD ° STRESS DISTRIBUTION ° ANALYTICAL CORRELATION ° LIFETIME FATIGUE CYCLES ° DAMAGE TOLERANCE ° RESIDUAL STRENGTH
FLIGHT TESTS	° FLUTTER MARGINS ° SYSTEMS FUNCTION/INTERACTION
LAMINATE ALLOWABLE TESTS	° MATERIAL DESIGN ALLOWABLES ° DATA BASE
STRUCTURAL ANALYSIS	° INTERNAL LOAD DISTRIBUTION ° MARGIN OF SAFETY ° PREDICTED RESPONSE AT ALL FLIGHT CONDITIONS ° CORRELATION WITH TESTS

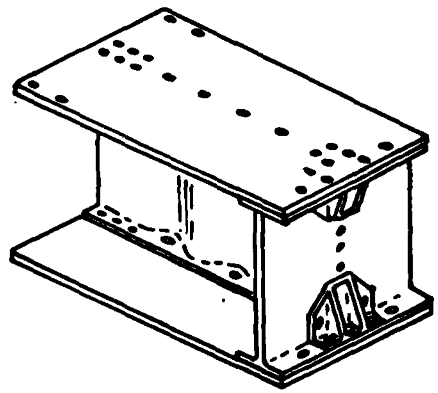
DC-10 STABILIZER MAJOR TEST COMPONENTS

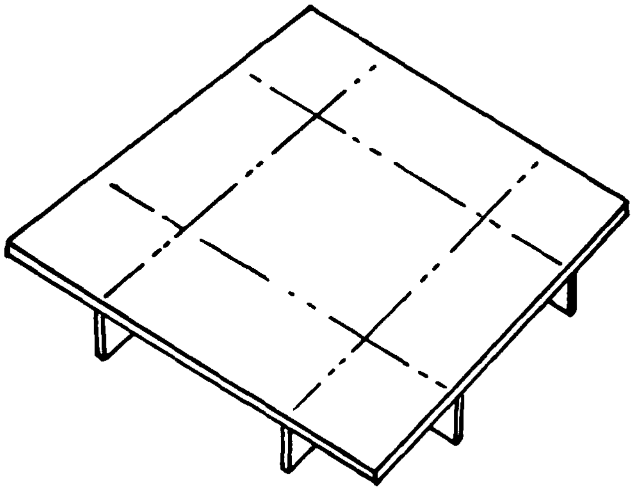
F8D
6/79

SPAR SHEAR-WEB ✓

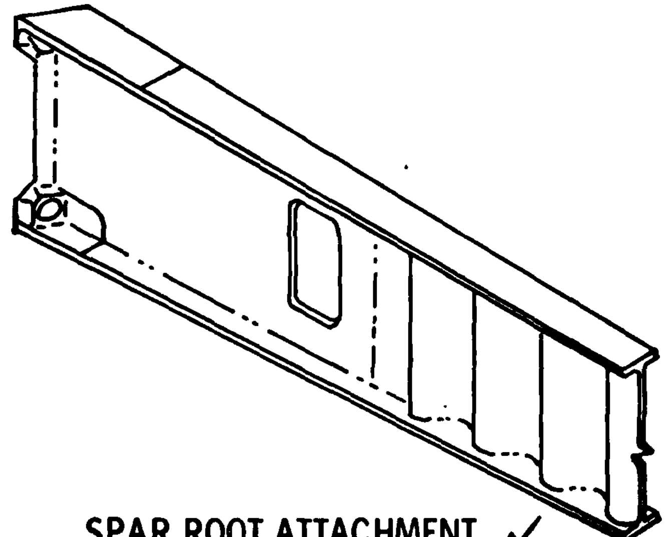


RUDDER SUPPORT FITTING ✓

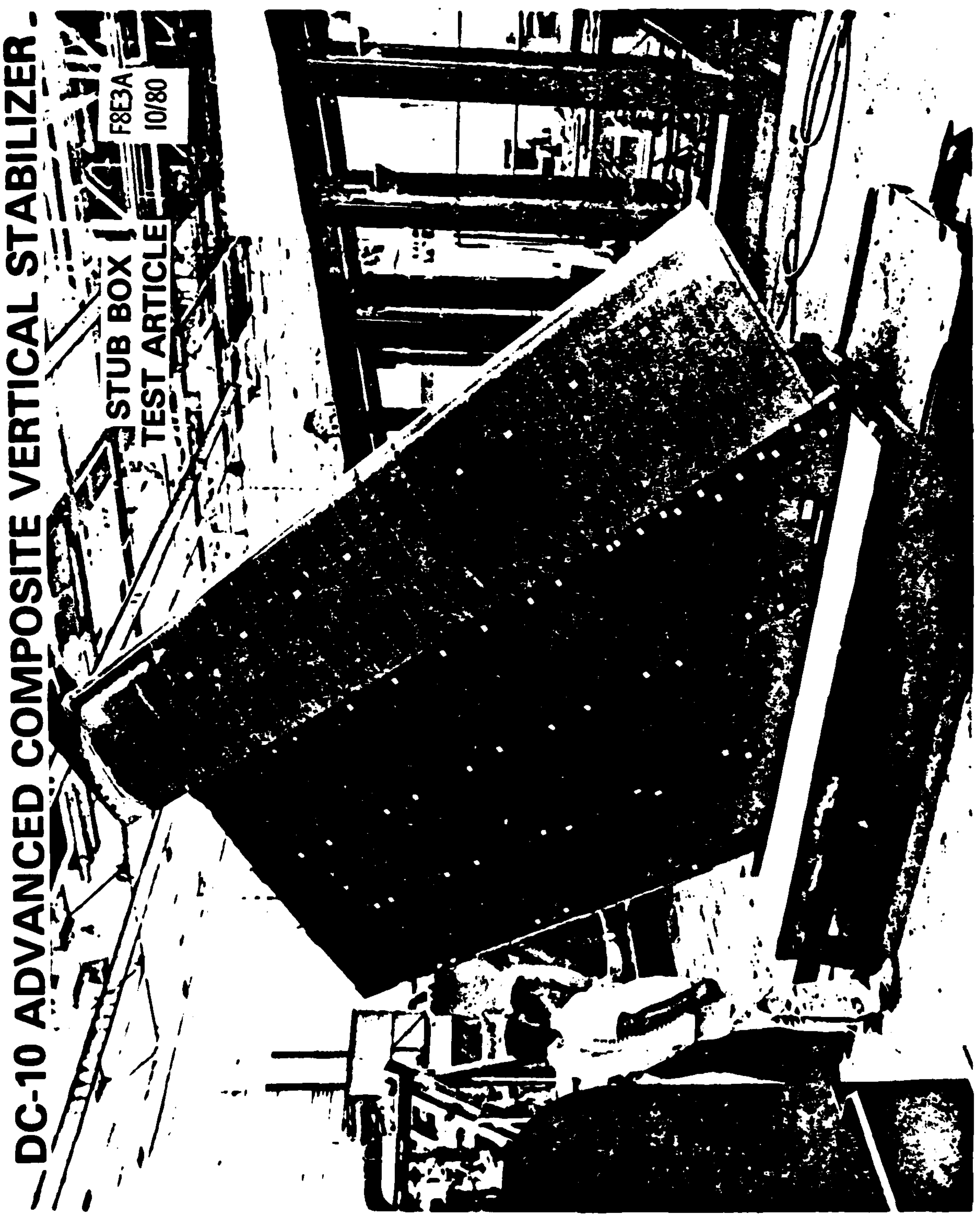




COMBINED LOAD PANEL ✓



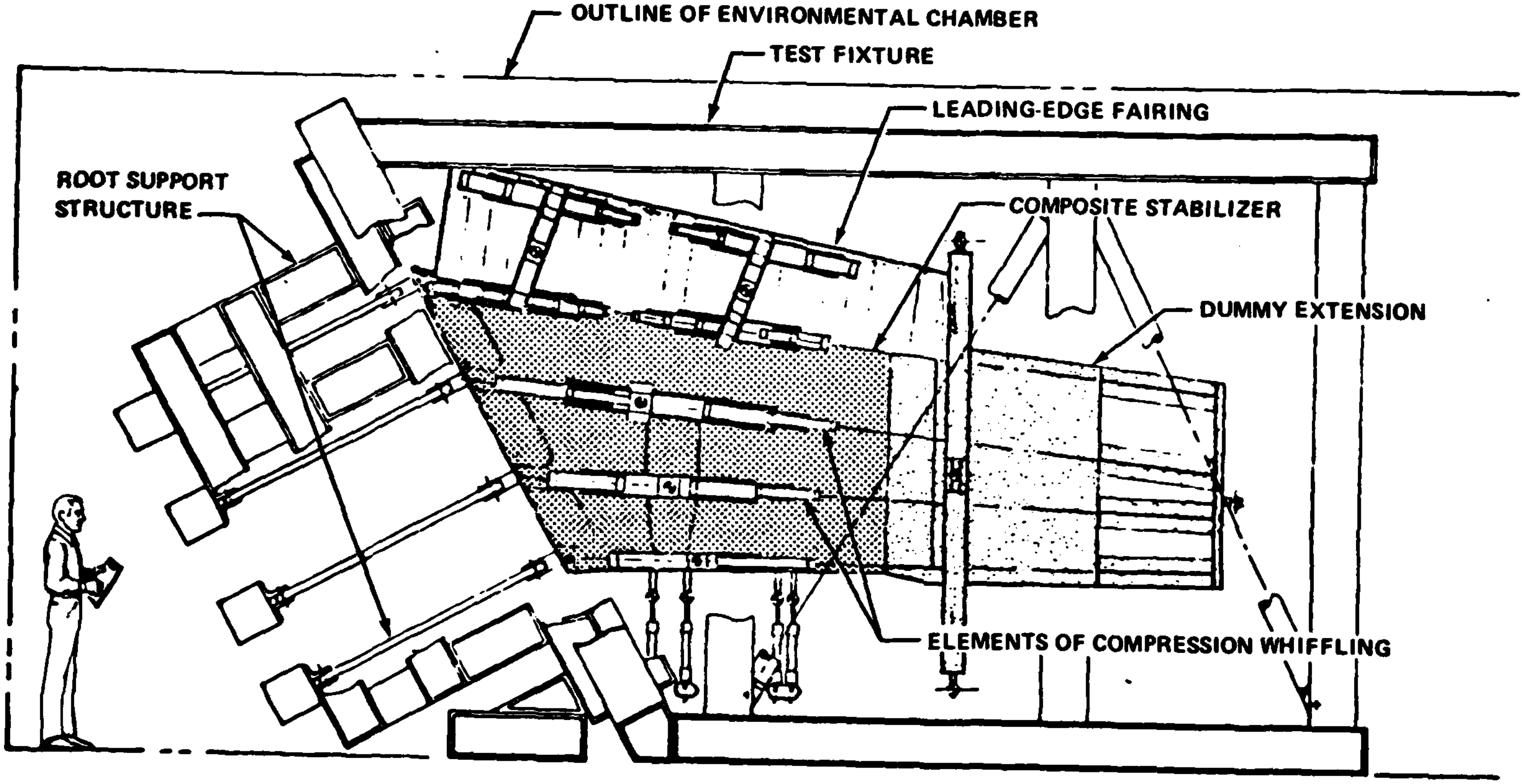
SPAR ROOT ATTACHMENT ✓


DC-10 ADVANCED COMPOSITE VERTICAL STABILIZER
STUB BOX
TEST ARTICLE
F8E3A
10/80

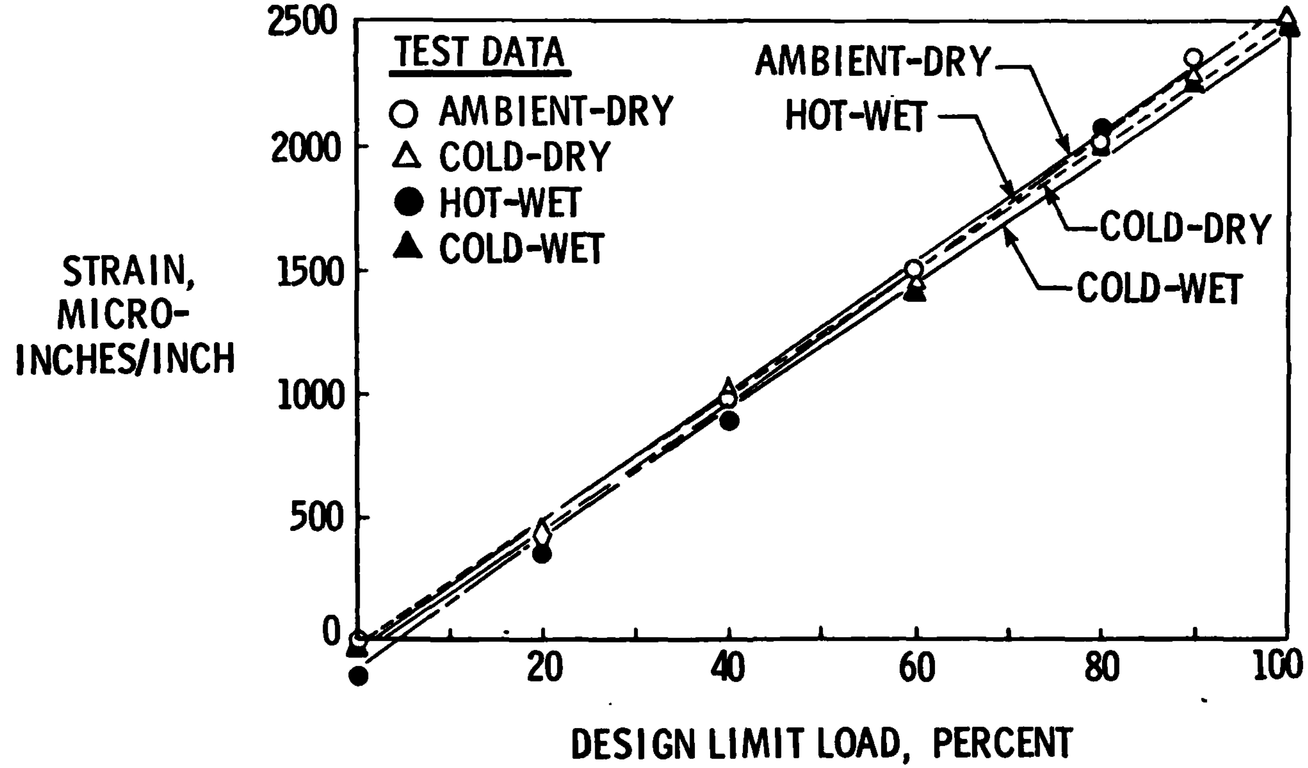
DC-10 COMPOSITE VERTICAL STABILIZER

BOX-BEAM TEST SETUP

F8E4
9/80



DC-10 COMPOSITE STABILIZER
BOX BEAM TEST RESULTS
REAR SPAR CUTOUT STRAINS

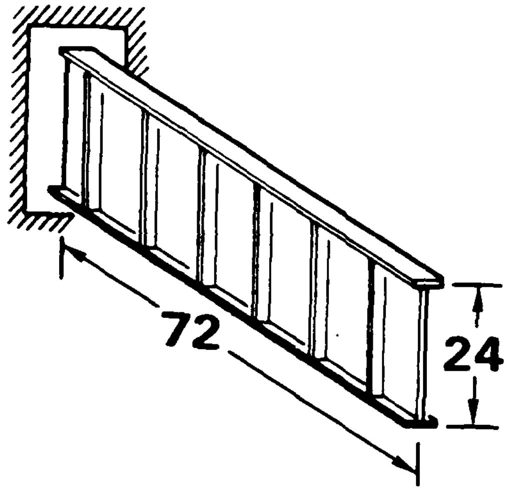


COMPOSITE EMPENNAGE STRUCTURE GROUND TEST SEQUENCE

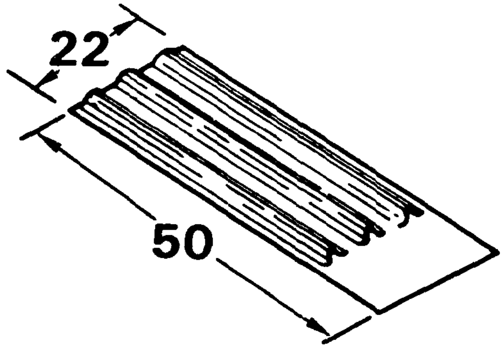
- LIMIT LOAD
- ONE FATIGUE LIFETIME
- ULTIMATE LOAD
- ONE FATIGUE LIFETIME WITH IMPOSED DAMAGE
- LIMIT LOAD WITH IMPOSED DAMAGE
- DAMAGE REPAIRED
- RESIDUAL STRENGTH TEST

PRODUCTION READINESS VERIFICATION PROGRAM

F6E
11/82



(A) SPAR SEGMENT

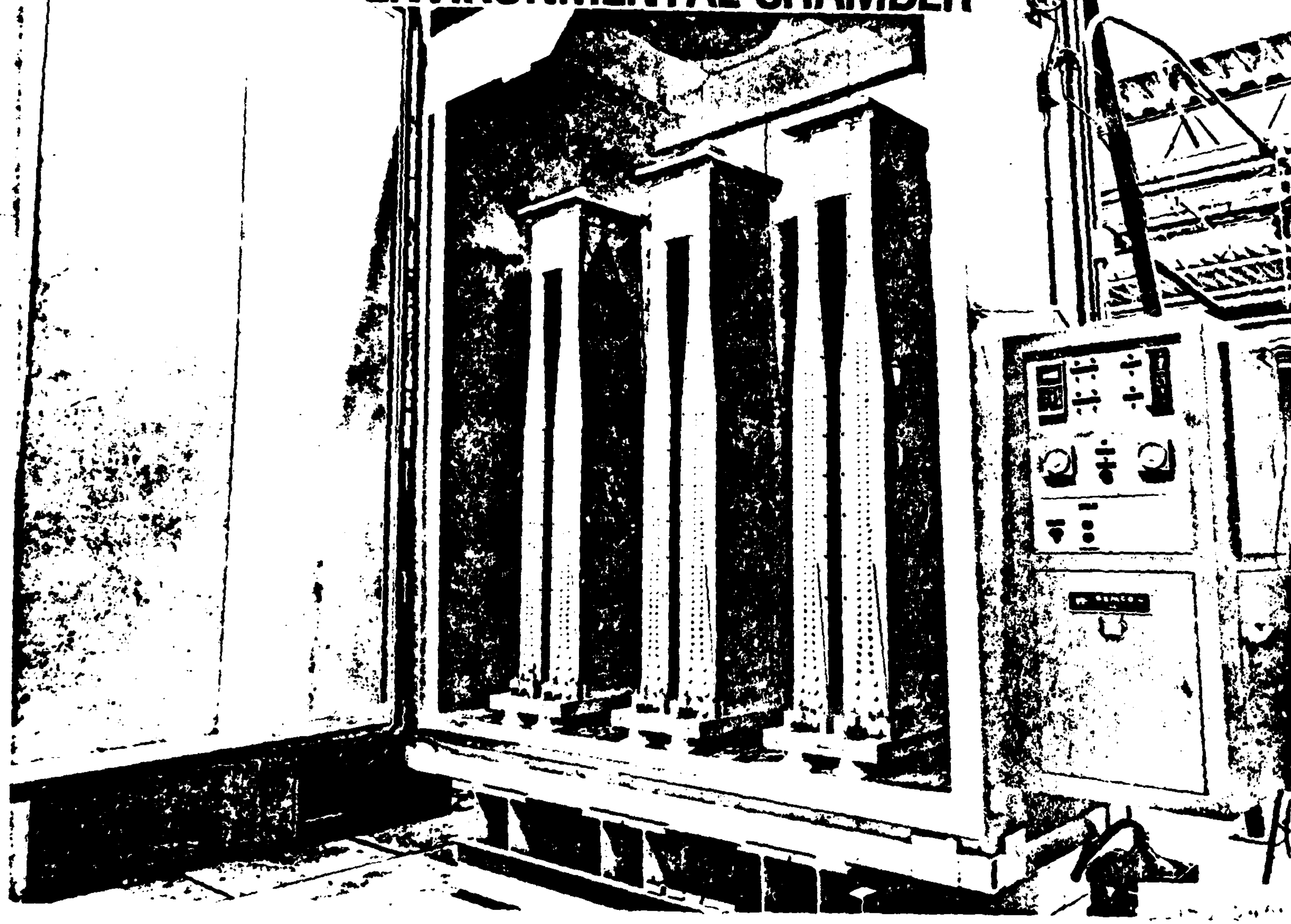


(B) COVER SEGMENT

(A)	Specimens	(B)
12	DURABILITY SPECIMENS	12
10	STATIC STRENGTH SPECIMENS	10
22		22

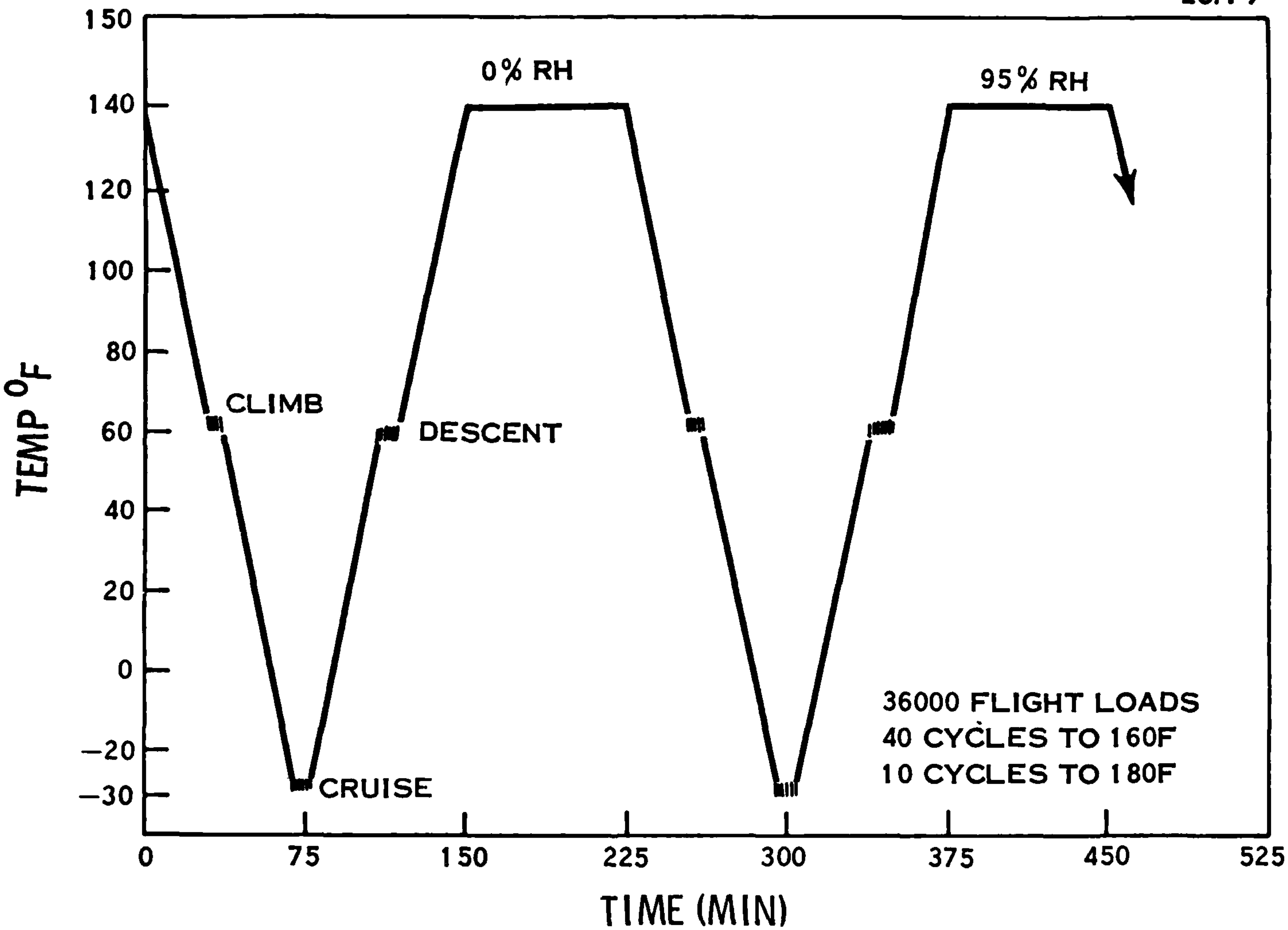
COMPOSITE SPAR COMPONENTS IN PRVT ENVIRONMENTAL CHAMBER

F6E1
5/79



LOAD ENVIRONMENTAL SIMULATION
(6.2 FLIGHT LOADS/CYCLE)

F6E2
10/79



NASA/INDUSTRY STANDARD SPECIFICATIONS FOR TOUGHENED COMPOSITE MATERIALS

PARTICIPANTS: NASA-LANGLEY, BOEING, DOUGLAS, LOCKHEED

ADVANTAGES:

- INDUSTRY-WIDE DOCUMENT
- PROMOTES DEVELOPMENT OF UNIFORM PROPERTY SET AND COMMON DATA-BASE
- PROMOTES COMPETITIVE PRICING
- ENCOURAGES DEVELOPMENT OF NEW MATERIALS
- ELIMINATES MULTI-QUALIFICATIONS FOR EACH SUPPLIER
- SHOULD REDUCE SUPPLIER COSTS

SPECIFICATION OUTLINE:

PREPREG, FIBER: PHYSICAL; CHEMICAL (INFORMATION "FINGER-PRINT" ONLY)

COMPOSITE: MECHANICAL; FRACTURE AND DAMAGE TOUGHNESS

PROCESSING
TEST PROCEDURES
QUALIFICATION PROCEDURES

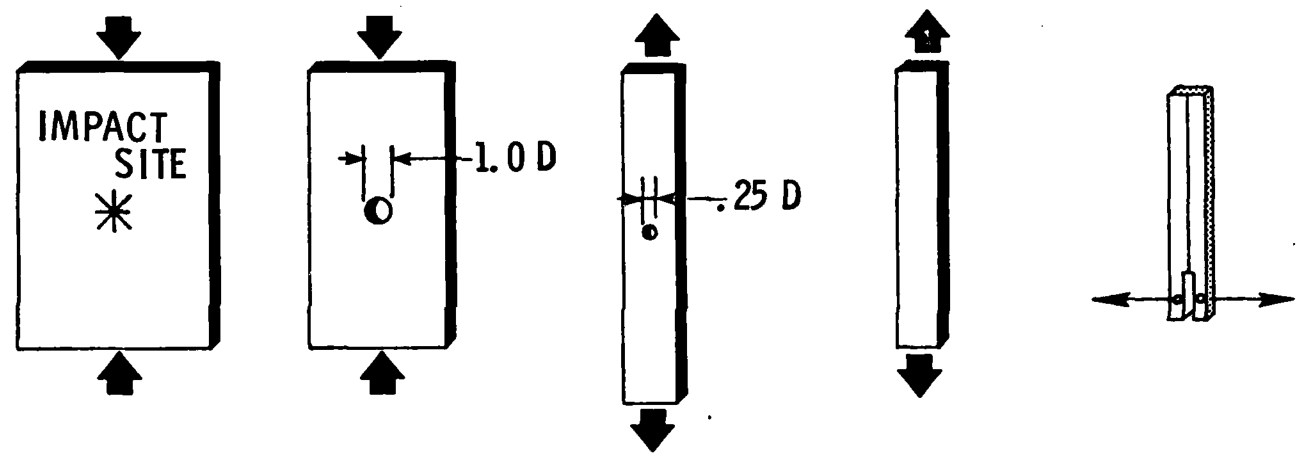
PROGRESS TO DATE:

SCOPE AND CONTENT IDENTIFIED
REQUIREMENTS AND TEST METHODS IDENTIFIED
TARGET VALUES FOR REQUIREMENTS IDENTIFIED
DRAFT DEVELOPED AND UNDERGOING REVIEW

STANDARD TESTS FOR TOUGHENED RESIN COMPOSITES

DAMAGE TOUGHNESS

FRACTURE TOUGHNESS



TYPE	COMPRESSION AFTER IMPACT	OPEN-HOLE COMPRESSION	OPEN-HOLE TENSION	EDGE DELAMINATION	DOUBLE CANTILEVER
SIZE, IN.	7 x 10	5 x 10	2 x 12	1.5 x 10	.5 x 1 x 8
THICKNESS, IN.	.25		.25	8 PLIES and 11 PLIES	.065 ±

CERTIFICATION OF COMPOSITES--SOME KEY FACTORS

1. DATE BASE - DATA TRANSFERABILITY

   - STANDARD SPECIFICATIONS

   - STANDARD TESTS

2. DESIGN VERIFICATION

   - VERIFIED ANALYSIS METHODS: STATIC, DYNAMIC, LIFE PREDICTION

   - QUANTITATIVE METHODS FOR NDE

FAA QUALIFICATION PRACTICES

Joe Soderquist
Federal Aviation Administration

FAA QUALIFICATION PRACTICES

Joe Soderquist

Federal Aviation Administration

The FAA regulations that contain the certification criteria for composite aircraft structures are Parts 23, 25, 27 and 29. These standards include all of the design validation process, such as structural requirements, flight test requirements, systems and equipment requirements and propulsion requirements. From the composites standpoint, these standards are supplemented by guidance contained in the form of an Advisory Circular which was recently revised to reflect technology advances. This revision reflects international agreement wherein the U.S. and the European community have agreed on a certain set of standards for composite certification for civil aircraft. The contents of this advisory circular are shown in the chart. They also show the major considerations which must be addressed by the manufacturer in order to receive FAA approval from the structural substantiation standpoint. The three issues that I will discuss briefly are material property development, proof of structures (static and repeated load) and quality control.

The FAA regulations that involve material property development indicate that design values should be developed and should be based on tests of material meeting approved specifications and they should have a sound statistical basis. These regulations also state that material allowables contained in MIL Handbook 17 should be used or other values as approved by the administrator. Now, there are no material allowables in MIL Handbook 17 for the systems currently being used; however MIL Handbook 17 is developing procedures for getting material allowables, i.e. statistical procedures, chemical characterization procedures and standardizing test methods. I recommend that, in any material allowable development program, manufacturers use these procedures, that are being developed by MIL Handbook 17. FAA Advisory Circular 20-107A states that material design values should be established at the laminate level, by either tests of the laminate or by tests of the laminate in conjunction with a test-validated analytical method. Typically, the manufacturer will conduct tests at the ply level and establish properties which they will then put in their laminate analysis and failure criteria and validate the results at the laminate level. Of course, material property considerations should also include the effect of the environment.

The FAA also requires that "A" basis allowables should be used for single load path structure, failure of which would result in loss of the structural integrity of the component, and "B" basis allowables should be used for redundant structure, wherein the failure of a single element will result in the loads being redistributed to adjacent elements. As most of the build-up structure found in aircraft today is redundant, "B" basis allowables are typically developed.

Exploratory data analysis should be an integral part of any material development program in order to find the optimum statistical model to be used as your data may contain outliers and multi-modality which can seriously affect the results. The methodologies used are either parametric or non-parametric. In the parametric approach, enough observations are made to determine the best functional representation, for either the Weibull, the normal, the log normal, and so on. In the non-parametric approach, the lowest order ranked data point for 29 observations is the "B" basis allowable.

AMMRC, which has custodianship of MIL Handbook 17, has identified two other non-parametric approaches which is a fairly simple approach; the lowest order ranked data point is multiplied by a factor depending on sample size, among other things. For a sample size of 15 observations, the lowest order ranked data point is multiplied by 48%. This could be quite severe if there is low dispersion in the test data; however, if the scatter is large, it may prove attractive. Recently, the Bayesian approach has been used wherein "B" basis allowables can be determined very accurately for small data sets having prior information of the material's response. They are now trying to evaluate this approach for different failure modes; the objective is to be able to determine "B" basis allowables for small data sets, e.g. using 10 hot wet compression specimens given data for 30 room temperature dry tensile specimens. Sufficient batches of material should be employed in order to adequately represent the population.

In the event that a manufacturer wishes to use a material other than the one for which he has determined allowables, he must evaluate the alternate material within the operational window that he expects the component to function and he must assure that the material properties are at least equivalent to or better than the original material system. This testing is typically done at the laminate coupon structural element level and consists of the tests shown in the chart.*

With regard to static strength, the FAA currently requires that all safety-of-flight composite materials structure be tested to ultimate load and that environmental considerations be taken into account. This can be done in either of these two phases. The component can either be placed in the environmental chamber or it can be tested in an ambient state. If it is tested in an ambient state, a thorough environmental subcomponent test program

*p. 130.

must be conducted to identify the effects of the environment. These tests are also supported by other testing, e.g. structural element tests which are generic type tests on such things as stringers and shear panels and non-generic type tests such as structural detail tests on specific design features, such as major joints, etc. This is all supported by materials allowable testing which was discussed earlier. Some of the smaller manufacturers would choose to go this route because, if an enhancement factor comes out of all this testing which must be applied to the full scale article, it may be restrictive, from a weight standpoint.

Because composite materials are sensitive to normal forces, and the fact that it is virtually impossible to eliminate secondary loads from built-up structures, two things should be done. One is the selective use of fine mesh finite element analysis of complex load transfer areas should be conducted and also component level validation should be conducted in addition to subcomponent validation in order to interrogate these secondary loads and any off-angle loads which may result in distortion of the structure under load.

Damage tolerance is the recommended approach in evaluating the repeated load response of composite materials structure. Included in this assessment should be anticipated manufacturing and service-related impact damage. It should be based on achieving a level of safety at least equivalent to that of metal structure. We are not willing to accept a greater failure rate than we now have for metallic structure. Two approaches can be used in damage tolerance - no-growth and growth. In the no-growth approach, strain levels are set such that, should damage occur, growth will not result under the anticipated repeated load spectrum. In the growth approach, damage is characterized in the space interval set.

The 11 basic steps that should be taken in a damage tolerance assessment are shown in the chart* and they are organized in an orderly thought process. You would initially identify your safety-of-flight structure, e.g. a wing fuselage intersection at the sub-component level, then you would evaluate the repeated load response of that component to identify any "hot spots" that may be there. You would then establish the probable types of defects or damage and the critical locations in which they may occur in the sub-component. You would then establish the extent of initially detectable damage dependent upon the inspection technique to be employed. This is the start of the damage characterization phase. You would also go to the other extreme and determine the extent of damage for residual strength assessment, i.e., how much damage can this structure take and still sustain limit load? You would then characterize the defect damage between these two points. You would evaluate the residual strength of the damage that you have determined in this characterization process plus two others which I'll mention later. You should then establish inspection intervals because, without inspection, you don't have damage tolerant structure whether you use growth or no-growth. We include damage in multiple sites where appropriate including the effects of the environment and evaluate the capability of the structure to sustain immediately obvious damage such as engine burst.

In the residual strength area, the types of damage that should be investigated for residual strength are the intrinsic and discrete source damage which was originally addressed there and two other types of damage. You should evaluate severe accidental damage, e.g. a spar cap missing, a skin stringer cut, a tire iron being kicked up off the runway, etc. That kind of damage should be good for limit load as well as large area manufacturing defects, such as weak bonds which don't have the structural integrity for which they were designed.

*p. 132.

In the quality control area, the production approval holder has the ultimate responsibility of ensuring that the product that leaves his factory meets FAA approved design data and is safe to operate. This includes vendor - supplied articles whether they be domestic or foreign. Manufacturers' materials specifications are approved as part of the FAA design data. This represents an envelope of the types of tests being conducted by the manufacturers in the materials qualification testing. Manufacturers are tending to go toward characterizing the materials for notch effects, such as holes and impact damage. We are finding more and more of these types of tests in the materials specs. Materials acceptance standards are also approved as FAA type design data. They can usually be found in the material specification, and again, this is an envelope that the manufacturers are doing to accept material in house now. These tests are not all conducted by any one manufacturer but represent an envelope.

There are more than 40 carbon-epoxy structural applications that have received FAA approval or are currently involved in the FAA certification process. Three of these are all-composite airplanes. We have the Learfan, the Beech starship and the Avtec 400.

COMPOSITE MATERIAL CERTIFICATION CONSIDERATIONS IN CIVIL AIRCRAFT STRUCTURE

Joseph R. Soderquist
Federal Aviation Administration

Certification Criteria

— Composite Aircraft Structure —

Federal Aviation Regulations:

Part

- 23 Airworthiness standards: normal, utility, and acrobatic category airplanes
- 25 Airworthiness standards: transport category airplanes
- 27 Airworthiness standards: normal category rotorcraft
- 29 Airworthiness standards: transport category rotorcraft

Supplemented by guidance material contained in Federal Aviation Administration advisory circular AC 20–107A, Composite Aircraft Structure dated April 25, 1984

AC 20-107A:
Composite Aircraft Structure

Contents

Material and fabrication development

Proof of structure - static

Proof of structure - fatigue/damage tolerance

- Damage tolerance (fail-safe) evaluation
- Fatigue (safe-life) evaluation

Proof of structure - flutter

Additional considerations

- Impact dynamics
- Flammability
- Lightning protection
- Protection of structure
- Quality control
- Production specifications
- Inspection and maintenance
- Substantiation of repair

Applicable FAR and related advisory circulars

Definitions

Material Property Development — Recommendations —

Design Values:

- Based on tests of material meeting approved specifications
- Have a statistical basis
- Contanied in, or conform to, procedures being developed by MIL-HDBK-17

Tests:

- Ply level,
  - Consist of, F_x^t, F_y^t, F_x^c, F_y^c, E_x^t, E_y^t, E_x^c, E_y^c
    ϵ_x^t, ϵ_y^t, ϵ_x^c, ϵ_y^c, F_{xy}, G_{xy}, F_{LS}, ν_{xy}
- Laminate level,
  - Consist of, F^t, F^c, F_{xy}
- Include environmental considerations, e.g. hot/wet, cold/dry, etc.

Statistical Considerations

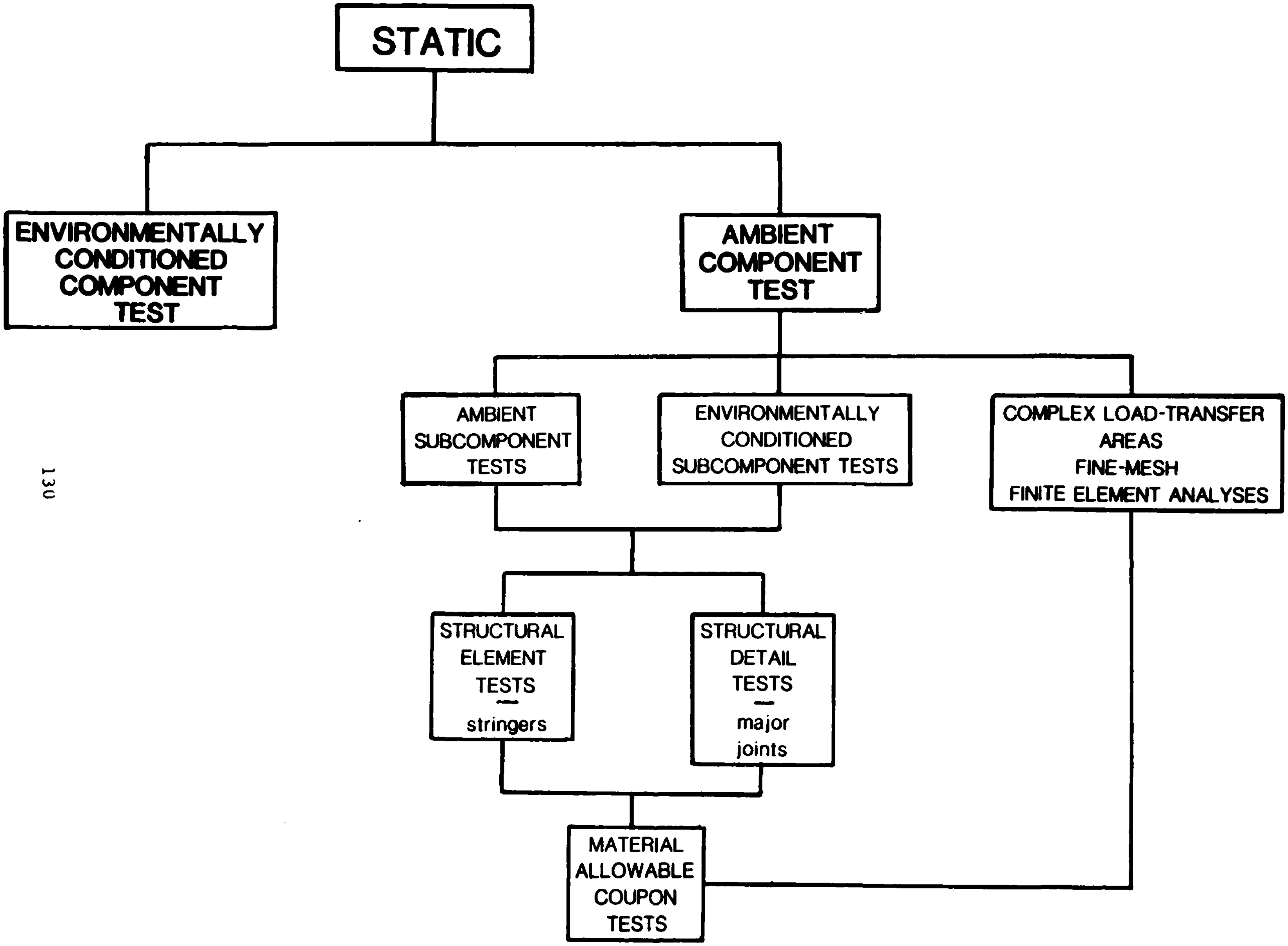
—Recommendations—

'A' Basis Allowables – single load path structure

'B' Basis Allowables – redundant structure

'B' Basis Allowables:

- Exploratory data analysis
- Parametric - enough observations to determine best functional fit
- Nonparametric,
  - Ranked data - 29 observations
  - Bayesian - $<$ 29 observations
  - Billings - $<$ 29 observations


STATIC
ENVIRONMENTALLY CONDITIONED COMPONENT TEST
AMBIENT COMPONENT TEST
AMBIENT SUBCOMPONENT TESTS
ENVIRONMENTALLY CONDITIONED SUBCOMPONENT TESTS
COMPLEX LOAD-TRANSFER AREAS FINE-MESH FINITE ELEMENT ANALYSES
STRUCTURAL ELEMENT TESTS — stringers
STRUCTURAL DETAIL TESTS — major joints
MATERIAL ALLOWABLE COUPON TESTS

Repeated Load
—Recommendations—

Damage Tolerance:

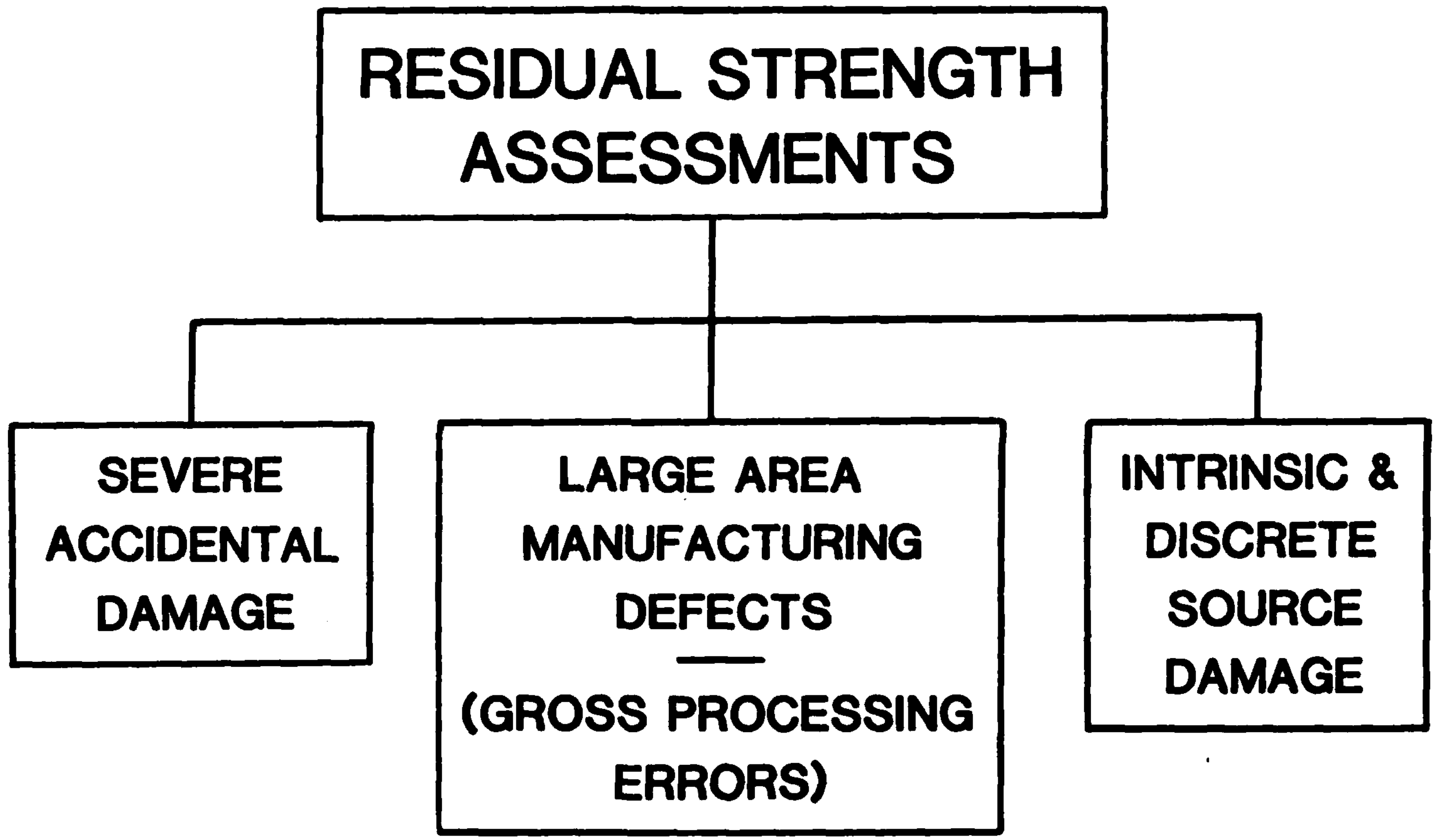
- No Growth
- Growth

Include anticipated manufacturing and service related impact damage

Achieve a level–of–safety at least equivalent to that of metallic structure

Damage Tolerance Design and Verification Criteria

- Identify principal structural elements
- Evaluate fatigue sensitivity of principal structural elements
- Establish probable types and locations of defect/damage
- Establish extent of initially detectable defect/damage
- Determine extent of damage for residual strength assessment
- Characterize defect/damage growth
- Evaluate residual strength
- Determine inspection intervals
- Include damage at multiple sites, where appropriate
- Include effects of temperature and humidity
- Evaluate capability of aircraft structure to sustain immediately obvious damage


RESIDUAL STRENGTH ASSESSMENTS
SEVERE ACCIDENTAL DAMAGE
LARGE AREA MANUFACTURING DEFECTS
(GROSS PROCESSING ERRORS)
INTRINSIC & DISCRETE SOURCE DAMAGE

Quality Control
Material Qualification

Laminate Mechanical Properties

Unidirectional Tape

Test	Condition
0 and 90 degree tensile: Strength/modulus/strain	cold/RT/hot dry/wet
0 and 90 degree compression: Strength/modulus/strain	cold/RT/hot dry/wet
0 degree flexural: Strength/modulus	cold/RT/hot dry/wet
Tensile strength: ±45 degree orientation	cold/RT/hot dry/wet
Short beam shear: 0 degree orientation	cold/RT/hot dry/wet
Quasi-isotropic: Tensile strength/strain	RT-dry
Quasi-isotropic Compression strength/strain	RT-dry, hot-dry hot-wet
Open hole, quasi-isotropic: Tensile strength/strain	RT-dry
Open hole, quasi-isotropic: Compression strength/strain	RT-dry, hot-dry hot-wet
Impact damaged: quasi-isotropic Compression strength/strain	RT-dry
Pin bearing: Quasi-isotropic:	RT-dry, hot-dry hot-wet

Quality Control

Material Acceptance Standards

Unidirectional Tape

Test	Condition
0 degree tensile: Strength/modulus/strain	RT-dry, hot-dry
0 degree compression strength	RT-dry, hot-dry
Short beam shear strength 0 degree orientation	cold-dry, RT-dry hot-dry, hot-wet
0 degree flexure: Strength/strain	RT-dry, hot-dry
90 degree flexure: Strength/strain	RT-dry, hot-dry

COMMERCIAL AEROSPACE PRACTICES

M. Katsumoto
Boeing Commercial Airplane Co.

COMMERCIAL AEROSPACE PRACTICES

M. Katsumoto

Boeing Commercial Airplane Co.

This morning, I'll be covering the materials flow diagram.* This is actually a comparison of the aluminum materials flow activity versus the carbon composite materials flow. I'll discuss the goals and requirements of materials qualification, qualification flow chart, qualification procedures, the supplier's process control document, a typical qualification program, and finally the conclusions and recommendations.

This is a comparison of the material flow process comparing the aluminum versus the carbon composite and one of the distinct differences you find is that in the case of aluminum, from the ore through processing to the end user, there is one focal point such as Alcoa, Kaiser, Reynolds, Dow, and they basically control the whole process. There is also another common thread in the aluminum industry and that is that alloy 2024 that is made by Alcoa, Kaiser, Reynolds and Dow is the same whereas, in carbon composite, you really have a difference in terms of the fiber technology and the resin technology. In our qualification, we will be covering the prepreg manufacturing products, the weaving and also the catalyzed resin system, and to some degree, the carbonization process.

In the materials qualification goals, one of the important features is to establish engineering requirements and control these requirements, establish processability of aircraft components, establish multiple sources both foreign and domestic. In our commercial business, because of reciprocal requirements, we are forced to provide business overseas so we do have qualified suppliers not only domestically but also in overseas sites. Of course, it is important

*p. 146.

to establish consistency and reproducibility among the suppliers. As far as qualification is concerned, the material must meet the strength, stiffness and durability requirement, demonstrate material equivalency to provide multiple sources, demonstrate material consistency control within each material and several batches of material, and demonstrate traceability of raw materials and processing records.

Qualified materials are necessary to support the generic and point design allowables such as testing at the coupon level, durability testing, structural elements, sub-components and finally the full scale components. They are also necessary to support our engineering design activity and flight service evaluation. The bottom line is the certification of the airplane.

The flow chart*shows the main activities of the prepreg supplier, fiber supplier, Boeing Co. and the fabricator. As far as the prepreg supplier is concerned, one of the requirements is that they have to prepare a process control document and they also have to implement the requirements of that document and do some of the material qualification testing. The fiber suppliers will be required to prepare a process control document and also do qualification testing. From our point of view, we run the material qualification tests, the design related tests, the manufacturing evaluation (and this is the scale-up of major components to make sure that the material is useable in making large parts. We are also involved in the fabricator qualification. They are required to be qualified in terms of their facilities, equipment and procedures and they will also run some of the qualification tests.

The chart** basically shows the material qualification procedures starting off with the pre-qualification. We normally require 3 batches of material from the suppliers

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*p. 149.
**p. 150.

in large scale-up quantity. We audit the manufacture and test of these materials. The supplier provides a process control document. We get involved in the chemical characterization of the resin system, the physical and mechanical property testing, manufacturing verification which includes scale-up of large parts, and design related testing to support the allowables activites.

I'd like to talk a little about the process control document. The objective of this document is to improve the prepreg consistency. It controls the raw materials and formulation, controls all details of the manufacturing process, identifies critical process variables, establishes nominal values and tolerances and controls measuring and recording procedures. It also ensures traceability of the completed product, and establishes in-process product assurance quality control procedures. It is prepared and maintained by the suppliers but we are involved in the initial release and revision and we do sign the document. Basically, the key effort here is that the suppliers identify the key materials and process and we verify that they have followed the procedures that they have outlined.

Another chart* shows a typical material qualification program. It is broken into three different areas - physical tests which involve resin content, volatiles, etc. of prepreg, mechanical tests and the chemical tests.

BMS 8-212 is our basic composite specification and this is based on the MY720 - DDS system. This chart** shows the type of materials that are qualified to this specification. As far as the fiber is concerned, Union Carbide T-300, Celanese Celion and Hercules AS-4 are qualified. We have 6 prepreg suppliers; in most cases, they are qualified to at least two of the fiber systems. Along with that, we have qualified fabricators - BCAC Fabrication Div., Auburn, a

*p. 152.
**p. 153.

Canadian subsidiary; BMAC, Wichita and other domestic fabricators. Overseas, they include AIT CTDC in Japan, CASA in Spain, and Short Bros. in Ireland.

In conclusion, the qualification of the composite material provides control over the consistency of these materials, establishes equivalency among suppliers; we have a multi-supplier base. Producibility and scale-up studies are critical and so we emphasize scale-up not only at the level of the prepreggers but also within our own shop in terms of building large scale components. Standardization of material properties supports the design, testing and certification efforts.

There is obviously a need for industry standardization in the area of qualification and material designation. It would be nice if we could consider a composite to be identified like a 2024 or 7075. The specification effort that Louis Vosteen talked about is certainly headed in the right direction, and we are working very closely with them. During this exercise, we did find that there is a variety of receiving inspection required by different companies, so that has to be standardized. We certainly need an orderly material development activity to provide the right signals to our suppliers in terms of strength, modulus (should it be 34, 38, 40 million), strain (1.2, 1.5, 1.8 or 2%), impact requirements (we have a variety of requirements in that area), and also in the area of durability and testing.

In technology controls, in fiber technology, I think we have the carbonization technology well in hand domestically but, in the area of precursor, we are still dependent on overseas technology and basically a lot of the properties of the carbon fibers are dependent on the precursor technology. In resin technology, we do have some items that are still dependent on overseas suppliers and processing standards are not the same among the various suppliers. So, in this area, whether we can achieve the standardization that we have in the aluminum industry is unknown at this time. It certainly is worthwhile looking at it because I think one of the important things to come out of this is the large data base that we can interchange among the end users. With respect to vertical integration, we have not achieved a level of integration like that in the aluminum industry but we are seeing some movement in the area of vertical integration. In the future, we'd like to see some teaming effort by the corporate technology partners being formed so that we can have a standard material and standard process. In the area of cost control, we are pretty confident that we can achieve the process efficiencies through automation and techniques. Material cost is a concern to us in terms of cost per pound of weight saved. Based on current pricing, it looks like we might have difficulty in justifying the use of composites in some of our applications.

Composite Material Qualification Procedures

M.T. Katsumoto

Boeing Commercial Airplane Company

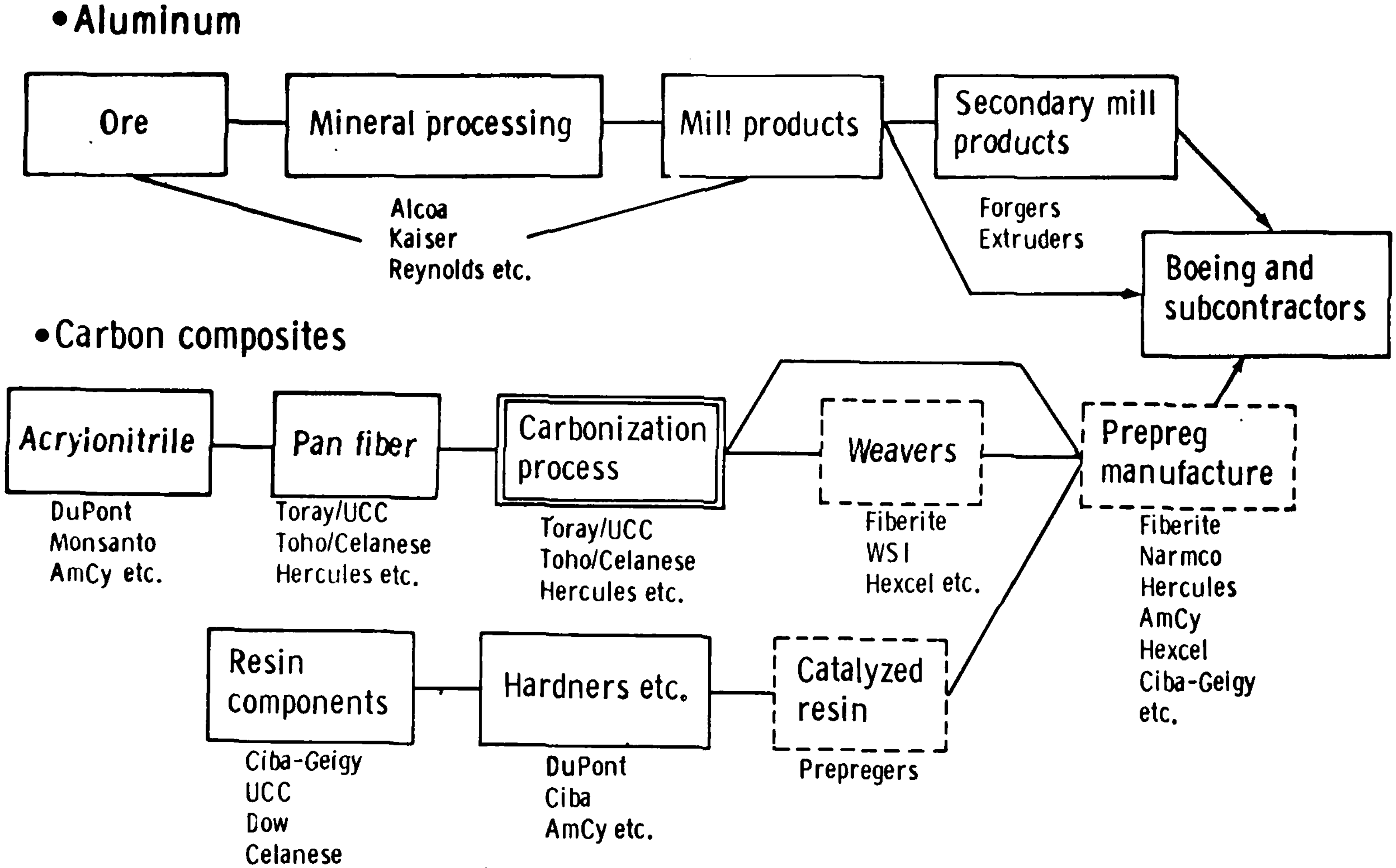
BMT84-1417

Composite Material Qualification

- Materials flow diagram
- Goals and requirements of qualification
- Qualification flow chart
- Qualification procedures
- Supplier process control document (PCD)
- Typical qualification program
- Conclusions
- Recommendations

BMT84-1418

Material Processing Flow
Carbon Composite and Aluminum Comparison



BMT84-1419

Material Qualification
Goals and Requirements

- Goals
  - Establish engineering requirements
  - Control requirements
  - Establish processability of airplane components
  - Establish multiple sources - foreign and domestic
  - Establish consistency and reproducability among suppliers
- Qualification
  - Meet strength, stiffness and durability requirements
  - Demonstrate material equivalency
  - Demonstrate material consistency controls
  - Demonstrate traceability of raw materials and processing records

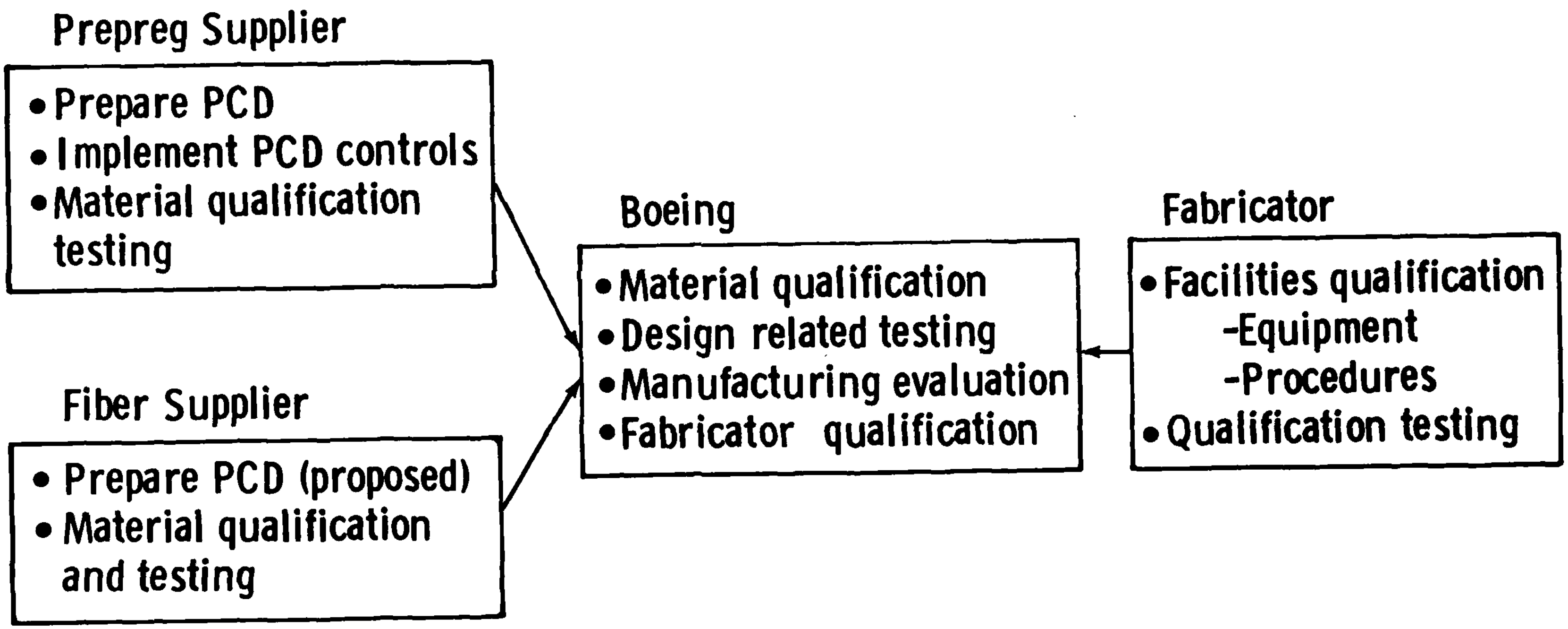
BMT84-1420

Qualified Materials

- Generic and point design allowables
  - Coupon
  - Durability
  - Structural elements
  - Sub-component
  - Full scale component
- Engineering design
- Flight service evaluation
- Certification

BMT84-1428

Material Qualification Flow Chart



BMT84-1421

Material Qualification Procedures

- Prequalification
- Supplier scale-up
- Audit of manufacture and test of qualification materials
- Supplier process control document
- Chemical characterization of resin system
- Physical and mechanical properties testing
- Manufacturing verification
- Design-related testing

BMT84-1422

Supplier Process Control Document (PCD)

- Objective - Improve prepreg consistency
  - Controls raw material and formulations (purchase, acceptance, release to production, storage and records retention)
  - Controls all details of manufacturing process
    - Identifies critical process variables
    - Establishes nominal values and tolerances
    - Controls measurement and recording procedures
  - Ensures traceability of completed product
  - Establishes in-process and product assurance quality control procedures
- Prepared and maintained by supplier
- Initial release and each revision approved by Boeing

BMT84-1423

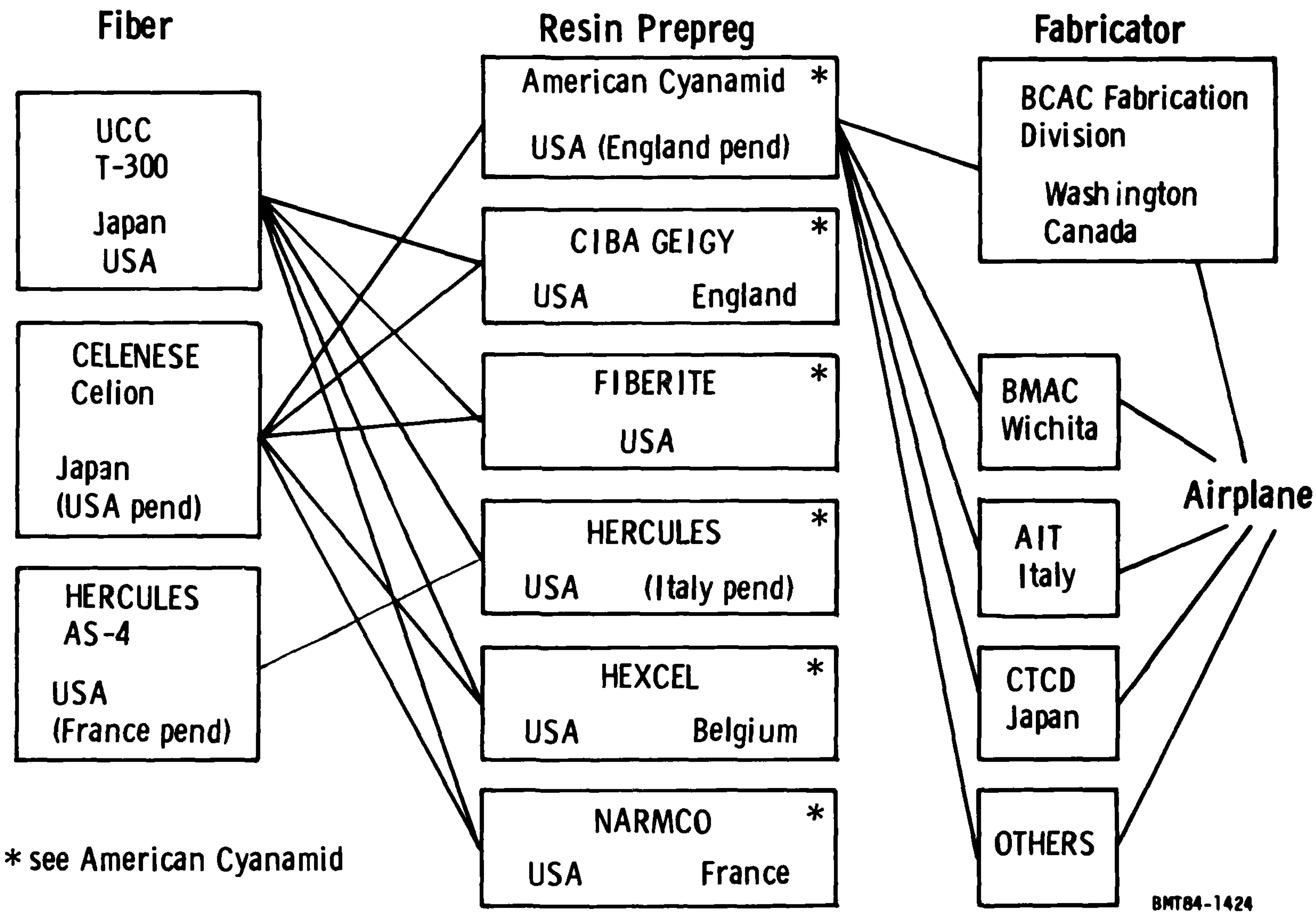
Typical Material Qualification Program

Physical Tests	Mechanical Tests 1/	Chemical Tests
Resin content	Dynamic mechanical test (DMA)	Infrared spectrometer
Volatiles content	Instrumented impact	Liquid chromatography
Prepreg tack	Fracture toughness (G_{IC})	Differential scanning calorimetry
Areal weight	Tension	
Laminate ply thickness	Compression	
Laminate void content	Compression interlaminar shear	
Laminate density	Open hole tensile strength	
Laminate fiber volume	Open hole conpression strength	
Laminate flammability	Compression after impact	
Surface resistivity (electrical)	Pin bearing ultimate	
	Fatigue	
	Solvent sensitivity compression strength	

1/ Testing is conducted at various temperatures/exposure conditions/out-times.

BMT84-1150-1

BMS 8-212 Qualified Suppliers



Conclusions

- Qualification of composite materials provides control over the consistency and quality of these materials
- Qualification of materials establishes equivalency among suppliers
- Producibility and scale-up studies are critical
- Standardization of material properties supports engineering design, testing and certification efforts

BMT84-1426

Recommendations

- Industry standardization
  - Qualification
  - Material designation
  - Specification standards - NASA activities
  - Receiving inspection testing
  - Material development
    - strength, modulus, strain, impact resistance, durability etc.
- Technology controls
  - Fiber technology
    - precursor/carbonization
  - Resin technology
    - curing agents/processing standards
  - Vertical integration
    - single source
    - cooperative technology partners
- Cost controls
  - Process efficiencies/automation
  - Material cost

BMT84-1427

COMMERCIAL AEROSPACE PRACTICES

Robert Stone

Lockheed California Co.

COMMERCIAL AEROSPACE PRACTICES

Robert Stone

Lockheed California Co.

Lockheed California Co. is becoming more of a military oriented company. Our experience to date on composite qualification and certification has been primarily for commercial aircraft structures and therefore has been in accordance with FAA requirements, as I will be describing. Our initial programs were our two NASA ACE programs, the L1011 composite vertical fin and the L1011 inboard aileron. In both cases, we fabricated full scale structures and carried them through FAA certification. In the case of the inboard aileron, we are flight testing it now on 4 L1011s. More recently, we have had a program from NASA on the technology necessary to fabricate a composite wing and, in conjunction with this program, Lockheed has conducted a fairly comprehensive series of screening tests on various second generation toughened epoxies, ie. epoxies which are modified to have improved toughness combined with high strain graphite fibers. Currently, we have two programs from NASA - a program to evaluate composite fuselage technology and, an immediate hardware program to develop a composite wing box for the C-130. For all of these programs, the major elements for the qualification and certification will be as indicated.*

The first step is our materials screening. When we initiated the vertical fin and aileron program, we went to the state-of-the-art material which we now call the first generation of untoughened epoxies (specifically Narmco 5208) combined with the T-300 graphite fiber which is 30-35 million modulus and 1.2% strain-to-failure. For these materials, we have well established materials specifications. For the C-130 wing box, and the programs that we are looking at in the future, we are looking at the second generation systems

*p. 165

and, in conjunction with the C-130 wing box program, we are in the final stages of our material selection. We are down to about 3 or 4 final candidate materials and we will be shortly making a final selection and we will prepare the material specification at that time. Our intent for the C-130 wing box is to use the joint industry/NASA specification that L. Vosteen was describing. It should be ready in the next few months. The process specification can be considered the final element of materials qualification. At Lockheed, we consider processability a significant enough factor that we include a processability trial in our material specification not only for qualification but also for batch acceptance. Process specification is part of the documentation that is required by the FAA as back-up data for the certification.

In the certification process itself, we start off with our baseline material properties which are necessary inputs into the design and the design allowables. We conduct structural tests based on the FAA requirements, as outlined by previous speakers. We have coupon tests, structural sub-element tests including the environmental factors. Our final full-scale development testing is done at ambient temperature and some damage and repair is included in our fatigue tests.

In materials screening, we consider that being able to chemically characterize the resin is a factor in our selection. We want to establish a baseline and determine how each batch of resin varies from the baseline. Our major concern, based on some production experience, is resin variability as it affects processing. So, the most critical thing is to be able to control resin variables so that we can process the materials and make parts repeatedly consistent, batch after batch. This has been a problem in some of our programs in the past. As we move from lightly loaded structures such as vertical stabilizers into wings and fuselages, we are getting into load levels which means that, in compression loading particularly, we do get damage growth on cyclic loading. Therefore, we have to be very concerned about damage tolerance, the impact resistance of the material and resistance to damage growth. The mechanical properties are run, of course, in materials screening and we look very carefully at the environmental effects. The combined effects of humidity and temperature have proven to be the limiting factors for many composite systems.

Once we have selected our material, we go through the qualification procedure, of course. This goes through the qualification requirements that we developed for our vertical fin program. That is our existing specification today. This is a very large complex primary structure even though it is not highly loaded. There was some discussion earlier about cutting the qualification costs. That's a worthwhile goal, but we feel that, for primary structure and large components, this is what is necessary.

In the prepreg properties, cured resin content and areal weight are important. For the physical properties, our policy is that for every test laminate for any purpose, including batch acceptance, we run resin content, thickness and NDI on these laminates to make sure that they are void-free. Our new specification on mechanical tests for toughened resins will be a completely different series and I believe an earlier speaker went through the various tests that are going to be performed - notched tensile, compression after impact, fracture toughness tests, edge delamination and the double cantilever beam. Chemical characterization will be run to establish a baseline fingerprint against which we can evaluate variability, and a viscosity profile which relates directly to the most critical property of the resin which affects processing, namely its flow behavior during a given cure cycle. We have found, from experience, that process-ability is greatly improved if we have a minimum viscosity that is considerably higher than the minimum viscosity of some of the earlier systems that we used. Late in our vertical fin program, we found that we could not make acceptable parts by the process that we had been using for a couple of years. We found that chemical characterization and viscosity could not screen out these problem batches. We wish they could. We had to resort to a processability trial laminate which, in our case, was 32 plies thick and 2' by 2' in area. We found that, if we made a void-free laminate of this size, we could then make good parts. We do not do any fiber tests at Lockheed but we do define the fiber requirements in our specification.

The acceptance tests are pretty much like the qualification tests but the number of tests is severely limited. We still run the processability laminate. It is expensive, but it is necessary to screen out the problem batches and the test is whether it passes NDI. We use the processability trial laminate for our mechanical tests. As for the chemical characterization of resins, in the case of our first generation systems, the Narmco 5208, we actually established quantitative chemical limits. For the toughened epoxy materials, this will be for informational use only which will enable us to see any severe changes in the resin. We ask only for certification reports on viscosity profile on uncured prepreg properties. In 2 more recent programs using a high flow resin system, we found that the processability laminate did not screen out the problem batches. In fact, we found that the only way we detected the problem in processing was when we fabricated a bad part. Fortunately, in our second generation systems which also tend to be controlled flow systems, we have not experienced similar problems. But this bothers us that we are unable to detect a resin variation which affects our processability. Microsections show differences in laminates made from two different batches of the same material.

Ply level tests are run as part of the certification process.* These are 0°, 90°, ± 45° tensile and compression, run at room temperature, dry. This provides the basic stress-strain data which is entered into our computer program and this provides the mechanical properties for any laminate that the designers want to come up with. As the design process progresses, we take representative laminates, run them at room temperature, dry, un-notched, notched, impacted and we also introduce the environmental factors, principally the hot wet conditions. This gives us our knock-down factors and defines the particular combination of design factors and environments that gives us our design limit condition, ie. the lowest design load to which we have to limit our design. The chart** shows in simplified form the results of some of our allowables programs. In tension, we see the control - hot wet properties, without any notches or impact, manufacturing defects, impact and ¼" diameter hole; it is obvious that, in tension, the limiting factor is a notch or a hole. In compression, we have control, moisture, manufacturing defects, ¼" diameter hole and impact; it is obvious from this chart that post-impact compression is the limiting factor in compression and, in fact, is the overall limiting factor. As we look at a composite transport wing, the requirement that it meet 6000 in/in micro-strain to failure in compression after impact cannot now be met by the current toughened epoxy and high strain-to-failure graphite fibers, so right there we are up against a limiting factor.

To summarize, so far, our Lockheed activities, our certification requirements for the vertical fin and inboard aileron on the L1011 and in the future for our C-130 wing box are covered by FAR 25 and FAA Advisory Circular 20-107A. We have developed qualification and certification procedures to conform with FAA requirements plus additional requirements that Lockheed imposes on itself. The major problem that we see is the inability to detect resin variables affecting processability using existing test procedures.

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*p. 172.
**p. 173.

COLLOQUIUM/WORKSHOP

on

STANDARDIZATION, QUALIFICATION AND CERTIFICATION OF COMPOSITE MATERIALS AND STRUCTURES

LOCKHEED OVERVIEW
ARTHUR M. JAMES
LOCKHEED-CALIFORNIA COMPANY

SPONSORED BY THE DEPARTMENT OF DEFENSE
NATIONAL ACADEMY OF SCIENCES, WASHINGTON, D.C.

MAY 8 – 10, 1984

MAJOR ELEMENTS OF QUALIFICATION AND CERTIFICATION PROCESS FOR COMPOSITE MATERIALS/STRUCTURES

QUALIFICATION PROCESS

- SELECT MATERIAL SYSTEM/FORM
- ESTABLISH MATERIAL REQUIREMENTS (SPECIFICATION)
- ESTABLISH PROCESS SPECIFICATION

CERTIFICATION PROCESS

- ESTABLISH MATERIAL PROPERTIES AND DEVELOP DESIGN ALLOWABLES
- CONDUCT STRUCTURAL TESTS AS REQUIRED BASED ON CERTIFYING AGENCY'S AND IN-HOUSE REQUIREMENTS

QUALIFICATION PROCESS FOR COMPOSITE MATERIALS

SELECT MATERIAL SYSTEM/FORM

- COMPREHENSIVE SCREENING PROGRAM CONDUCTED
- PARAMETERS EVALUATED INCLUDE:
  - CHEMICAL CHARACTERIZATION
  - PROCESSING
  - PRODUCIBILITY
  - TOUGHNESS (DAMAGE TOLERANCE)
  - MECHANICAL PROPERTIES
  - ENVIRONMENTAL STABILITY

QUALIFICATION OF COMPOSITE MATERIALS

- COMPREHENSIVE SERIES OF TESTS, DEFINED IN MATERIALS SPECIFICATION FOR APPROVAL OF MATERIAL SUPPLIERS AND PRODUCTS, INCLUDING:
  - PRE-PREG PROPERTIES
  - CURED PHYSICAL AND MECHANICAL PROPERTIES
  - CHEMICAL CHARACTERIZATION OF RESIN
  - VISCOSITY PROFILE
  - PROCESSABILITY TRIAL LAMINATES
  - FIBER PROPERTIES DEFINED

BATCH ACCEPTANCE TESTS — COMPOSITE MATERIALS

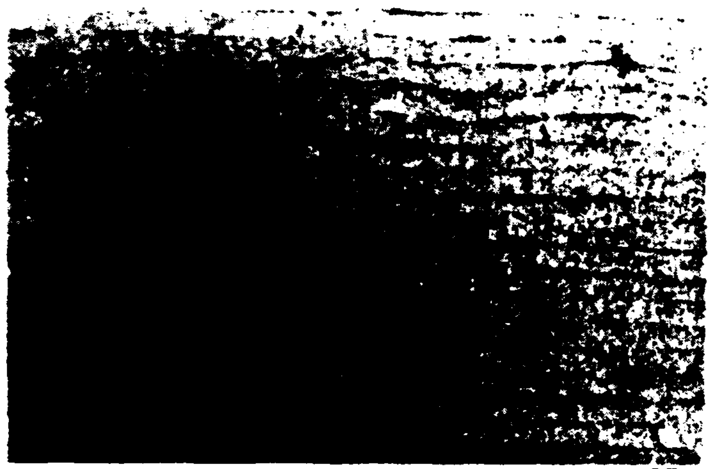
- LIMITED NUMBER OF QUALIFICATION TESTS, AS DEFINED IN MATERIALS SPECIFICATION, RUN ON EACH INCOMING PRE-PREG BATCH TO ENSURE PRODUCT CONSISTENCY. TESTS INCLUDE:
  - PROCESSABILITY TRIALS — BASED ON NDI OF REPRESENTATIVE TEST LAMINATE
  - LIMITED PHYSICAL AND MECHANICAL TESTING
  - CHEMICAL CHARACTERIZATION OF RESIN
  - VISCOSITY PROFILE/FLOW CHARACTERISTICS
  - UNCURED PRE-PREG PROPERTIES, WORKMANSHIP
  - FIBER CERTIFICATION REPORTS REQUIRED

QUALIFICATION PROCESS FOR COMPOSITE MATERIALS

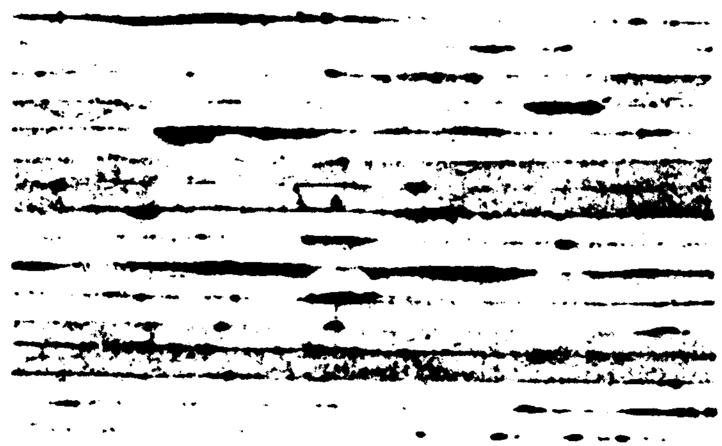
- ACCEPTANCE REQUIREMENTS FOR IN-COMING MATERIAL NOT ADEQUATE ENOUGH TO DISCRIMINATE BETWEEN 'GOOD' AND 'BAD' MATERIAL

- MATERIAL PROBLEM APPEARS AFTER FABRICATION OF A PRODUCTION COMPONENT

COMPARISON OF LAMINATE CROSS SECTIONS 'SAME' MATERIAL PROCESSED IN IDENTICAL MANNER



TYPICAL LAMINATE
PRIOR TO MATERIAL
PROBLEM

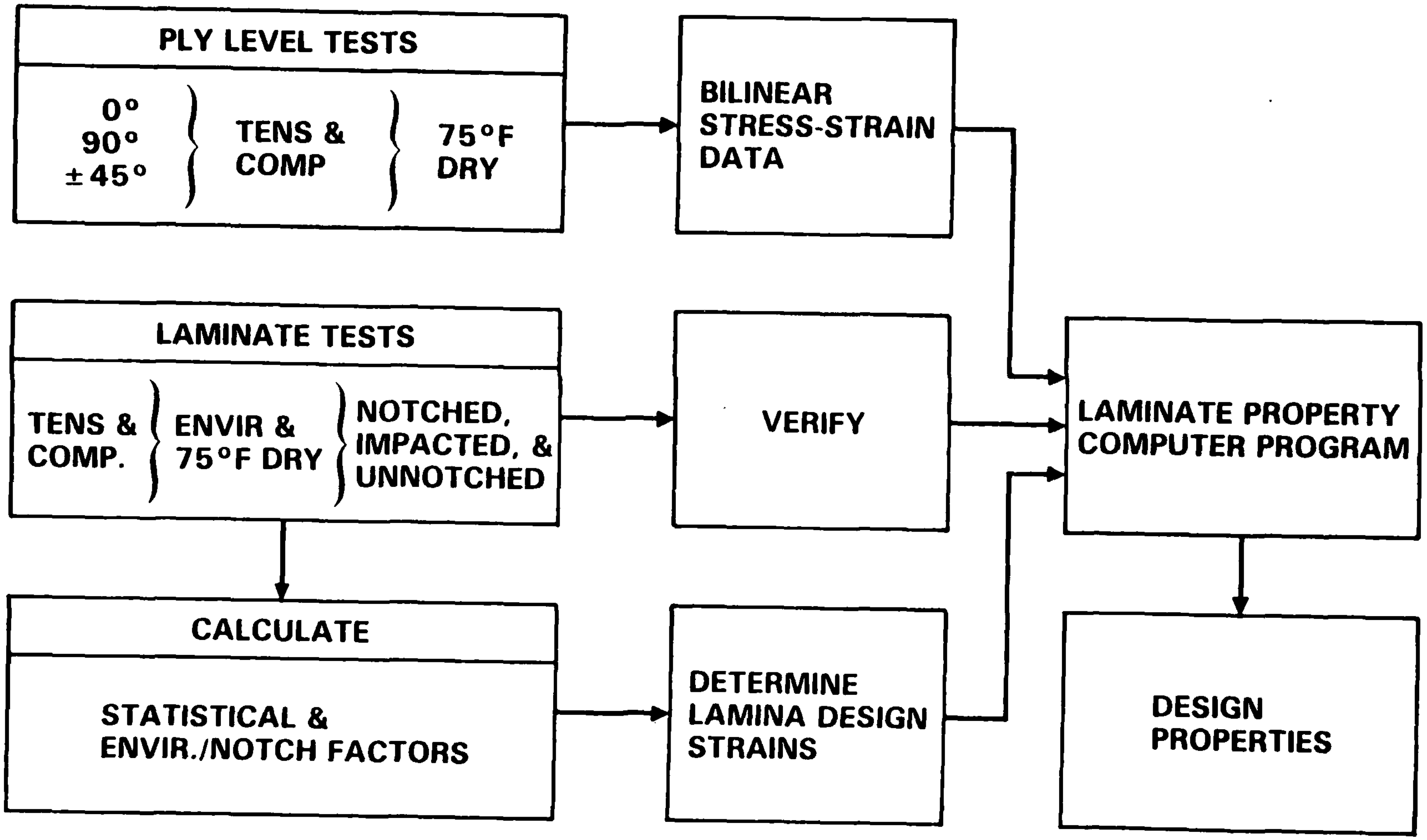


TYPICAL LAMINATE
CONSTRUCTED FROM
PROBLEM MATERIAL

HISTORICAL REVIEW OF COMPOSITE MATERIAL PROPERTY/ALLOWABLES ACTIVITIES

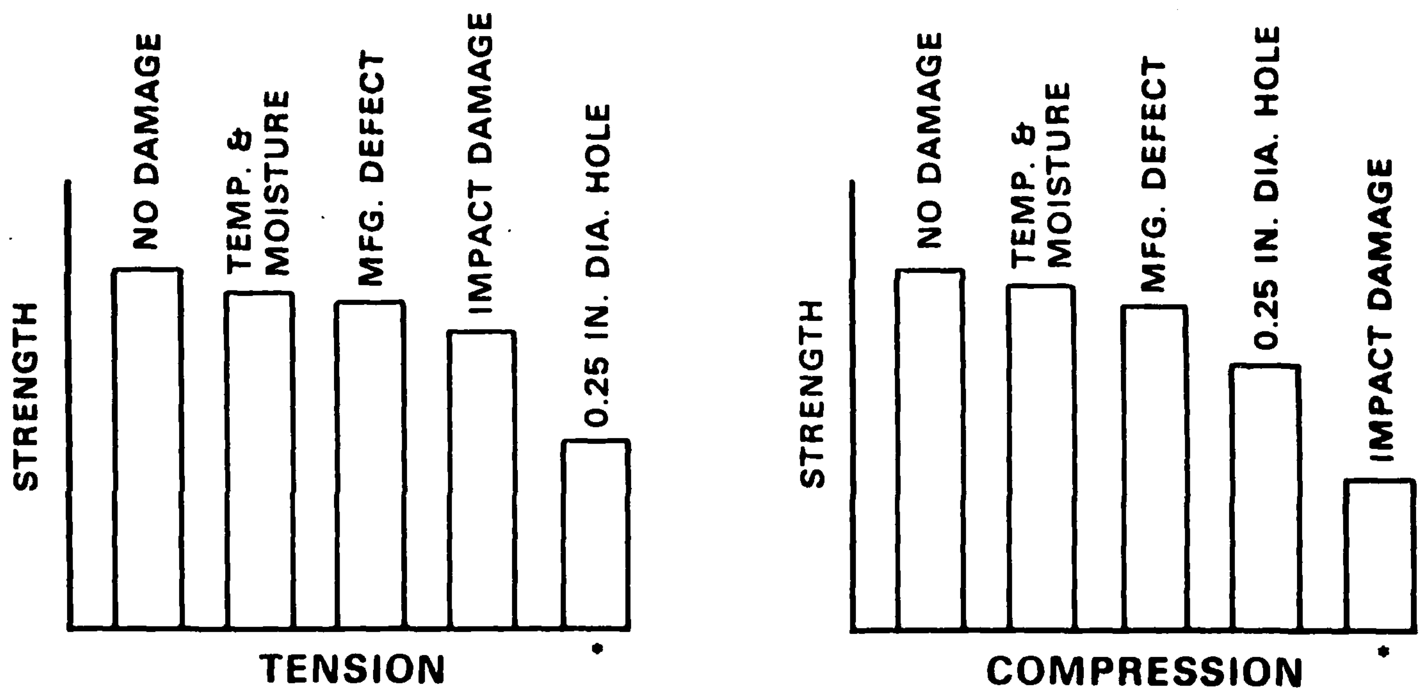
- **1972 TO 1977**
  - EVALUATION OF MANY COMPOSITE MATERIALS FOR APPLICATION TO TRANSPORT AIRCRAFT STRUCTURES
  - OBTAINED DESIGN PROPERTIES FOR T300/5209 TAPE AND K49/5209 FABRIC
- **1977 TO 1980**
  - QUALIFICATION AND DESIGN ALLOWABLES FOR T300/5208 TAPE AND FABRIC
- **1980 TO 1982**
  - QUALIFICATION OF AS4/3502 AS AN ALTERNATIVE TO T300/5208
- **1982 TO PRESENT**
  - EVALUATION OF HIGH STRAIN FIBER/TOUGHENED RESIN SYSTEMS
- **FUTURE**
  - QUALIFICATION AND DESIGN PROPERTIES OF IMPROVED GRAPHITE/RESIN MATERIALS

CERTIFICATION PROCESS FOR COMPOSITE MATERIALS DESIGN ALLOWABLES APPROACH



ALLOWABLES APPROACH CONT'D

- ALLOWABLE MUST REFLECT INFLUENCE OF ENVIRONMENT, NOTCHES, DEFECTS, IMPACT DAMAGE, ETC.



*CONDITION SELECTED FOR DETERMINATION OF DESIGN ALLOWABLES

CERTIFICATION PROCESS FOR COMPOSITE STRUCTURES

- CERTIFICATION REQUIREMENTS FOR COMMERCIAL AIRCRAFT ARE COVERED BY FEDERAL AVIATION REGULATION PART 25.

- FAA ADVISORY CIRCULAR NO. 20-107A HAS BEEN ESTABLISHED TO PROVIDE GUIDANCE MATERIAL FOR SHOWING COMPLIANCE WITH CERTIFICATION REQUIREMENTS OF COMPOSITE AIRCRAFT.

SUMMARY

- COMPOSITE MATERIAL QUALIFICATION AND CERTIFICATION PROCEDURES HAVE BEEN ESTABLISHED AT LOCKHEED IN CONFORMANCE WITH IN-HOUSE AND FAA REQUIREMENTS.
- THE MAJOR PROBLEM IS THE INABILITY TO DETECT RESIN VARIABLES AFFECTING PROCESSABILITY USING EXISTING TEST PROCEDURES.

COMMERCIAL AEROSPACE PRACTICES

Ray Palmer
Douglas Aircraft Co.

COMMERCIAL AEROSPACE PRACTICES

Ray Palmer

Douglas Aircraft Co.

I will confine my talk to the materials specification part of my responsibilities. I have guided my presentation to supplement what Mr. Stone has just done as far as the details of what is going into the specification. Our approaches are very similar to those of Lockheed and Boeing. I am now going to cover the overall procedures on the qualifications, step by step, for the original qualification, second qualification, identify some of the problems and some suggestions on solutions to these problems.

First, we have to decide that we do need a new material. Then, we establish pretty much in rough order what these properties should be. We contact the materials suppliers and the literature and we go after the best material we can get, based on what we think we want at the time. We write a preliminary specification identifying these tests. giving a rough order of magnitude of the values, then we write a test plan which is written in detail to identify all of the specimens required, and all of the environments required. That plan is submitted to the FAA for their acceptance. They may accept, add to or subtract from the plan and then we proceed to implement the plan by manufacturing the specimens and doing the testing. Finally, we publish a report. Once the report is published and we have reduced all the data, we put the data into the basic material specification. That specification and the report are submitted to the FAA as evidence of qualification. At the same time as this is going on, the structural people create a test plan for first part usage design allowables. This is also submitted to the FAA for their acceptance, and has the same environments that we have heard from the other two manufacturers. We then implement the test plan with FAA witnessing the fabrication and testing and write a design allowable report, and that report is submitted with the material specification for qualification of the materials to use on the aircraft.

We are going through the process now of getting ready to qualify alternate sources of material for use on our aircraft. Our alternate source is a little bit different in that we will have a specification with real numbers. We will create a test plan around that specification. We will implement the fabrication and testing of these materials. We'll write a test report and we will submit to the FAA as certification that we have qualified an alternate source to this specification.

So far, it sounds very straightforward, so what are the problems? As I see it, the bottom line in all of our problems is the high cost of getting the material qualified to place it on that airplane. It is very, very difficult. I'm going to start in at about 11 o'clock on this chart and work my way around these items which contribute to this cost. Some are necessary, some are good, some of them perhaps we can attack in the workshop and find ways of reducing these costs. I can remember going to our chief engineer some ten years ago and trying to sell him on the idea of trying to put composites on our airplanes at that time. His response was "You want me to put material on an airplane that we guarantee for a service life of 20 years and you say it was developed last year." There was no chance of getting it at that time; however, we have been learning continuously and the head designers are now getting far more receptive to composites as they are seeing the values, and the proof is all of the thousands of flight hours on both military and the ACEE programs at NASA: they have been very helpful to us.

We are interested in the best possible material that we can get, and there is a combination of goodness and badness.

If you have a critical part, say a basic structure on a plane, we absolutely want the assurance of the best material that we can get; however, there are many parts on our aircraft that we call feathers, such as fairings, which are very lightly loaded structures and, if something would happen, it really wouldn't make any difference to the serviceability or safety of the aircraft. We suspect that we could save a great deal of money if we were not so critical on the quality of the materials that go into these non-flight-critical parts. We all ask for special materials, such as special thickness, special resin content, etc. We have to minimize the use of these special materials as much as we can. Standardization will help that. Small quantities contribute to high cost, but, in development programs, we have to buy small quantities. I'm not sure what the answer is but it is a problem. It takes us a long time to qualify a new material; someone said about a year, and that is about what it takes us. We do ask for quite a number of tests for incoming quality control. In some places, we may not ask for enough; in others, we ask for more than is required from each batch of material, depending on the application. If you have a single source of material in the commercial world, the old saying that you charge what the market will bear seems to be true. We believe that we must have at least two, and preferrably three, sources before we rest at ease at the Douglas Co. If we need something in a hurry, it is expensive to obtain this material under those conditions. Perhaps materials suppliers will find a way that they can store the material and provide small quantities in a hurry. Multiple source qualification is expensive because of all the multitude of tests that we have.

What I feel is needed is an industry standard specification. I think we can do it. We've made a nice start on it and I'll give you a status report on where we stand in the Boeing/Lockheed/Douglas/NASA program. We should standardize on our material forms as to types and classes and grades. The material forms might include resin contents, thicknesses per ply or types of woven cloth. Whatever we choose, we should try to standardize and each of us use the same forms as much as we can. We need standard methods of test. In creating this standard material specification effort, we found that each of us was testing in different ways and it is very frustrating going through a batch of data, trying to come up with a data base, when you see that the suppliers have been testing by different techniques. We do get different results with different techniques. So, I think that standardization of test methods is one of the high priorities that we must address.

I would like to see an FAA certified testing laboratory established. What I'm really after is to be able to have a company (eg. a prepreg company) go to a certified testing laboratory and, on a particular test plan, pay for that laboratory to test that material once, and if it meets a particular specification, an industry specification, then that material could be used by all companies. It would only have to go through one testing cycle if we had a common specification. For industry standard specifications, I would visualize that for a given material, we would have close tolerance specification for critical applications and a very loose tolerance for non-critical applications to help in the cost factor associated with using these materials. As for the FAA certified laboratory, I would visualize the possibility of a funded NASA or DOD program to help create the material specification and help qualify the materials testing laboratory and then they drop out of the picture and the suppliers or the users would fund the cost of qualifying his materials. The user would then be in the position of only having to satisfy himself that he can obtain the same general preperties that are in the specification by running a few critical tests. Each individual company would do its own total design allowable program.

Assume that we have a standard material specification. It is a reality. The materials supplier develops a new material that he thinks will meet that specification. He submits that to the FAA approved Laboratory and we have a test plan that has been approved by the specification. They implement the test plan and pay for the report and the material then becomes a qualified material as far as that specification goes. In talking with several of the people here on design allowables, I find it a little difficult to say that we can give design allowables data to our competitors, but there is a chance that we might be able to work up a way of exchanging data, if we have the same specimen configurations, same materials and same processing, then let each of us reduce the data in our own way for our own working level of design allowables. There is a possibility there that we might sell.

Now, I will give a status of the common specification. Two years ago, the chief engineers of the Boeing, Lockheed and Douglas companies exchanged a series of letters concerning the possibility of trying to consider the creation of common specifications to help us on this costing business. After a period of sole searching, it was agreed that the three companies would try it together. At the first meeting, we agreed that we would write the specification around Narmco 5208 - T300 material. It so happened that all three companies were using that material. We also exchanged company specifications and we went home with the assignment that one of us would write the mechanical properties and test methods, another would write the prepreg tests and test methods and the third would write the handling, packaging and a strawman specification by taking the inputs of the other two companies. We got started on that, then we discontinued it because the 5208 system went out of favor, and it did not look as though it would continue to be used on a production basis. That is when NASA came to the rescue and recognized the benefits that can come from a common specification. They wanted to include toughness in the specification and suggested that the material should be one that would be used on the next go-around of aircraft and the next go-around of activities on the NASA ACEE program. So, we got together again and we agreed again to write a specification, this time incorporating the types of things that L. Vosteen talked about. We created a strawman specification and it was discussed at a second meeting. A revision is now being circulated among the three companies and NASA. We will create another version with all of the comments and it should be ready in another two months for final proof-reading by the companies involved. At that time, DoD or FAA might be interested in seeing it. If we can get this document out and publish it under a NASA standard format, that gives the three of us a starting material specification that we can use. This opens the door for the industry as a whole to use it and then we have to decide if we have to go to SAE or some other format to publish it. I think we can make it.

COMPOSITE MATERIALS AND STRUCTURES

STANDARDIZATION
QUALIFICATION
CERTIFICATION

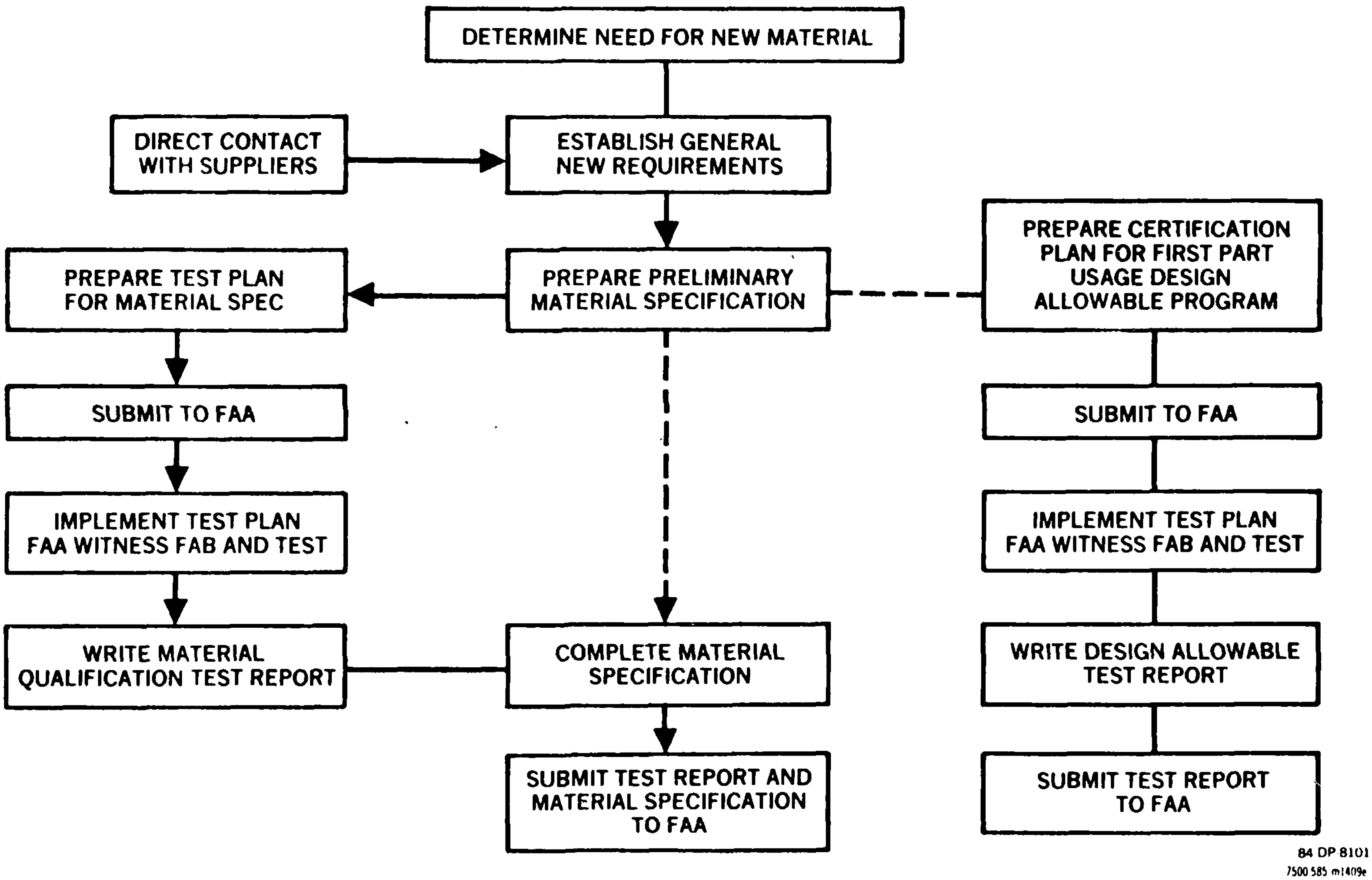
NATIONAL ACADEMY OF SCIENCE
WASHINGTON, D.C.

MAY 8-10, 1984

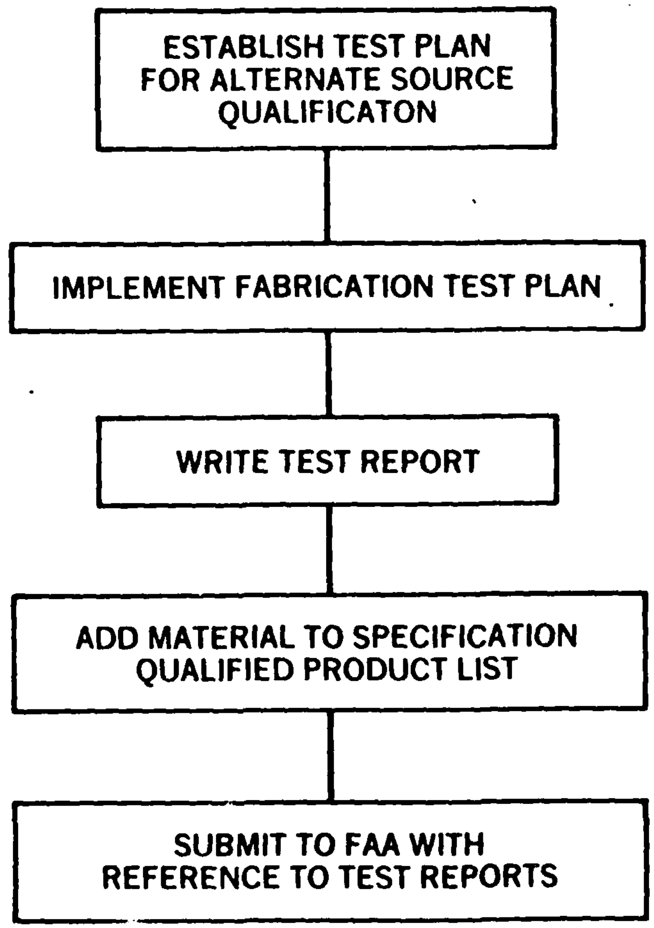
RAY PALMER

DOUGLAS AIRCRAFT COMPANY
MCDONNELL DOUGLAS CORPORATION

ORIGINAL MATERIAL QUALIFICATION AND CERTIFICATION

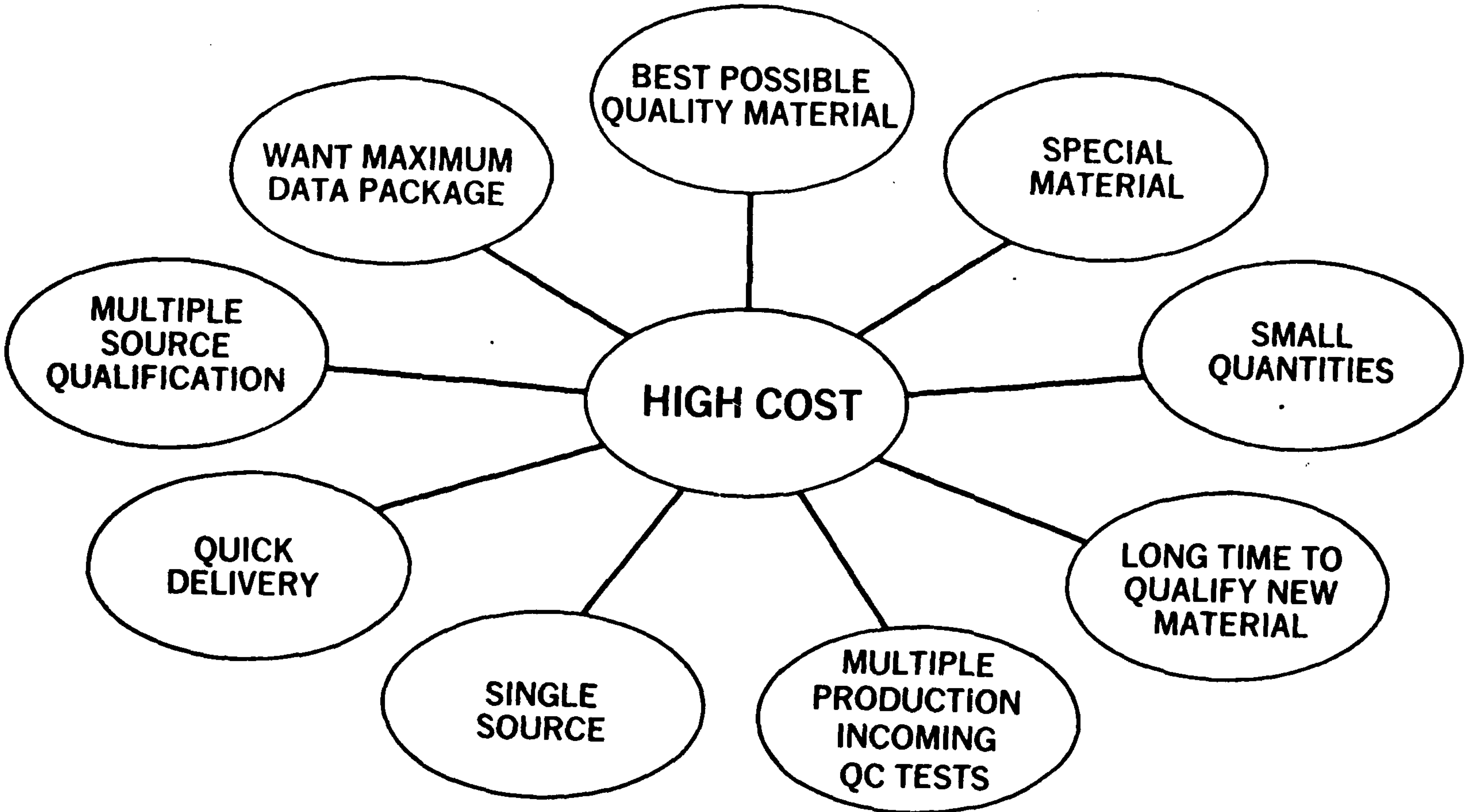


ALTERNATE SOURCE MATERIAL QUALIFICATION AND CERTIFICATION



84 DP 8099
7500 585 m 409d

WHAT IS THE PROBLEM?



84-DP-8098
7500 585 m1409

WHAT IS NEEDED?

STANDARD INDUSTRY MATERIAL SPECIFICATIONS

STANDARD MATERIAL FORMS — TYPES, CLASSES, GRADES

STANDARD METHODS OF TEST

FAA-CERTIFIED FABRICATION AND TESTING LABORATORIES

ONE-TIME FAA ACCEPTANCE TEST PROGRAM FOR ALL INDUSTRY

84 DP 8100
7500 585 m14(9)

SUGGESTIONS FOR REDUCING COSTS

NASA/DoD-FUNDED DEVELOPMENT

STANDARD INDUSTRY MATERIAL SPECIFICATIONS

- CLOSE TOLERANCE — CRITICAL PARTS
- EASY TOLERANCE — NONCRITICAL PARTS

CENTRAL FAA-APPROVED FABRICATION AND TEST LABORATORIES

- FAA-CERTIFIED DATA FOR MATERIAL QUALIFICATION

SUPPLIER PAY FOR FUNCTION OF FAA-APPROVED LABORATORIES

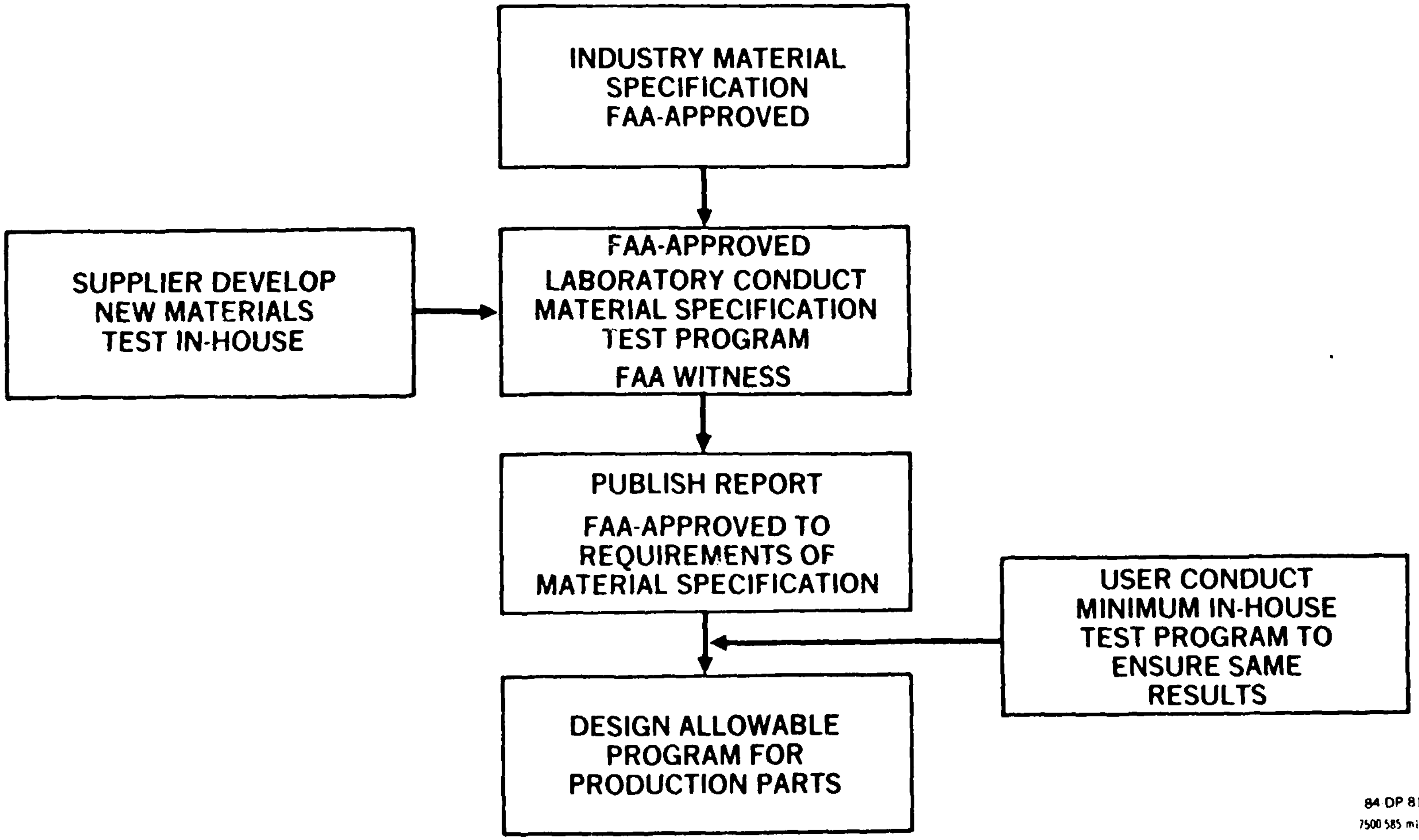
- USE INDUSTRY SPECIFICATIONS
- OBTAIN FAA-ACCEPTED SPECIFIED MATERIAL FOR INDUSTRY

USER

- MINIMUM TESTING OF MATERIALS AND PROCESS PROPERTIES
- CONDUCT INDIVIDUAL DESIGN ALLOWABLE PROGRAM

84 DP 8097
7500 585 m14196

SUGGESTED APPROACH FOR FAA APPROVAL OF NEW MATERIALS



84 DP 8103
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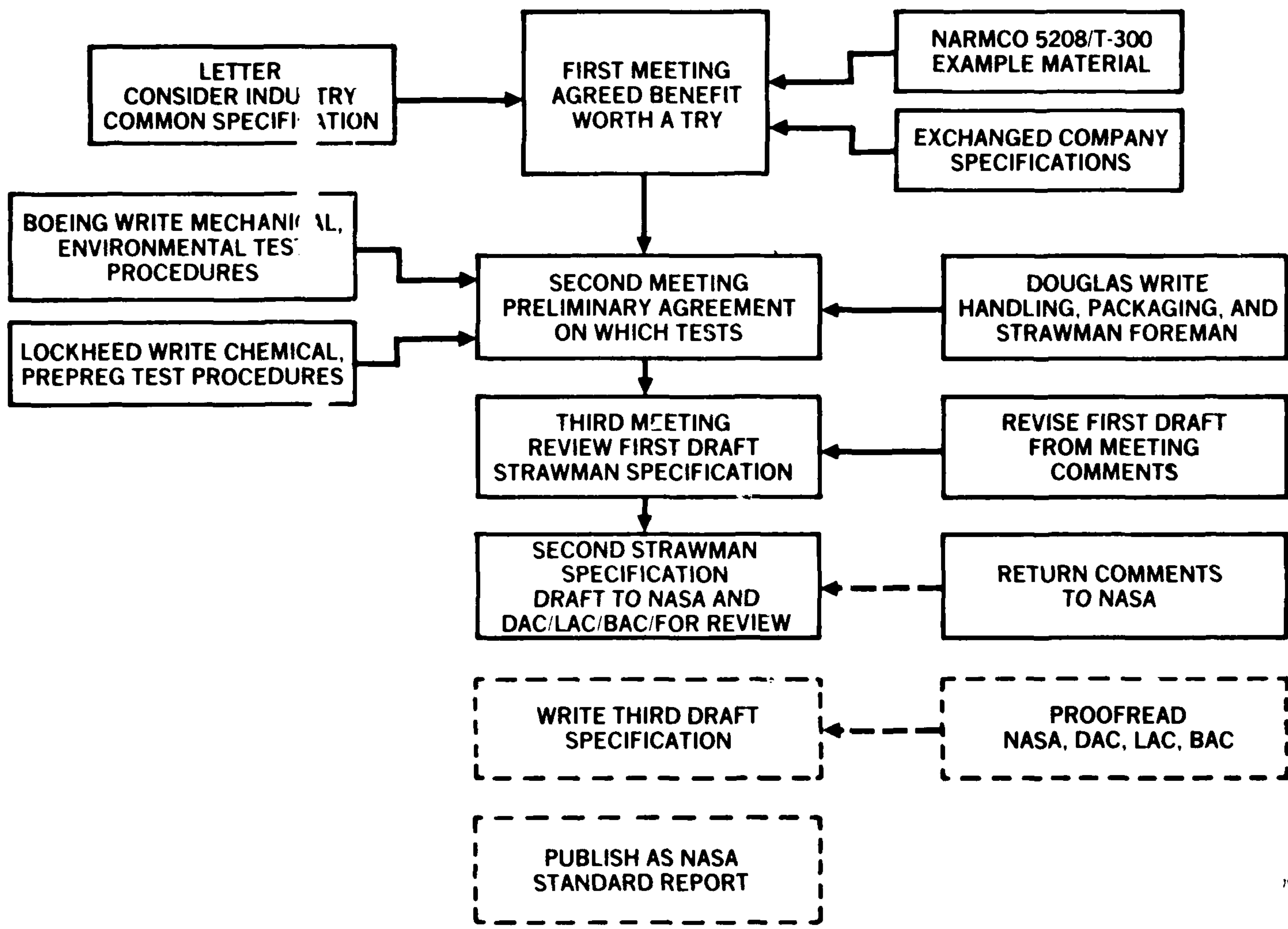
STATUS OF DAC/LAC/BAC SPECIFICATION

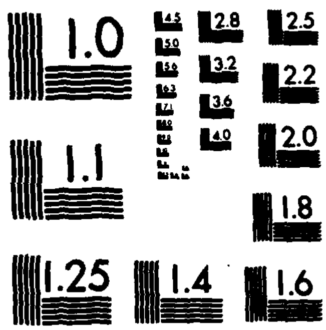
NASA COORDINATION



84 DP 8102

AD-A149 039 PROCEEDINGS OF COLLOQUIUM/WORKSHOP ON COMPOSITE MATERIALS AND STRUCTURES..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA S L CHANNON JUL 84 IDA-D-70 3/6

UNCLASSIFIED MDA903-84-C-0031 F/G 11/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

INDUSTRIAL PRODUCTS

Gerald Sauer
Narmco Materials, Inc.

INDUSTRIAL PRODUCTS

Gerald Sauer

Narmco Materials, Inc.

When Dr. Channon asked me to speak today on industrial products, I asked myself - What does he mean? What are industrial products that are using composites? In putting together this list, I came up with the most obvious ones to which most of us have had a great deal of exposure, i.e., sporting goods. (Slides of fishing rods, golf shafts and heads, racket ball rackets, masts, race car, boats were shown)*. Nobody has addressed the forms of the composites today which include different tapes, tape widths, fiber areal weights, resin content, various kinds of fabrics, chopped fibers, roving tapes, and resin series (epoxies, polyester, bismaleimide, phenolics, etc.). At one time, it was thought that the automotive industry would be a large user of advanced composites. The worldwide production capacity was indicated at 10-15 million pounds of carbon fiber annually at one time. If each car manufactured this year had one pound on it, it would consume the entire supply. Another application for composites is piping.

We have seen the qualification requirements from the aerospace companies and they are just as complex as you have heard today. From the suppliers standpoint, it is very complicated because we have a wide range of applications to be concerned with. The applications in the industrial field are extremely simple. There is practically no requirement for mechanical properties. The prepregs are specified usually by the supplier based on his knowledge of the user's application. The user tries it in his product using a trial run of 20-25 pounds and, if it works, he will continue to buy it. However, the one factor that is more stringent is the

*p. 198.

cosmetic requirement, eg. in the fishing rods where puckers or splits will cause a defective rod. The quality control consists of a tip bent through 180 without breaking. If it does break, the manufacturer goes after the material supplier. At this point in time, simplicity is the name of the game in the non-aerospace industry, and it applies no matter what they are building with it. An X-ray cassette made from carbon fiber is checked by X-ray to see if it is clean and does not show shadows. That is the only requirement.

As suppliers, we establish the criteria and the quality level for commercial applications. We generally recommend the resin content. We try to predict the fiber weight that we think will work in his application. We decide, with him, whether he will get a supplementary scrim on the fiber and usually that is just for handleability. The competition is extremely tough in the industrial market because the requirements are fairly low and just about anybody who can put the materials together can get into the commercial business. His ability to stay will depend on how good he is. We would ordinarily do the gel, flow, tack type tests as an in-process control for ourselves. These are the things that we can adjust in our own manufacturing operation to correct any problems that might develop in the use of the material.

Keep in mind that the user is probably putting those materials together with people who have the least experience in the industry because, in the sporting goods business, the people are hired right off the street and they are told nothing about the materials, or they understand little of it, or they are just following directions like a cook book. In many cases, the supervisors or management know very little more. So we must maintain a good close liaison with the fabricators so we can detect and correct any anomalies, and keep him out of trouble.

Actually, you are looking at a complex arrangement between the user and the supplier in the industrial area. We provide his quality control essentially. We are much closer to a commodity because, as a supplier, we have the ability to dictate the resin content, fibers, etc. and we often try to develop a product that will be usable by a number of people and thus reduce the proliferation of products.

INDUSTRIAL PRODUCTS

THE BEST KNOWN ARE IN THE SPORTING GOODS MARKET:

(1) GOLF CLUBS
- A) SHAFTS
- B) HEADS

(2) FISHING RODS
- A) FRESH WATER FISHING
- B) SALT WATER FISHING

(3) BOATS
- A) GLASS - PLEASURE CRAFT
- B) KEVLAR - HIGH PERFORMANCE
- C) CARBON - SAIL BOAT MASTS

(4) RACQUETS
- A) TENNIS
- B) RACQUET BALL
- C) BADMINTON

(5) OTHERS
- A) ARROWS AND BOWS
- B) POLE VAULT POLES
- C) SKI POLES
- D) BOAT OUTRIGGERS
- E) TUBULAR PRODUCTS

MOST SPORTING GOODS APPLICATIONS USE THE FOLLOWING FORMS:

1. GRAPHITE
   A) UNIDIRECTIONAL TAPES
   B) SINGLE STRAND ROVING OR WET WINDING
   C) VERY LITTLE FABRIC
   D) EVEN LESS CHOPPED FIBER MOLDING COMPOUNDS

2. KEVLAR
   A) FABRIC PREDOMINATES
   B) SOME SINGLE STRAND USED
   C) VERY LITTLE TAPE

3. GLASS
   A) CHOPPED FIBER PREDOMINATES
   B) FABRICS AND TAPE ARE POOR SECONDS

THE RESINS USED ARE:

1. POLYESTERS
2. EPOXY
3. SOME PHENOLICS

THE HIGHEST CURE TEMPERATURE NORMALLY IS >250 - 275°F WITH THE LOWER TEMPERATURES PREFERRED.

OTHER INDUSTRIAL APPLICATIONS:

1. AUTOMOTIVE

   A) MOLDED PANELS, HINGES, WINDOW FRAMES, BRACKETS

   B) FILIMENT WOUND- DRIVE SHAFTS

   C) TAPE - SPRINGS, BUMPERS, FRAMES

THE FACTORS APPEAR TO BE RETARDING THE WIDESPREAD USE OF COMPOSITES IN THE AUTOMOTIVE FIELD:

   A) COST OF CARBON FIBER

   B) DIFFICULTY IN PROCESSING

   C) DESIGN CHANGES

      1) SMALLER VEHICLES

      2) FRONT WHEEL DRIVE (DRIVESHAFT ELIMINATION)

   D) STABILIZATION OF WORLD OIL PRICES

WORLDWIDE AVAILABILITY OF CARBON FIBER IS 10 MILLION LBS. THIS EQUATES TO <1 LB. PER VEHICLE AT A WORLDWIDE PRODUCTION RATE OF 18 MILLION VEHICLES ANNUALLY.

AS YOU CAN SEE, IF THE WORLD AUTO INDUSTRY ELECTS TO START USING CARBON FIBER, THE AVAILABLE SUPPLY WILL NEED TO INCREASE SUBSTANTIALLY.

OTHER INDUSTRIAL APPLICATIONS: (CONTINUED)

2. PRESSURE VESSELS AND PIPING
   A) CHEMICAL INDUSTRY
   B) STORAGE TANKS
   C) BOOMS AND CRANES
   D) MEDICAL INDUSTRY
      (X-RAY TABLES, CASSETTES)

THE MAJORITY OF THE COMPOSITE APPLICATIONS ARE GLASS AND KEVLAR FIBERS, HOWEVER, SEVERAL INDUSTRIAL APPLICATION I.E. MEDICAL, ELEVATORS, ETC. ARE ACTIVELY STUDYING CARBON FIBER COMPOSITES.

QUALIFICATION REQUIREMENTS

I. VERY SIMPLE COMPARED TO AEROSPACE

1. "USE" OR "TRIAL" TESTING IS THE BASIC PROCEDURE
2. THE SPECIFICATION IS USUALLY DETERMINED BY THE SUPPLIER
3. LITTLE OR NO MECHANICAL TESTING IS PERFORMED
4. PHYSICAL "COSMETIC" PROPERTIES ARE MORE STRINGENT THAN AEROSPACE
5. THE USER IS LESS KNOWLEDGEABLE THAN SUPPLIER OR AEROSPACE COUTERPART
6. SIMPLICITY AND EASE OF FABRICATION ARE PARAMOUNT
7. USE OF TAPES IS MOST COMMON

QUALIFICATION REQUIREMENTS

II. COMPARISON OF TWO SYSTEMS:
COMMERCIAL VERSUS AEROSPACE

1. TYPE OF FIBER OR CONTROL OF RESIN TOTALLY UP TO SUPPLIER

2. COMPETITION FOR EXISTING BUSINESS IS STRONG, WITH COST OF PREPREG A LEADING DECISION FACTOR

3. USER IS GENERALLY UNABLE OR UNWILLING TO MODIFY OR ADJUST PROCESS TO ACCOMMODATE PRODUCT PROCESSING DIFFERENCES

   A) GEL TIME

   B) FLOW

   C) TACK

4. MANUFACTURING AND SUPERVISION HAVE LITTLE OR NO UNDERSTANDING OF COMPOSITES, THEREFORE, REQUIRING THE SUPPLIER KNOW AND UNDERSTAND USER'S SYSTEM AND EQUIPMENT TO PROVIDE A SUITABLE SYSTEM

5. MUCH CLOSER TO A "COMMODITY" PRODUCT THAN AEROSPACE

STANDARDS ACTIVITIES

W. Stinchcomb
Chairman, ASTM Committee D-30

STANDARDS ACTIVITIES

W. Stinchcomb

Chairman, ASTM Committee D-30

For about 85 years, ASTM has been active in the development of voluntary consensus standards for materials and test methods. Currently, the membership of ASTM is about 30,000 and is international. The organization is broken down into about 140 working groups or standards writing committees which address specific topics, and those committees are further broken down into a number of sub-committees and task groups. The information that is collected by ASTM is communicated in a number of ways. Perhaps the most familiar of these is the book of standards which is put out annually and contains all of the documents that have been developed. I'll be talking about some of these others in a few moments.

In the area of composite materials specifically, one of the major working groups within ASTM is Committee D-30 on High Modulus Fibers and their Composites. This group has a directive to develop standards, sponsor symposia, stimulate research and also to exchange technical information on fibers having a modulus of 3 million psi or greater and composite materials fabricated using those fibers. Areas of our activities which are well defined and established at this point are carried out in various sub-committees. Other areas that are developing or emerging are less well defined and that activity is carried out in a number of task groups. I have identified those on the chart:- delamination and debonding, fracture and fractography, metal matrix composites. In addition, because composites are truly an interdisciplinary technology, we find it very important to interface with other organizations. Within ASTM, we have an active liaison with the plastics committees, fatigue committee, fracture committee and the mechanical testing committee.

We have approximately 200 members. If we choose to identify these members in a number of ways - there are about 125 from industry and various independent research laboratories, about 30 from Government agencies and Laboratories and about 40 from the Universities. A little less than 10% of them are international. If we classify these people according to their interests, about 2/3 make up the producers and users from the industry group and the remaining Government and University people make up about 2/3 of the general interest group.

I have listed some rather general accomplishments that have taken place in this group over the past 18 years or so.* With direct focus on composite materials, there are 26 standards which are on the books at this time and an additional 36 documents which are also standards, but are under the jurisdiction of other committees of ASTM, which we call supporting documents. In the process of developing these standards, we have also sponsored various symposia on special topics over the years at the rate of about two per year. Some have been so important that, in testing and design, we have had 7 and there have also been 7 on fatigue, fracture and long term behaviour. These symposia have resulted in a number of documents and we are proud of the fact that the Special Technical Publications which come out of these symposia are really the base line for composite materials. There are 33 of those published or in the process. Composites Technology Review, a quarterly Journal is sponsored by Committee D-30 and a compilation of various works related to composites will be published annually. It is important to recognize that one of the things that we must do is to communicate very well within a diversified community such as that of composite materials. This is one of the goals of these publications.

*p. 214.

I should also point out that, in the document that you will get with the proceedings of this symposium, there will be more specific information related to the various standards, the STPs and some of the on-going activities within Committee D-30.

We are in the process of developing the standards and of reviewing the standards that we now have. I have outlined here a process which is used in the development, hopefully, of an ASTM standard test method. Problems need to be identified and they need to have some initial research done on them, evaluated, develop a working document, then go through a series of evaluations of the working document through round robin testing, various revisions so that we can develop a precision and accuracy statement to include in the document. Because we are a consensus organization, we have to go through a series of ballots, both at our working committee levels, main committee level and at the Society level, so everybody has a chance to review the work that is turned out. Once the work has gone through that ballotting process, and we can resolve the various negatives that have been cast, we do then have an ASTM test method.

Two of the activities that are continuing, and that most of you would think we should hurry up and get finished, are a workable shear test method (most people are not happy with the ones that are available) and a good series of compression test methods.

Various activities have been identified as thrust areas. We have just heard a presentation on high volume production composites. We have an active sub-committee in that area, which sponsored a symposium in 1983 and a publication will be forth-coming from that symposium. One of the very active and critical areas to the composites community right now is the issue of delamination, debonding and adhesive joining. L. Vosteen has talked about this and we do have an active task group in this area. Some of the outcome from the joint venture between NASA and the commercial airframe manufacturers is being transitioned at this point into ASTM. We are in the process of developing standard test methods as part of that activity. Recently, a symposium was held on this and a Special Technical publication is forthcoming and we are about to embark on a round robin test procedure to begin the standardization process of various test methods. A second outcome of that activity is the new resin (so-called tough composite materials) activity on which a symposium will be held in the Spring of next year. One of the areas in which we are quite interested is the metal matrix activity, and with the cooperation of DoD, we will be holding a symposium on metal matrix test methods about a year and a half from now.

There are a number of problem areas that I would like to address, that we have to put up with in the standardization process. I think we all recognize that the voluntary consensus process is a time consuming process and some of you don't like that. I too wish that we could turn out a product in a shorter period of time, but we are faced with the parameters of time and need on the one hand, and we must also provide a document that has quality and reliability in it. So we try to do the best that we can with a volunteer organization. Standard test methods must be kept current. Once we turn out a product, it doesn't mean that it is never looked at again. Every four years, we are required to revalidate a test method, and if needs arise for change, those needs are incorporated. This does not mean that the needs are only instituted on a four year basis. Changes are made when needed. However, we are dealing with a new technology and many rapid advances are being made. In some cases, we have had to begin work on revisions of a test method the day it was published.

Unfortunately, not all of the test methods are used as we intended them. We are faced with a very real issue of either non-use or mis-use of the test methods that are put out. From time to time, we learn that the standard test methods that have been issued are used incorrectly; they may also be used inappropriately and, in some cases, they are not used at all. Quite often, these test methods have been cited to validate a data base that has been generated. I think we all recognize that, on any committee, there are always fewer participants than members. I wish there was something that we could do about that because I think it does translate directly into whether or not the composites community has full access to the product that we attempt to produce.

I have identified a number of needs that I would like to address. We've heard a lot this morning about the need for a data base. Those of us who are involved in the development of standard test methods do need a data base with which to work. We would like to be able to have better round robin testing and analysis programs being run. We would like to be able to design those programs using a good design basis and develop sound procedures for the conduct of those round robin programs. We would like to be able to say that we had active voluntary participation in all aspects of the standard development process, so that the bottom line that we could turn out would be a traceable document with data and various procedures. One of the comments that I would like to obtain on Thursday would be some indication as to whether or not unified and systematic certification procedures will be used and if you would like to have ASTM involved. Because test method development is not usually an identifiable item in most DoD and NASA contracts, those who have been actively involved in the development of test methods either in government agencies or in industries often perform this activity by a bootlegging process, and that usually involves a significant expenditure. I would encourage those people who are in DoD and NASA and various other organizations to simply begin to encourage us to be more willing to develop sound test methods. Communications are an important activity because we are a diversified group working to develop these documents. We would like to have your communication to us and our communication to you on various statements and goals and definitions of responsibilities in this area.

Finally, some recommendations and suggestions. I think we all recognize that the development of sound workable test methods is an important activity in composite materials, but it needs to go beyond the point of recognition and needs to have a commitment associated with it. And so I would ask that the various standards writing organizations, the industries, universities and the various government agencies make that commitment for developing test methods for composite materials and structures and to support that activity at all levels. In addition, I would like some feedback from a group such as this. We would like to know how good the test methods are that we develop, - are they being used, and can they be used? At the same time, perhaps coming out of this meeting this week, I would like to receive various recommendations and priorities so that the test method development process can continue in an efficient manner. I think we recognize that we are involved in a lengthy and time consuming process but it would certainly help those of us who are involved in test method development if there was some forecasting of what the needs were going to be. If we could do a better job of foreseeing needs, I think we could do a better job of developing test methods. Right now, in many cases, test method development is reactionary. We respond to a need when it has been identified as critical.

ASTM'S ACTIVITIES IN DEVELOPING STANDARD TEST METHODS FOR COMPOSITE MATERIALS

WAYNE W. STINCHCOMB

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
BLACKSBURG, VIRGINIA 24061

CHAIRMAN -- ASTM COMMITTEE D-30
HIGH MODULUS FIBERS AND THEIR COMPOSITES

PRESENTED AT THE
COLLOQUIUM / WORKSHOP

COMPOSITE MATERIALS AND STRUCTURE:
STANDARDIZATION, QUALIFICATION, CERTIFICATION

MAY 8-10, 1984

ORGANIZED BY THE INSTITUTE FOR DEFENSE ANALYSIS

ASTM

VOLUNTARY CONCENSUS STANDARDS SINCE 1898

- 30,000 MEMBERS

- ORGANIZATION
  - 140 STANDARDS WRITING COMMITTEES
  - 2000 SUBCOMMITTEES
  - THOUSANDS OF TASK GROUPS

- PUBLICATIONS
  - BOOK OF STANDARDS
  - SPECIAL TECHNICAL PUBLICATIONS
  - TECHNICAL JOURNALS

ASTM COMMITTEE ON COMPOSITE MATERIALS

D-30 HIGH MODULUS FIBERS AND THEIR COMPOSITES

- SCOPE -- TO DEVELOP STANDARDS, SPONSOR SYMPOSIA, STIMUALATE RESEARCH, AND EXCHANGE TECHNICAL INFORMATION PERTAINING TO FIBERS HAVING A YOUNG'S MODULUS GREATER THAN 3×10^6 PSI AND COMPOSITES FABRICATED FROM THESE FIBERS.

- SUBCOMMITTEES
  - EDITORIAL
  - AUTOMOTIVE AND INDUSTRIAL COMPOSITES
  - RESEARCH AND MECHANICS
  - HIGH PERFORMANCE COMPOSITES

- TASK GROUPS
  - DELAMINATION AND DEBONDING (JOINT WITH THE ASTM FRACTURE COMMITTEE)
  - FRACTURE AND FRACTOGRAPHY
  - METAL MATRIX COMPOSITES

- LIAISON WITH ASTM COMMITTEES ON
  - PLASTICS
  - FATIGUE
  - FRACTURE
  - MECHANICAL TESTING (COMPRESSION)

COMPOSITION OF COMMITTEE D-30

MEMBERSHIP: 192

- COMPOSITION BY TYPE OF ORGANIZATION:
  - INDUSTRY AND INDEPENDENT RESEARCH LABORATORIES -- 124
  - GOVERNMENT AGENCIES AND LABORATORIES -- 29
  - UNIVERSITIES -- 39

- -

- COMPOSITION BY INTERESTS:
  - PRODUCERS -- 32
  - USERS -- 51
  - GENERAL INTEREST -- 96
  - UNCLASSIFIED -- 13

ASTM Standards for Composite Materials

D-30 Standards

No.	Title
C0613	Resin Content of Carbon and Graphite Prepregs by Solvent Extraction
D2290	Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method
D2291	Fabrication of Ring Test Specimens for Glass-Resin Composites
D2344	Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short Beam Method
D2585	Preparation and Tension Testing of Filament-Wound Vessels
D2586	Hydrostatic Compressive Strength of Glass-Reinforced Plastic Cylinders
D3039	Tensile Properties of Fiber-Resin Composites
D3171	Fiber Content of Resin-Matrix Composites by Matrix Digestion
D3317	Specifications for High Modulus, Organic Yarn and Roving
D3355	Fiber Content of Unidirectional Fiber-Resin Composites by Electrical Resistivity
D3379	Tensile Strength and Young's Modulus for High-Modulus Single Filament Materials
D3410	Compressive Properties of Unidirectional or Crossply Fiber-Resin Composites
D3479	Tension-Tension Fatigue of Oriented Fiber Resin Matrix Composites
D3518	In-Plane Shear Stress-Strain Response of Unidirectional Reinforced Plastics
D3529	Resin Solids Content of Carbon Fiber-Epoxy Prepreg
D3530	Volatiles Content of Carbon Fiber-Epoxy Prepreg
D3531	Resin Flow of Carbon Fiber-Epoxy Prepreg
D3532	Gel Time of Carbon Fiber-Epoxy Prepreg
D3544	Reporting Test Results on High Modulus Fibers
D3552	Tensile Properties of Fiber-Reinforced Metal Matrix Composites
D3553	Fiber Content by Digestion of Reinforced Metal Matrix Composites
D3800	Density of High-Modulus Fibers
D3878	Definitions of Terms Relating to High-Modulus Reinforcing Fibers and Their Composites
D4018	Tensile Properties of Continuous Filament Carbon and Graphite Yarns, Strands, Rovings, and Tows
D4102	Thermal Oxidate Resistance of Carbon Fibers
D4255	In-plane Shear Properties of Composite Laminates

Applicable Documents for D-30 Standards and Related Standards

No.	Title
B193	Test for Resistivity of Electrical Conductor Materials
C581	Chemical Resistance of Thermosetting Resins Used in Glass Fiber Reinforced Structures
D123	Definition of Terms Relating to Textiles
D256	Impact Resistance of Plastics and Electrical Insulating Materials
D543	Resistance of Plastics to Chemical Reagents
D618	Conditioning Plastics and Electrical Insulating Materials for Testing

D638	Test for Tensile Properties of Plastics
D648	Deflection Temperature of Plastics Under Flexural Load
D671	Flexural Fatigue of Plastics by Constant-Amplitude-of-Force
D695	Compressive Properties of Rigid Plastics
D696	Coefficient of Linear Thermal Expansion of Plastics
D756	Practice for Determination of Weight and Shape Changes of Plastics Under Accelerated Service Conditions
D790	Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792	Tests for Specific Gravity and Density of Platics by Displacement
D891	Tests for Specific Gravity of Industrial Aromatic Hydrocarbons and Related Materials
D1423	Test for Twist in Yarns by the Direct Counting Method
D1505	Test for Density of Plastics by the Density-Gradient Technique
D1822	Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
D2236	Dynamic Mechanical Properties of Plastics by Means of a Torsional Pendulum
D2289	Tensile Properties of Plastics at High Speeds
D2343	Test for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics
D2584	Ignition Loss of Cured Reinforced Resins
D2587	Acetone Extraction and Ignition of Glass Fiber Strands, Yarns, and Roving for Reinforced Plastics
D2734	Void Content of Reinforced Plastics
D2990	Test for Tensile, Compressive, and Flexural Creep and Creep Rupture of Plastics
D3029	Test for Impact Resistance of Rigid Plastic Sheeting or Parts by Means of a Tup (Falling Weight)
D3163	Strength of Adhesively Bonded Rigid Plastic Lap-Shear Joints in Shear by Tension Loading
D3418	Transition Temperatures of Polymers by Thermal Analysis
D3647	Classifying Reinforced Plastic Pultruded Shapes According to Composition
D3846	In-Plane Shear Strength of Reinforced Plastics
E4	Load Verification of Testing Machines
E6	Definitions of Terms Relating to Methods of Mechanical Testing
E12	Definitions of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases
E18	Tests for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E83	Verification and Classification of Extensometers
E467	Recommended Practice for Verification of Constant Amplitude Dynamic Loads in an Axial Load Fatigue Testing Machine

ASTM Special Technical Publications
on Composite Materials

STP No.	Title	Pub. Date
427	Fiber-Strengthened Metallic Composites	1967
438	Metal Matrix Composites	1968
452	Interfaces in Composites	1969
460	Composite Materials: Testing and Design	1969
497	Composite Materials: Testing and Design (Second Conf.)	1972
521	Analysis of the Test Methods for High Modulus Fibers and Composites	1973
524	Applications of Composite Materials	1973
546	Composite Materials: Testing and Design (Third Conf.)	1974
568	Foreign Object Impact Damage to Composites	1975
569	Fatigue of Composite Materials	1975
580	Composite Reliability	1975
593	Fracture Mechanics of Composites	1976
602	Environmental Effects on Advanced Composite Materials	1976
617	Composite Materials: Testing and Design (Fourth Conf.)	1977
636	Fatigue of Filamentary Composite Materials	1977
658	Advanced Composite Materials--Environmental Effects	1978
674	Composite Materials: Testing and Design (Fifth Conf.)	1979
696	Nondestructive Evaluation and Flaw Criticality for Composite Materials	1979
704	Commercial Opportunities for Advanced Composites	1980
723	Fatigue of Fibrous Composite Materials	1981
734	Test Methods and Design Allowables for Fibrous Composites	1981
749	Joining of Composite Materials	1981
768	Composites for Extreme Environments	1982
772	Short Fiber Reinforced Composite Materials	1982
775	Damage in Composite Materials	1982
787	Composite Materials: Testing and Design (Sixth Conf.)	1983
797	Producibility and Quality Control	1983
813	Long-Term Behavior of Composites	1983
xxx	Effect of Defects in Composite Materials	1984
xxx	US-Japan Conference on Composite Materials	1985
xxx	Composites in Ground Transportation and High Volume Applications	1985
xxx	Delamination and Debonding of Materials	1985
xxx	Composite Materials: Testing and Design (Seventh Conf.)	1985

COMMITTEE D-30
ON
HIGH MODULUS FIBERS
AND THEIR COMPOSITES

ASTM 1916 Race St Philadelphia, PA 19103 (215) 299-5400
TWX 710-670-1037

Chairman: W. W. STINCHCOMB, Virginia Polytechnic Inst. & State University, Norris Hall, Engrg. Science & Mech. Dept., Blacksburg, VA 24061 (703-961-5316)
Vice-Chairman: R. F. ZABORA, Boeing Commercial Airplane Co., Mail Stop 3N-33, P.O. Box 3707, Seattle, WA 98124 (206-773-9340)
Secretary: PAMELA G. SULLIVAN, Lockheed Missiles & Space, 62-60/104/1, P.O. Box 504, Sunnyvale, CA 94088 (408-742-0783)
Membership Secretary: N. R. ADSIT, General Dynamics Convair, M. Z. 43-6332, P.O. Box 80847, San Diego, CA 92119 (619-277-8900)
Staff Manager: M. E. LIEFF (215-299-5516)

Committee D-30

Scope: To develop standards, sponsor symposia, stimulate research, and exchange technical information pertaining to fibers (having a Young's modulus greater than 20 GPa (3 x 10^6 psi) and composites fabricated from these fibers. These activities will be coordinated with those of other relevant committees of ASTM and other organizations.

Subcommittee D-30.01: Editorial

Chairman: Elizabeth C. Goeke

Scope: Responsible for by-laws, nomenclature, definition of terms, and editorial aspects of the Standards under the jurisdiction of the Committee D-30. At least one appointed member from each of the other subcommittees will serve on Subcommittee 30.01.

Subcommittee D-30.02: Research and Mechanics

Chairman: George P. Sendeckyj

Scope: Responsible for the development of test methods, recommended practices, nomenclature, classification, stimulation of research and investigation of fibers having a modulus exceeding 3 x 10^6 psi and composites fabricated from these fibers.

Subcommittee D-30.03: Automotive/Industrial Composites

Chairman: Dale Wilson

Scope: Responsible for the development of test methods, standard guides, specifications, nomenclature, classification, stimulation of research and investigation of specialized fibrous composites * which have organic matrices and are directed toward high volume use.

The primary input to this subcommittee will be requirements of the automotive, transporation and other commercial industries, government agencies and research laboratories using materials whose unique properties are formulated for high volume applications.

* Specialized fibrous composites will include composite systems such as fiber-reinforced laminates, three-dimensional laminates, hybrid composites, sandwich structures with laminate faces and/or cores and other developing composite systems.

Subcommittee D-30.04: High Performance Fibers and Composites

Chairman: Paul Lockwood

Scope: Responsible for the development of test methods, specifications, standard guides, nomenclature, classification, stimulation of research and investigation of man-made fibers, filaments and whiskers in a single or multifilament form having a modulus exceeding 3×10^6 psi.

Responsible for the development of test methods, standard guides, specifications, nomenclature, classification, stimulation of research and investigation of specialized fibrous composites* which have organic or inorganic matrices.

The primary input to this subcommittee will be requirements of industries, government agencies and research laboratories using and producing high performance fibers and composites, such as the aerospace industry.

* Specialized fibrous composites will include composite systems such as fiber-reinforced laminates, three-dimensional laminates, hybrid composites, sandwich structures with laminate faces and/or cores and other developing composite systems.

ACCOMPLISHMENTS

- 26 Standards

  36 supporting documents from other committees

- 31 Symposia on Special Topics including series on:
  - testing and design (7)
  - fatigue, fracture, and long-term behavior (7)

- 33 Special Technical Publications (STP's)

  refereed papers from technical symposia

- Other Publications
  - Composites Technology Review (CTR)
    ASTM quarterly journal co-sponsored by D-30
  - Compilation
    New ASTM publication to include all standards and supporting documents for composite materials plus the tables of contents for all STP's and CTR's.

CONTINUING WORK

- STANDARDS DEVELOPMENT AND REVIEW
  - PROBLEM / NEED IDENTIFICATION
  - RESEARCH
  - EVALUATION
  - WORKING DOCUMENT
  - ROUND ROBIN TESTING
  - REVISIONS TO WORKING DOCUMENT (AS NEEDED)
  - PRECISION AND ACCURACY STATEMENT
  - BALLOTING (SUBCOMMITTEE, COMMITTEE, SOCIETY)
  - RESOLUTION OF NEGATIVES
  - ASTM STANDARD TEST METHOD
- SHEAR TEST METHODS
- COMPRESSION TEST METHODS

THRUST AREAS

- HIGH VOLUME PRODUCTION COMPOSITES
  - SUBCOMMITTEE
  - SYMPOSIUM, NOVEMBER 1983
  - SPECIAL TECHNICAL PUBLICATION
- DELAMINATION, DEBONDING, ADHESIVE JOINTS
  - TASK GROUP
  - SYMPOSIUM, NOVEMBER 1983
  - SPECIAL TECHNICAL PUBLICATION
  - ROUND ROBIN TESTING
- NEW RESIN SYSTEMS / TOUGH COMPOSITES
  - SYMPOSIUM, MARCH 1985
- METAL MATRIX COMPOSITES
  - TEST METHODS SYMPOSIUM, NOVEMBER 1985

PROBLEM AREAS RELATED TO STANDARDS DEVELOPMENT FOR COMPOSITE MATERIALS

- Development of Voluntary, Consensus Standards is a Lengthy Process
  - -- TIME AND URGENT NEED VS. QUALITY, RELIABILITY, AND UTILITY
- Standard Test Methods Must be Kept Current
  - -- EACH METHOD IS REVIEWED, UPDATED, AND REVISED EVERY FOUR YEARS
  - -- CHANGES ARE MADE MORE FREQUENTLY WHEN NEEDED
  - -- NEW MATERIALS AND NEW TECHNOLOGY ARE BEING INTRODUCED AT A RAPID RATE
- Nonuse and Misuse of Standard Test Methods for Composites
  - -- STANDARDS USED INCORRECTLY
  - -- STANDARDS USED INAPPROPRIATELY
  - -- STANDARDS NOT USED
  - -- NONUSED OR MISUSED STANDARD TEST METHODS ARE OFTEN CITED TO 'VALIDATE' A DATA BASE
- Token Representation on Standards Writing Committees
  - -- FEWER PARTICIPANTS THAN MEMBERS

NEEDS FOR IMPROVED STANDARDS DEVELOPMENT

- IMPROVED DATA BASE FOR TEST METHOD DEVELOPMENT
    - -- THE CURRENTLY AVAILABLE, GENERAL DATA BASE IS INCOMPLETE
    - -- MORE ROUND ROBIN TESTING AND ANALYSIS
    - -- GOOD DESIGN OF ROUND ROBIN TEST PLANS AND PROCEDURES
    - -- MORE VOLUNTARY PARTICIPATION IN ALL ASPECTS OF TEST DEVELOPMENT AND STANDARDIZATION
    - -- TRACEABLE DOCUMENTATION ON DATA AND PROCEDURES

- STANDARD TEST METHODS FOR COMPOSITE STRUCTURES AND COMPONENTS
    - -- ARE SYSTEMATIC AND UNIFIED CERTIFICATION PROCEDURES TO BE USED?

- DOD/NASA ENCOURAGEMENT OF TEST METHOD DEVELOPMENT
    - -- TEST METHOD DEVELOPMENT AND ROUND ROBIN TESTING ARE OFTEN 'BOOT-LEGGED' BY INDUSTRIES AND GOVERNMENT LABS.
    - -- THE FINANCIAL COMMITMENT TO DEVELOP RELIABLE TEST METHODS IS SUBSTANTIAL.

- BETTER INTERACTION AND COMMUNICATION BETWEEN STANDARDS WRITING ORGANIZATIONS, INDUSTRIES, UNIVERSITIES, AND DOD/NASA AGENCIES
    - -- STATEMENT OF GOALS
    - -- DEFINITION OF RESPONSIBILITIES

SUGGESTIONS AND RECOMMENDATIONS FOR STANDARDS RELATED ACTIVITY

- COMMITMENT BY STANDARDS WRITING ORGANIZATIONS, INDUSTRIES, UNIVERSITIES, AND GOVERNMENT AGENCIES TO
  - -- THE CONCEPT OF DEVELOPMENT OF STANDARD TEST METHODS FOR COMPOSITE MATERIALS AND STRUCTURES
  - -- THE SUPPORT OF ALL ASPECTS OF TEST METHOD DEVELOPMENT AND STANDARDIZATION, INCLUDING COST, TIME, MATERIALS, PERSONNEL, AND OTHER RESOURCES

- THE COMPOSITES COMMUNITY, AS A BODY
  - -- ASSESS AND REPORT THE CURRENT STATUS OF STANDARD TEST METHODS (QUALITY, RELIABILITY, UTILITY) FOR COMPOSITE MATERIALS
  - -- MAKE SPECIFIC RECOMMENDATIONS AND ESTABLISH PRIORITIES FOR EFFICIENT, LONG-TERM PLANNING AND DEVELOPMENT TO MEET THE ANTICIPATED NEEDS OF DOD/NASA AND INDUSTRIES
    - * MAKE THE STANDARDS DEVELOPMENT PROCESS MORE TIME AND COST EFFICIENT BY DOING A BETTER JOB OF FORESEEING NEEDS RATHER THAN JUST RESPONDING TO THEM.

STANDARDS ACTIVITIES

L. Johnson
Secretary, SAE/AMS Non-Metallics Committee

STANDARDS ACTIVITIES

L. Johnson

Secretary, SAE/AMS Non-Metallics Committee

Thank you for this opportunity to present SAE's activities in composites standards development. These activities go back to 1939 with the issuance of the first 101 aerospace materials specifications by the SAE aircraft materials division. Since then, the SAE specifications have grown to 2000 loose-leaf documents which are known and used throughout the world. The Composites Committee of ASE is one of the Non-Metallics Committee groups, and one of 11 operating committees involving materials, processes and testing under the Aerospace Materials Division. The Standards activities for composites principally involve three types: 1. AMS - the Aerospace Materials Specification which is the principal document used for the procurement of materials, 2. AIR - the Aerospace Information Report which is mainly a document to identify new materials and processes and is not normally used for procurement purposes, 3. ARP - Aerospace Recommended Practices which covers procedures and methods used to identify composite manufacturing techniques. The SAE specification activities go back 30 years with the publishing of the glass fabric matrix specifications. In the early 70's, the graphite specifications were published and, in the late 70's, the aramid specifications were published. Currently, 120 of the 2000 standards are related to composites. Last year, 35 new and revised specifications were issued. These are updated every five years to current practices; one fourth of them have been updated in the last year. The Committee participants involve many of the large aerospace companies, material manufacturers and DoD agencies. The content of the committees is intended to represent the viewpoints of the producer, consumer and regulator. Besides the voting participants, non-voting participants are also invited who have expertise in the area.

With the requirements of MIL STD 143 and the recently issued OMB Circular A019 which encourages the government to use more volunteer standards where possible, the amount of AMS specifications, included in DODISS, has been increasing. Currently, 700 AMS specifications are listed in DODISS, 40 percent of the AMS composite specifications (about 30) are listed in DODISS. This is up from 26 percent about three years ago. Many of the AMS specifications are also accepted by the American National Standards Institute, to move further toward international standardization. Currently, 40 percent of the AMS composite specifications are listed in ANSI.

The AMS composite specifications cover most of the materials used in the industry. The reinforcements of glass, boron, aramid and quartz are covered by specifications which are utilized in prepreg materials, with additional fibers of silica and asbestos, combined with resins such as polyester, epoxy, polyimide, phenolic and polysulfone to form prepreg specifications. Other materials covered by AMS material specifications including sandwich cores, foamed polyurethane, honeycomb materials of aramid, glass fiber, polyimide, polyimide paper phenolic, polyamide paper phenolic and glass phenolic. Various adhesives are used to assemble these structures in both film and paste form, including polyimide and epoxy resins. A number of ARPs and AMSs exist covering various fabrication techniques, such as sandwich panel fabrication, composite structures, automated manufacture of graphite-epoxy broad goods and manufacture of radome sandwich materials. Several ARPs exist covering quality testing by physical and chemical analysis of epoxy resins and prepreg materials by tracer fluoroscopy.

The basic technique of writing AMS specifications is to use one specification for one material/form. In the case of composite materials, with the great complexity of resins, binders and conditions, this was not considered too easy to do and would lead to errors and complexity in use. Therefore, it was decided to use the slash series format to assemble these specifications. The basic specification would cover the items common to the family and the slash series would cover the details for each specific combination. For instance, AMS 3892 covering the graphite fibers for structural composites has 5 variations covering tensile and modulus combinations. The same fiber is used in AMS 3894 as prepreg and is assembled into a series of 16 specifications covering several conditions of strength, modulus and use temperature. That same graphite is also used as a prepreg with polysulfone resin. AMS 3899 is currently a series of 2 with several conditions of strength, modulus and use temperature.

A number of concerns affect the composites standards development and affect the industry too. One of these is the lack of commonality of repair which causes problems with different people around the world using different methods and materials. The difficulty can be shown by the complete prohibition of the use of aluminum by some companies as a repair on composite facing. Because of this problem, and at the instigation of the Air Transport Association, SAE has started a task force to get at this problem. They have had two meetings but are still in their formative stage.

Another problem is the problem of export of technology, wherein two government agencies have regulations concerning the export of technology which affects the development of standards for composite materials, and in some cases, getting the standards published and distributed. Currently, this problem is under study by a number of government and industry organizations and SAE is developing plans in this area.

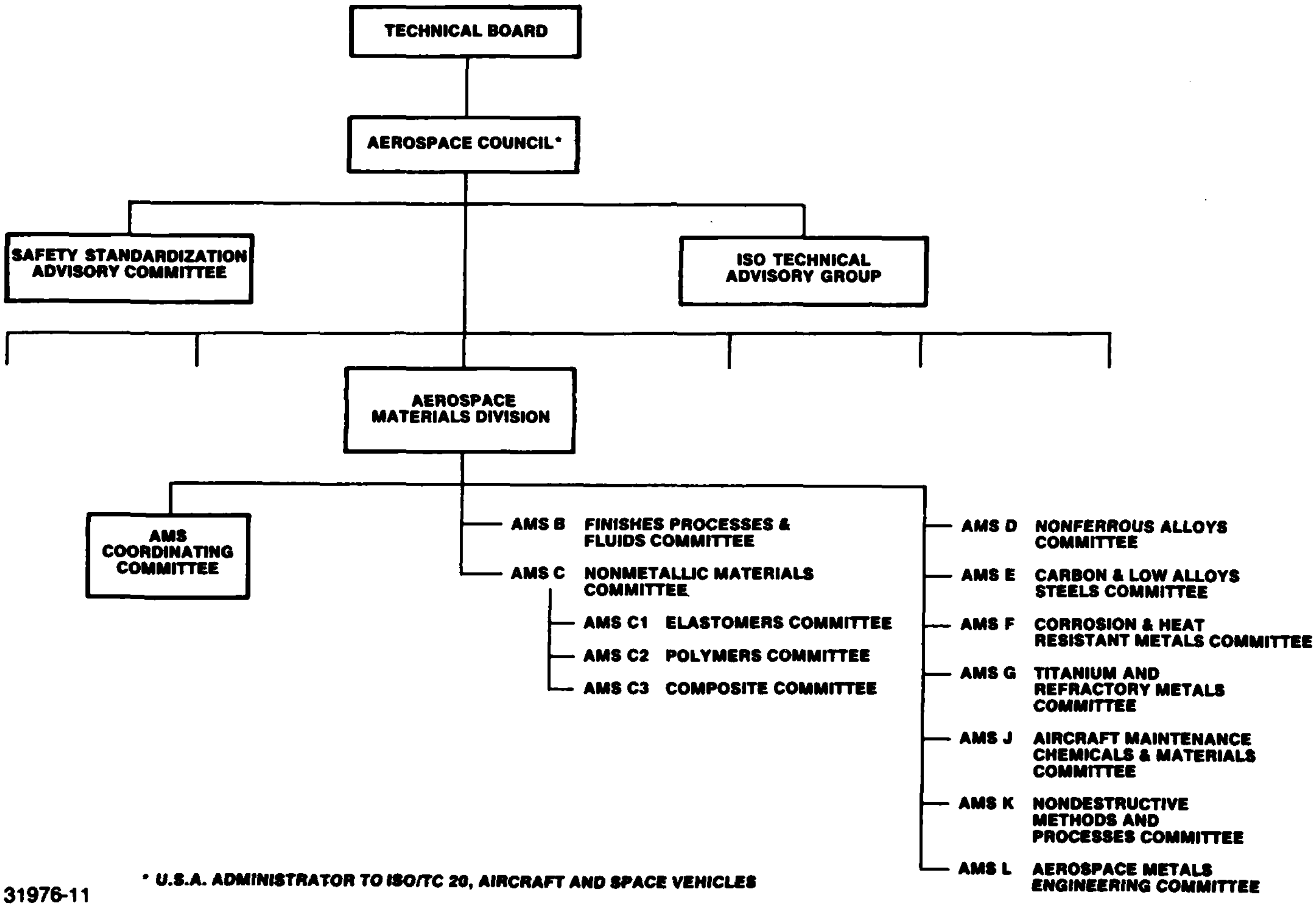
Another problem is the qualification of parts and materials. Because DoD is lacking in manpower to maintain the present qualification program, and with the increasing adoption of the specifications in DODISS, this is becoming more acute. The maintenance of lists of qualified suppliers is costly and cumbersome, but without these lists, it is more costly and time consuming for each individual user to develop their own sources. DoD is seeking help of standards bodies in this activity and SAE is working with DoD to establish plans in this area.

SAE ACTIVITIES IN COMPOSITE STANDARDS DEVELOPMENT

L. I. JOHNSON

HONEYWELL DEFENSE SYSTEMS DIVISION
600 SECOND STREET N. E.
HOPKINS, MINNESOTA 55343

SAE Aerospace Council Organization



* U.S.A. ADMINISTRATOR TO ISO/TC 20, AIRCRAFT AND SPACE VEHICLES

31976-11

SAE Standards Activities

AMS—Aerospace Material Specification

AIR—Aerospace Information Report

ARP—Aerospace Recommended Practice

120 SAE composite standards (2000 total active AMS)
35 New and revised in last year
25% revised annually

31976-1

SAE Composite Committee Participants

Represent viewpoints of:

Producer	Material Manufacturers
User	Major Aerospace Companies
Consumer	DoD Agencies
Regulator	

31976-2

Standards Widely Accepted

- Mil-Std-143 and OMB-A119 emphasis
- 40% of AMS composite spec in DODISS
  - Increasing rate of acceptance by DODISS
- 40% of AMS composite specs adopted by ANSI

31976-3

Raw Materials
Covered by AMS Specifications

Reinforcements—Fibers, Yarn, Roving

- Glass
- Quartz
- Boron
- Graphite
- Aramide

Pre-Preg Materials — Roving, Tape, Cloth

Reinforcements	Resins
Glass	Epoxy
Silica	Polyester
Quartz	Polyimide
Asbestos	Phenolic
Boron	Polysulfone
Graphite	
Aramide	

31976-12

SAE Specification Coverage of Composite Materials

Sandwich cores

- **Foam—polyurethane**
- **Honeycomb**
  - Aramide Fiber/phenolic
  - Glass Fiber/polyimide

  - Polyamide paper/phenolic
  - Glass Fiber/phenolic
- **Adhesives for Composites**
  - Film and paste
  - Polyimide
  - Epoxy

Fabrication

- of sandwich panels
- of composite structures
- of graphite/epoxy broadgoods
- radome of sandwich materials

Quality Testing

- by Physical-Chemical analysis of epoxy resins
- by Tracer Fluoroscopy

31976-13

AMS COMPOSITE MATERIAL SPECIFICATION ORGANIZATION

AMS 3892	+	Fibers, Graphite Tow and Yarn—for Structural Composites
AMS 3892/1	+	Tow, Graphite Fibers—for Structural Composites, GT 350 (2413) Tensile Strength, 30,000,000 (207) Tensile Modulus
AMS 3892/2	+	Tow, Graphite Fibers—for Structural Composites, GT 300 (2069) TS 50,000,000 (345) Tens. Mod.
AMS 3894C		Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated
AMS 3894/1A		Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 110,000 (758) Tensile, 27,000,000 (186) Modulus, 175 (350)
AMS 3894/2A		Carbon (Graphite) Fiber Tape and Sheet, Epoxy Resin Impregnated, G 150,000 (1034) Tensile, 20,000,000 (138) Modulus, 175 (350)
AMS 3899		Graphite Fiber Tape and Sheet—Polysulfone Resin Impregnated
AMS 3899/1		Graphite Fiber Tape and Sheet—Polysulfone Resin Impregnated, G PS 170,000 (1172) Tensile, 16,000,000 (110) Modulus, 120 (250)
AMS 3899/2		Graphite Fiber Tape and Sheet—Polysulfone Resin Impregnated, G PS 140,000 (965) Tensile, 27,000,000 (186) Modulus, 120 (250)

31976-Cb-257

Composite Repair Standardization

- Commonality of repair procedures is lacking
- Difficult to deal with repairs made in other shops
- SAE task force working on problem

31976-6

Export of Technology Regulations and Problems

- May adversely affect development of specifications for some processes
- May increase difficulty of getting some standards published and distributed
- Problem under study by a number of government and industry organizations

31976-14

Qualification of Parts, Materials, Producers

- DoD unable to maintain present qualification programs
- Problem becoming more acute
- DoD seeking help of volunteer standards bodies

31976-5

MIL-HANDBOOK-17

P. Doyle
Army Materials & Mechanics Research Center

MIL-HANDBOOK 17

P. Doyle

Army Materials & Mechanics Research Center

In this brief overview, I's like to define what MIL-Handbook 17 is, what our method of operation is, and when we hope to be out on the street with a revised document.

Basically, MIL-Handbook 17 is going to be a reference and the key thing is that it will be standardized. In order to be a viable document, it has to be acceptable to the DoD, the FAA and hopefully NASA. This document will be a fully coordinated effort with industry. Our committee is made up primarily of industry, the primary aircraft manufacturers, etc. We are after "A" and "B" basis allowables. We are trying to establish guidelines for testing and methods for data analyses to come up with these allowables. These are the same as those defined in MIL-Handbook 5 for metallic structures.

MIL-Handbook 17 is reasonably new. It started in the 60's and was under the control of the Air Force at that time at Forest Products Laboratories. It was later taken over by Plastec and, in the 70's, AMMRC took over the responsibility. There have been a number of meetings with industry. In May 1979, we decided to go out to industry to obtain data for inclusion in the handbook. As everybody knows, the data does not exist, or at least it did not exist to us. This changed the method of operation. It became apparent that, in order to have a viable handbook with any reasonable data in it, we would have to generate our own. It is a long tiresome task. Since we had to generate our own data, we decided that we had to completely characterize the systems. We are very strong on chemical analysis to get fingerprints on each of the batches. Several people fabricate our panels. We take samples from several locations within a batch. We run all of the mechanical tests at AMMRC so that we don't have the variability from one test laboratory to another. We do our own analysis of data. We are coming up with guidelines for data analysis and will hopefully publish "A" and "B" basis allowables.

Our basic method of operation is that the material is chosen at one of our meetings (which are semi-annual now) and they are usually voted on by the members at the meeting. We buy the prepreg. The prepreg is characterized using HPLC, FTSIR. The material is then shipped to the fabricator (Boeing, Lockheed, Northrop, etc.). The panels are returned to AMMRC and we determine that they are fully cured. We run short beam shear tests as a characterization method and we NDE each panel. We prepare specimens and condition them. Currently, we are looking at the hot wet condition, room temperature and 50 percent RH, and a cold dry condition. We seem to have homed in on those conditions. They are tested primarily at AMMRC. AFML has now volunteered to do some of the testing with us and they do a whole block of specimens. We don't split from one to the other. The data is analyzed at AMMRC and then we will report it in similar format to MIL-Handbook 5.

There was quite a bit of discussion this morning on what it costs to run a design allowables program. We are not a very heavily funded program, in the order of $200-300,000 per year to buy the material, run the tests, do the analysis, etc. We interface with most of the government agencies. In the private sector, we cover most of the aircraft manufacturers. Those involved in filament winding are just getting involved in MIL-Handbook 17 at this point. About 109 different representatives from different companies are invited to our meetings and normally we get about 60 attendees. Last year, we went to a two day, semi-annual meeting format and, in two days, we could not cover all of the controversial items that needed to be covered. We have had a tremendous amount of support from the participants at the meetings. We have looked at the glass systems for which we did most of the fabrication in-house. Since then, we have evaluated Kevlar, AS4/3501-6 and the T-300. The aerospace companies have volunteered to fabricate panels of about 25-30 sq.ft., all fabricated to the same process specification. Since we supply the material, this gives us a fair amount of control over what the end product will be. I'd like to thank each of these companies for their active participation because, without them, we would not have a viable program today. As far as testing is concerned, I know there is a lot of controversy over the types of specimens being used. We feel that we have to standardize on a specimen. At this point, we are using the ASTM standard for compression and tension. The short beam shear is not for design purposes but we use it for quality control on the panel. We don't use a bolt bearing test but we have a sub-committee which is looking into the types of tests for fasteners, etc. We use the $+/-45^\circ$ shear test but, again, there is a lot of controversy over what type of shear test is best.

An example of the Kevlar Phase II test program is shown in the chart.* The numbers don't mean very much. We are looking at about 1400 specimens to condition and test. Similarly, in the graphite program, we will be testing on the order of 2600 specimens for the two graphite fibers, AS4 and T-300.** Because of the conditioning time of 2-3 months for some specimens, it is a fairly long program.

An example of the statistical analysis on one fabricator using Kevlar with the Hexcel resin system is shown in the chart.*** We look at it with 3 methods, a log normal, normal and Weibull distribution. We compare

*p. 263
**p. 264
***p. 265.

all three methods but have not yet come up with a guideline as to which method we will use. It might be noted that, in MIL-Handbook 5, they are having problems with the skewed distribution with some of the metal data, so they are beginning to look at Weibull analyses for the non-normal distributions. We normally run 30-40 specimens from each fabricated panel and each condition depending on the size of the panels supplied by each of the fabricators.

Some of the items under discussion at our semi-annual meeting are presented in chart form. We have pretty much finished the multi-site data on the glass. The intent here was to take short beam shear specimens (which aren't the best specimens) from a panel and have them tested in a round robin with three laboratories to see how well the data would agree. As it worked out, we had excellent agreement, but we took great care to see that each laboratory tested them in the same way. The specimens were fabricated and conditioned at AMMRC and then tested by the Air Force, NASA and AMMRC. The Kevlar data is complete. We are continuing with statistical analysis. The T-300 and the AS-4 will probably be finished within the next 6-8 months.

Some of the areas of concern that we have include batch-to-batch variation - how many batches do you test? We take a look at fingerprints for each one. We look for differences in the fingerprints. We have not yet been able to correlate the mechanical properties to the fingerprint for the newer materials. We are attempting to do that. We are requesting that the companies who are involved in fingerprinting let us have information if they see some unusual indications, so that others will not fall into the same trap.

There are a number of ways of normalizing data. We hope to resolve that problem by our next meeting. We have a working group looking at joints, particularly fastened joints. We are not at this time looking at adhesively bonded joints. We will probably end up ballotting to determine what system we look at next. Each interest group wants us to evaluate a different system. When we select a new system, it will be 2-3 years before it comes out in handbook form. We have pretty well homed in on testing conditions. We are just beginning to get involved in filament winding. We have a working group that is going to come up with recommendations as to whether we do get involved and, if so, how do we test it, etc. This will be reported on at our next meeting.

A rough schedule on when we hope to have data available for publication is presented. The glass data is essentially available now. It is in our data bank. We have written a chapter for that. It has not been distributed but it is available. The Kevlar chapter is being written at this time. Testing is complete and that should be out within 6 months or so. The two graphite systems will be out by some time in '86. New systems will be in the '88 time frame. By the Fall meeting, we hope to come up with guidelines for the testing and analysis methods. As soon as those are established, we will revise the Kevlar and Glass data and make the data available.

MIL-HDBK-17

COMPOSITE MATERIALS

FOR

AIRCRAFT AND AEROSPACE

APPLICATIONS

WHAT IS MIL-HDBK-17?

A REFERENCE AND CONTRACTUAL TYPE DOCUMENT PROVIDING APPROPRIATE DATA ON A STANDARDIZED BASIS ACCEPTABLE TO DoD, FAA AND NASA THAT WILL FACILITATE THE DESIGN, FABRICATION AND UTILIZATION OF KEY RESIN MATRIX COMPOSITE MATERIALS.

A & B VALUES

	PROBABILITY	CONFIDENCE
"A" . . .	99%	95%
"B" . . .	90%	95%

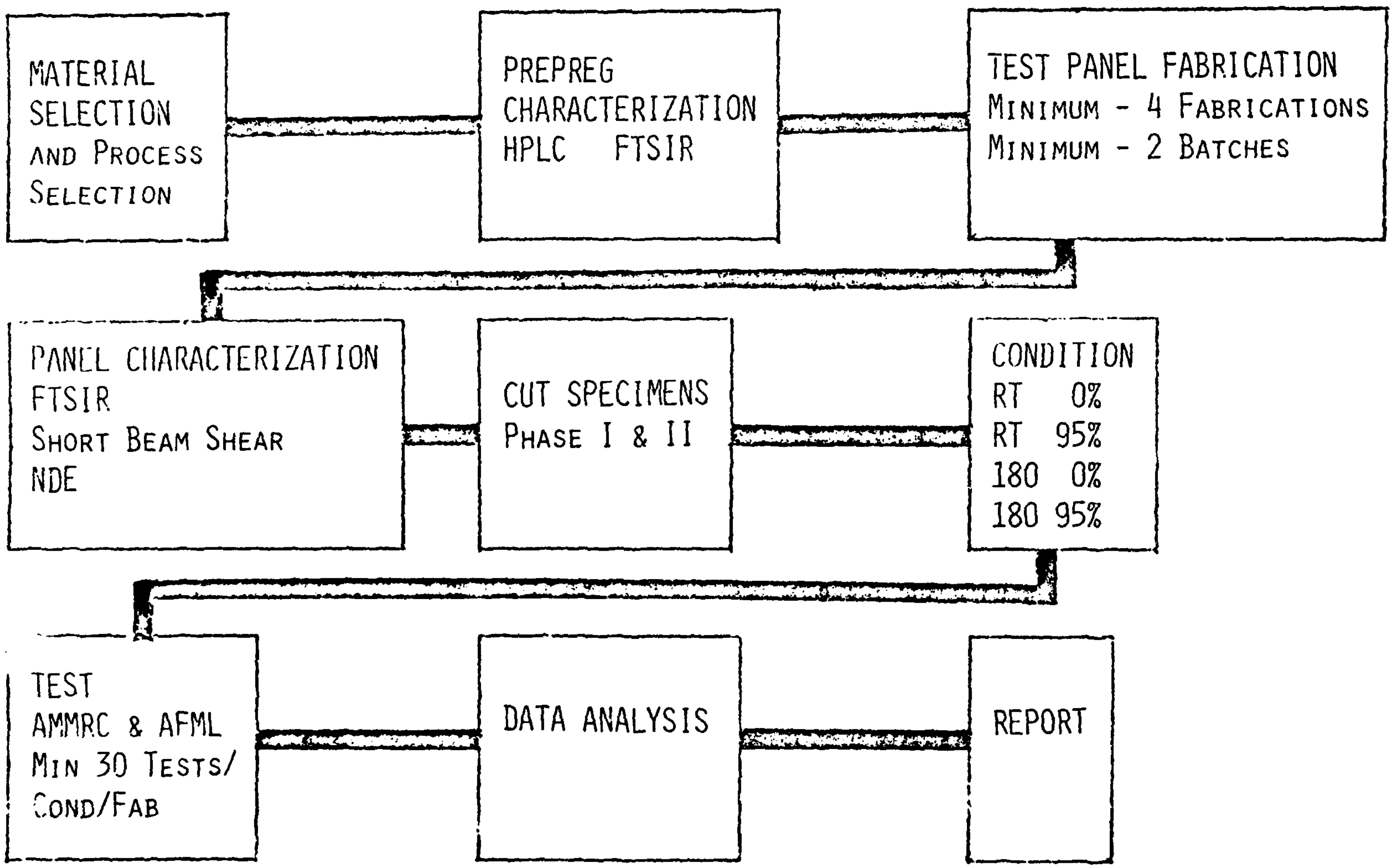
HISTORY OF MIL-HDBK-17

- EARLY 1960s - DOCUMENT COMPILED BY FOREST PRODUCTS LABORATORY, AIR FORCE PREPARING ACTIVITY
- MID 1960s - AIR FORCE PREPARING ACTIVITY, PLASTEC REPLACES FPL
- EARLY 1970s - REVISED EDITION PUBLISHED BY PLASTEC - *EMPHASIZES FIBERGLASS REINFORCED PLASTICS*
- MID 1970s - AIR FORCE EMPHASIZES DESIGN GUIDE FOR ADVANCED COMPOSITES (B&G REINFORCING FIBERS), MIL-HDBK-17 NOT UPDATED
- LATE 1977 - ARMY (AMMRC) ASSUMES PREPARING ACTIVITY

RECENT EVENTS

DATE	EVENT	RESULTS
APR 78	1ST MEETING OF GOVERNMENT REPRESENTATIONS	ORGANIZING & GENERAL ORIENTATION. ESTABLISHED OBJECTIVES. TITLES & MATERIALS
JUN 78	2ND MEETING OF GOVERNMENT REPRESENTATIVES	SOLIDIFIED OBJECTIVES. ESTABLISHED APPROXIMATE FUNDING REQUIREMENTS. AGENDA FOR GOV'T/INDUSTRY MEETING
JUN 78	1ST MEETING OF GOVERNMENT AND INDUSTRY REPRESENTATIVES	GENERAL ORIENTATION FOR INDUSTRY PERSONNEL. DISCUSSED OBJECTIVES. RECEIVED INDUSTRY IDEAS. INDUSTRY ENTHUSIASTIC ABOUT MIL-HDBK-17. ESTABLISHED NEED FOR QUESTIONNAIRE
AUG 78	QUESTIONNAIRE SENT TO INDUSTRY	RESPONSE TO PRELIMINARY QUESTIONNAIRE IS GOOD -- RESULTS WILL BE MADE AVAILABLE AT UPCOMING MEETINGS
OCT 78	3RD MEETING OF GOVERNMENT REPRESENTATIVES	QUESTIONNAIRE EVALUATED AND ON-SITE VISITS PLANNED
OCT 78	2ND MEETING OF GOVERNMENT AND INDUSTRY REPRESENTATIVES	QUESTIONNAIRE EVALUATED AND ON-SITE VISITS PLANNED
FEB-MAY 79	ON-SITES VISITS TO INDUSTRY	GATHERING OF DATA

MIL-HDBK-17 REVISION PROGRAM



MIL-HDBK-17 TESTING

PHASE I	COMPRESSION	ASTM D 3410	
	TENSION	ASTM D 3039	
	SHORT BEAM SHEAR	ASTM D 2344	*
PHASE II	BOLT BEARING	ASTM D 1602	
	SHEAR	ASTM D 3518	

* FOR INITIAL MATERIAL EVALUATION ONLY

	FY83	FY84	FY85	FY86	FY87	FY88	FY89
FUNDING	200	250	300	350	400	400	400

GOVERNMENT INTERFACE FY83-85

AMMRC
- ORGANIC MATERIALS LABORATORY
- METALS & CERAMICS LABORATORY
- MECHANICS & STRUCTURAL INTEGRITY LABORATORY

AVRADCOM
NAVAL AIR SYSTEMS COMMAND
NASA
AFWAL
FAA
ARRADCOM
MICOM

PRIVATE INDUSTRY INTERFACE FY83-85

BEECH	HUGHES
BELL	LEAR FAN
BOEING AIRPLANE	LOCKHEED
BOEING VERTOL	MARTIN MARIETTA
CIBA-GIEGY	MCDONNELL DOUGLAS
CONVAIR	NORTHROP
GRUMMAN	SIKORSKY
GULFSTREAM AMERICAN	SOCIETY OF MANUFACTURING ENGS
HERCULES	VOUGHT

MEETINGS

ANNUALLY, APPROXIMATELY 105 REPRESENTATIVES INVITED WITH APPROXIMATELY 60 ATTENDEES.
AS OF NOVEMBER 83 WE WILL HAVE SEMI-ANNUAL MEETINGS.

GOVERNMENT/INDUSTRIAL INTERFACE

PARTICIPANTS/FABRICATORS

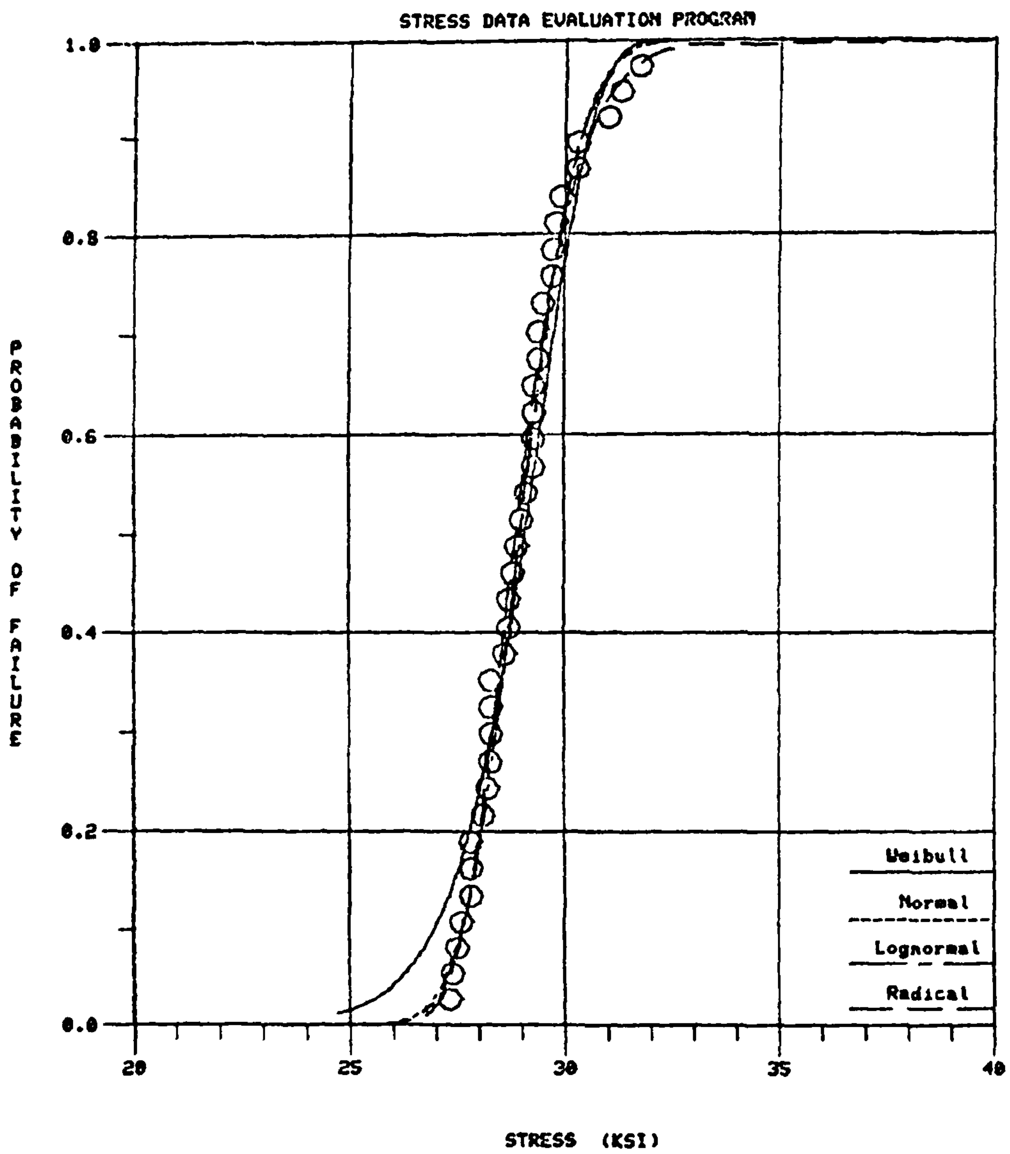
KEVLAR	AS4/3501-6	T300/934
CONVAIR	SIKORSKY	BOEING AIRCRAFT
GRUMMAN	NORTHROP	LEAR FAN
BOEING VERTOL	MCDONNELL AIRCRAFT	NORTHROP
BOEING AIRPLANE	LOCKHEED-GEORGIA	LOCKHEED MISSILE
LOCKHEED-CALIFORNIA	AMMRC	AMMRC
LOCKHEED-GEORGIA		
DOUGLAS AIRCRAFT		
AMMRC		

ESTIMATED KEVLAR PHASE II TEST SPECIMENS

TEST	MATERIAL	CONDITION	# FAB	TEST/FAB	TOTAL TESTS			
±45 SHEAR	CYCOM	RT/0%	4	20	80			
" "	"	RT/95	4	20	80			
" "	"	160/95	4	20	80			
TOTAL						240		
BOLT BEARING	SAME AS SHEAR					240		
±45 SHEAR	HEXCEL	RT/0	4	20	80			
" "	"	RT/95	4	20	80			
" "	"	160/95	4	20	80			
TOTAL						240		
BOLT BEARING	SAME AS SHEAR					240		
TOTAL KEVLAR PHASE II							960	
ADDITIONAL TESTS								
TENSION	CYCOM	RT/0	4	30	120			
"	HEXCEL	RT/0	4	30	120			
COMPRESSION	CYCOM	RT/0	4	30	120			
"	HEXCEL	RT/0	4	30	120			
TOTAL ADDITIONAL							480	
TOTAL TESTS								1,440

ESTIMATED GRAPHITE TEST SPECIMENS

TEST	MATERIAL	CONDITION	# FAB	TESTS/FAB	TOTAL TESTS			
TENSION	AS-4	RT/0%	6	20	120			
	"	RT/95	6	20	120			
	"	180/95	6	20	120			
TOTAL						360		
COMPRESSION	SAME AS TENSION					360		
SHEAR ±45	SAME AS TENSION					360		
BOLT BEARING	SAME AS TENSION					360		
TOTAL AS-4							1.440	
TENSION	T300	RT/0%	5	20	100			
"	"	RT/95	5	20	100			
"	"	RT/95	5	20	100			
TOTAL						300		
COMPRESSION	SAME AS TENSION					300		
SHEAR ±45	SAME AS TENSION					300		
BOLT BEARING	SAME AS TENSION					300		
TOTAL T300							1.200	
TOTAL TESTS								2.640



RMS ERROR

	Normal	Lognormal	Weibull	Radical
R1	.0341	.0317	.0660	.0305
R2	.0338	.0315	.0639	.0297
R3	.0340	.0317	.0611	.0290

		90% CONFIDENCE INTERVAL	
MEAN (KSI)=	28.992	28.681	29.303
S DEV (KSI)=	1.084	.911	1.348

WEIBULL PARAMETERS

		90% CONFIDENCE INTERVAL	
SLOPE M=	24.684	19.829	30.840
CHAR VALUE=	29.529	29.183	29.882
99% ORIGIN=	24.682	23.315	(95% CL)
ORIGIN=	.000		

RADICAL PARAMETERS

A=	35.037	EXP B (N)=	12.000
B=	5.574	EXP(R)=	12.090
C=	-12.106		
SIGI=	22.931	SIGF=	40.611

NON-PARAMETRI SOLN: A AND B ALLOWABLES
OPTIMAL:A(99,95,N=300)B(90,95,N= 30)
GIVEN DATA:
A(99,30,N= 36)B(93,98,N= 36)

WEIBULL:
DESIGN A= 23.315
DESIGN B= 26.205

NORMAL:
DESIGN A= 25.760
DESIGN B= 27.124

LOGNORMAL:
DESIGN A= 25.940
DESIGN B= 27.179

Hexcel Fabricator E - Compression
0%RH-RT Condition

Figure 43

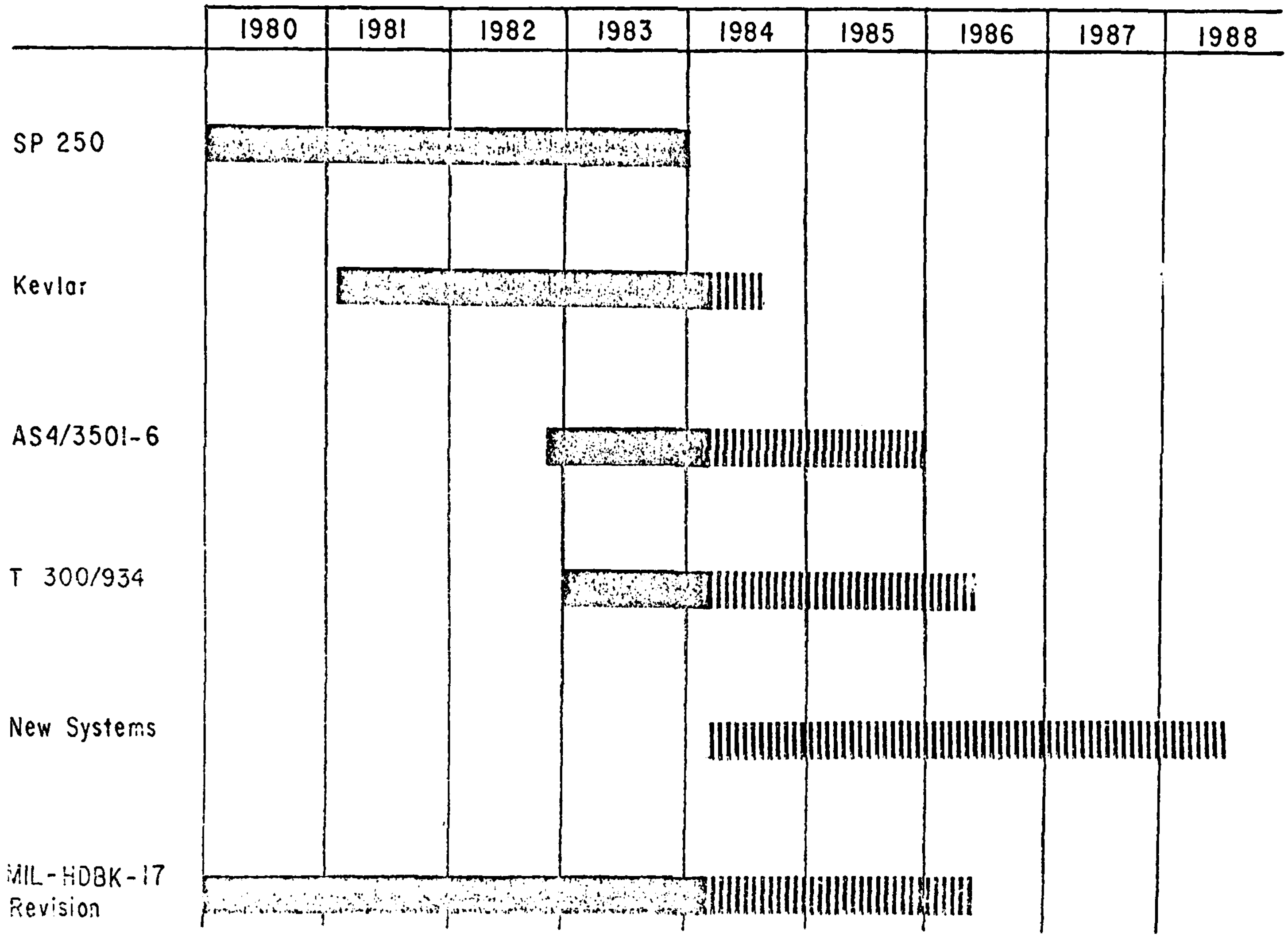
STATUS REPORT

ITEM	DESCRIPTION
• 81-1	GLASS MULTI-SITE DATA
• 81-2	PHASE I KEVLAR
• 81-3	STATISTICAL ANALYSIS
• 82-1	GLASS DATA PHASE II
• 82-2	KEVLAR PHASE II
• 82-3	AS4/3501-6 GRAPHITE PHASE I
• 82-4	AS4/3501-6 GRAPHITE PHASE II
• 82-5	T300/934 GRAPHITE PHASE I
• 82-6	T300/934 GRAPHITE PHASE II

ACTION ITEMS

ITEM	DESCRIPTION
• 83-1&2	BATCH TO BATCH VARIATIONS
• 83-3	NORMALIZE TENSILE DATA
• 83-4	NORMALIZE COMPRESSION DATA
• 83-5	JOINTS (WORKING GROUP)
• 83-6	BALLOT NEW SYSTEMS
• 83-7	BALLOT TESTING VS. CONDITIONING
• 83-8	FILAMENT WINDING (WORKING GROUP)

MIL-HDBK-17 REVISION SCHEDULE
Figure 1.



INTERNATIONAL STANDARDS

S.L. Channon
Consultant

INTERNATIONAL STANDARDS

S. L. Channon

Consultant

As part of the IDA study, some information was gathered on the present status of International Standards, i.e., those standards adopted by the International Standards Organization, and the efforts being made in Japan and Europe to establish standards relating to composites.

Composites have yet to become a part of the International Standards Organization agenda. The closest group is Working Group 4 of the Glass Committee TG-69, Subcommittee 11 which is concerned with commercial fiberglass rather than any of the advanced fibers. Inquiries into this Committee's activities revealed that progress on the commercial materials is very slow and there are communication problems with the various languages and the imprecise definition of words. There are no known plans at present to expand the scope of this committee or to add other subcommittees. It is understood that the last two meetings of the I.S.O. Committee on Aerospace Materials (which covers metals) were held in Moscow and Peking.

The Japanese carbon fiber producers established a Carbon Fiber Manufacturers Association 3 years ago and have already progressed to the point of recommending standard nomenclature and test methods for fibers. The participants in this "Club" are Toray Industries, Toho-Beslon, Mitsubishi Rayon, Sumika-Hercules and Asahi-Nippon. This Association works with the Japanese Industrial Standards Committee and is coordinated through the Ministry of International Trade and Industry although there is no M.I.T.I. control of its activities, according to the Japanese. Many Japanese fabricators use U.S. specifications and standards. Several prepreg producers are becoming qualified to U.S. specifications.

Many Japanese feel that it is too early to standardize products but others feel that, without standards, the industry will not grow.

The European standards activities in composites are numerous. At least a dozen groups in various countries have been identified. These groups seem to have difficulty agreeing on the technical criteria and format of inter-country standards and, in fact, it was found that U.S. standards are quite often used.

The European groups are summarized on the next two slides*, based on information provided by the various organizations visited in Europe. AECMA, headquartered in Paris, has a committee on composites which meets twice a year. Its activities are dominated by carbon fiber composites interests. The committee is composed of representatives from France, W. Germany, Italy, Spain, Sweden, Netherlands, U.K. and Belgium. Each product type (tape, fabrics, etc.) has a different chairman and subcommittee. In spite of numerous attempts to produce a single specification, each country is reluctant to change its system. They are close to having an agreement on carbon-epoxy prepreg but there is still a tendency to maintain individual company methods. The process is slow and tedious and is hampered by translation problems. The organization collects data and arranges test coupon exchanges between laboratories, but the test methods are different throughout Europe.

B.N.A.E. is a French organization which acts as the secretariat to AECMA, and also publishes and sells the AECMA standards in French, English and German.

CEN is a committee which meets in Brussels and covers a very wide range of products. It is supposedly preparing specifications for testing components but is trying to cover all types of applications with the result that progress is almost halted.

*pp. 278-279.

ACAP is a NATO publication which lists the qualified sources for materials and is said to be similar to U.S. MIL-Q-9858 A.

An organization identified only as Garteur which consists of participants from the Government Laboratories in France (ONERA), UK (RAE), W. Germany (DFVLR) and Holland (NLR) has been established for the purpose of setting up testing facilities for composites.

The Advisory Composite Technology Group, ACOTEG, is limited to three companies, British Aerospace (UK), MBB, (W. Germany) and Aerospatiale (France). This Group's purpose is to make recommendations for common specifications and standards between the three companies, which have several joint venture programs, such as Tornado. Problems have arisen in reaching agreement on format due to national preferences and review procedures, etc. UK funding to support ACOTEG has been reduced and UK representatives are concerned that the majority rule may result in the UK being forced to accept French and German standards.

The British Group (CRAG) is a composites research advisory group consisting of representatives from the government, RAE, and industry, including British Aerospace and others. Its goal is to establish some normalization of composites standards and recommend areas for future research. RAE plays a strong role in the UK in developing specifications and qualification criteria and provides funds for testing. Approval of materials is contingent upon the disclosure of resin formulation to the Ministry of Defense, whereas this information is not furnished to the fabricators who develop the specifications. AERE is attempting to determine what the specifications for resins should require in the way of testing. RAE is of the opinion that resin "fingerprinting" cannot be used to specify resins because there is insufficient differentiation between resins and minor contamination of the resin can have a strong effect on the properties.

In Europe, DIN is the organization which establishes standards for industry. It will most likely adopt Dornier's specifications for composites as the DIN standard for W. Germany. The aerospace standards in Germany are the responsibility of Normanstelle Luftfahrt and may also include composites. In Italy, UNAVIA establishes the standards for the aerospace industry and UNIPLAST is concerned with composites and plastics generally, although the specifications for advanced composites produced in Italy have been generally of U.S. origin.

The European Space Agency, headquartered in Noordwijk, Holland coordinates the specifications used by the participating countries. Meetings are held every 2 months, indicating a very active program.

Having heard reports of some of the U.S. standards and specifications activities from previous speakers and some of the numerous efforts overseas, it is apparent that there is much that needs to be done to improve the current situation.

To provide a reference point from previous studies, let me present one of the conclusions from a 1976 study by the National Materials Advisory Board on the subject of standards and specifications. This statement is based on a study of all types of materials and processes. Composite materials were included to some extent but not emphasized. The statement reads "There is no comprehensive, useful National policy or program that could lead to an efficient, cost-effective, practical National system (or systems) for the preparation and utilization of timely and technically up-to-date specifications and standards." These comments, although perhaps a little strong, do reflect the current situation with respect to composites. They offer a challenge to those of us who are concerned with this industry.

I would like to make a suggestion for the consideration of the attendees at this workshop. Recognizing that there is no central coordinating body which has a total perspective of the composites industry such as we have with other industries such as the Aluminum Association, it is proposed that a central organization for composites be established. Its functions could include some or all of the items listed in this chart* as well as others. As in Europe, the U.S. has many coordinating committees which meet periodically for information exchange, several specification groups in government and industry, voluntary standards organizations and many independent company activities, but these separate activities are not coordinated in total.

This approach has been favorably considered by several industry people with whom I have spoken and it also constitutes a step in response to the challenge issued by the NMAB Committee.

Several options are presented for the organization of such a function. They range from a fully government supported organization to a joint government and industry undertaking to a completely independent service organization, each with a number of pros and cons.

I would like you to consider this concept and the organizational options in the working group discussions and comment on them on Thursday.

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*p. 281.

INTERNATIONAL STANDARDS

S. L. Channon
Consultant to
Institute for Defense Analyses

4-23-84-21

INTERNATIONAL STANDARDS

- INTERNATIONAL STANDARDS ORGANIZATION (I.S.O.)
  - — COMPOSITES NOT INCLUDED
  - — GLASS COMMITTEE TG-69, SUB-COMMITTEE SC-11, WORKING GROUP 4
    - -- LANGUAGE PROBLEMS
- JAPAN
  - — ESTABLISHED CARBON FIBER MANUFACTURERS ASSOCIATION
    - -- NOMENCLATURE
    - -- TEST METHODS
  - — USE U.S. STANDARDS
- EUROPE
  - — SEVERAL GROUPS
  - — PROBLEMS IN TECHNICAL AGREEMENT AND FORMAT
  - — USE U.S. STANDARDS

4-23-84-22

EUROPEAN STANDARDS GROUPS

A.E.C.M.A. (ASSOCIATION EUROPEENE CONSTRUCTION DE MATERIAUX AERONAUTIQUE)
SUBCOMMITTEE 5 ON COMPOSITES

- 2 MEETINGS PER YEAR
- EACH COUNTRY USING ITS OWN STANDARDS

B.N.A.E. (BUREAU DE NORMALIZATION DE L'AEROSPACE ET DE L'ESPACE)

- PROVIDES TECHNICAL SUPPORT TO AECMA
- SELLS STANDARDS IN FRENCH, ENGLISH, GERMAN

C.E.N. (COMMITTEE EUROPEENE NORMALIZATION)

- COVERS WORLD

A.Q.A.P.-1 (ALLIED QUALITY ASSURANCE PUBLICATION)

- LISTS QUALIFIED SOURCES

GARTEUR

- INVOLVES ONERA (FR), RAE (UK), DFVLR (GERM), NLR (HOLLAND)
- SETTING UP TESTING FACILITIES FOR COMPOSITES

A.C.O.T.E.G. (ADVISORY COMPOSITES TECHNOLOGY GROUP)

- INVOLVES ONLY MBB (GERM), BRITISH AEROSPACE, AEROSPATIALE
- SEPARATE SPECS FOR EACH COMPANY
- TRYING FOR GENERAL SPEC

4-23-84-23

EUROPEAN STANDARDS GROUPS
(Cont'd)

C.R.A.G. (COMPOSITES RESEARCH ADVISORY COMMITTEE)
- UK ONLY, INVOLVES BAe, RAE AND INDUSTRY

D.I.N. (DEUTSCHLAND INDUSTRIE NORMALIZATION)
- ESTABLISHES GERMAN STANDARDS

N.L. (NORMANSTELLE LUFTFAHRT)
- ESTABLISHES AEROSPACE STANDARDS FOR GERMANY

UNAVIA
- ESTABLISHES AEROSPACE STANDARDS IN ITALY

UNIPLAST
- ESTABLISHES STANDARDS FOR COMPOSITES IN ITALY

E.S.A. (EUROPEAN SPACE AGENCY)
- PARTICIPANTS FROM VARIOUS COUNTRIES MEET EVERY 2 MONTHS

4-23-84-24

NMAB STUDY ON STANDARDS AND SPECIFICATIONS 1976

CONCLUSION

"THERE IS NO COMPREHENSIVE, USEFUL NATIONAL POLICY OR PROGRAM THAT COULD LEAD TO AN EFFICIENT COST EFFECTIVE, PRACTICAL, NATIONAL SYSTEM (OR SYSTEMS) FOR THE PREPARATION AND UTILIZATION OF TIMELY AND TECHNICALLY UP-TO-DATE SPECFICATIONS AND STANDARDS."

4-23-84-26

CENTRALIZED ORGANIZATION FOR COMPOSITES IN U.S.
— A SUGGESTION —

PURPOSE

— TO PROVIDE COORDINATING FUNCTION FOR INDUSTRY AND GOVERNMENT

— TO PROVIDE GUIDANCE AND COORDINATION OF STANDARDS AND SPECIFICATIONS

— TO MAINTAIN AWARENESS OF ALL COMPOSITES DEVELOPMENTS

— TO PROVIDE INDEPENDENT TESTING FACILITY

— TO PROVIDE DESIGN DATA AND PREPARE HANDBOOKS

— TO REPRESENT U.S. INTERESTS ABROAD

ORGANIZATIONAL OPTIONS

1. GOVERNMENT OFFICE
2. GOVERNMENT FUNDED INDEPENDENT CONTRACTOR
3. INDUSTRY SPONSORED ASSOCIATION, e.g., ALUMINUM ASSOCIATION
4. COMBINATION GOVERNMENT/INDUSTRY SPONSORSHIP
5. INDEPENDENT LABORATORY

4-23-84-25

H.N. Townsend
Union Carbide Corp.

H. N. Townsend

Union Carbide Corp.

For a few moments, I would like you to think like a commercial corporation - a Union Carbide. You have invested $30 plus million in a completely integrated (domestic) facility to produce PAN-based carbon fiber. This facility has a rated capacity of 30 metric tons of carbon fiber per month. To produce the best quality at the lowest cost, it must run 24 hours per day for long periods without shutdown. A short time after plant start up you have a large quantity of carbon fiber to sell. As Union Carbide, you have been in the carbon fiber business from its conception. You produce and sell rayon and pitch-based carbon fiber. You have been through IRC going out of the rayon business, the qualification of American Enka rayon, Enka going out of the rayon business, FMC's plant being destroyed by a hurricane related flood, and finally the qualification of Avtek rayon as the precursor for your rayon product. You have worked a number of years to get pitch-based carbon fiber qualified in aerospace programs - primarily ablative and stiffness critical applications. Successful qualification of pitch-based carbon fiber is still around the corner for production applications.

As Union Carbide, you are selling PAN-based T-300 carbon fiber made by Toray in Japan to most U.S. aerospace programs. Your experiences have certainly taught you to recognize the barrier presented by qualification. You know you can expect a minimum of a year from the time your plant has achieved start up and produced carbon fiber for program qualification to the point where carbon fiber can be sold to production aerospace programs. To overcome the barrier, Union Carbide has made extensive plans to shorten domestic plant qualification including budgeting and expenditure of major manpower and money resources. Short term goals include the following qualifications:

1. Boeing - BMS 8-168, BMS 8-212, BMS 8-256
2. McAir - MMS-549, MMS-716
3. Northrop - NAI-1460, NAI-1462
4. Sikorsky - SS-9611, SS-9626
5. General Dynamics - FMS-2023C
6. Lear Fan - LMS-1200, LMS-1201, LMS-1202, LMS-1203, LMS-1204
7. Canadair - CMS-532-05
8. Rohr - RMS-040, RMS-060
9. LMSC - Nav Ord WS-16042, Nav Ord WS-16041

Selection of qualification goals was established based upon the carbon fiber market offered by the program, current qualification of "Thornel" 300 (from Toray) on the program, and the customers expressed desire for domestic supply of carbon fiber. At first analysis, our qualification goals may appear quite modest, but consider the next step. Union Carbide is not in the prepreg business. To achieve these goals, full cooperation from a number of prepreggers is required. In many cases the prepreggers are already qualified with T-300 (Toray); and although willing to cooperate, they are not willing to spend their own money. In these cases, it will be necessary for Union Carbide to pay for prepregging and testing of material required for program qualification. A number of the prime users such as McAir, General Dynamics, and Sikorsky have one or more qualified suppliers and therefore are not willing to spend their money for qualification testing - again Union Carbide will have to pay for testing. The above qualification barriers represent not only an expense to Union Carbide but more importantly a time delay. Where prepreggers and composite manufacturers require payment, they have a qualified material to meet current requirements, and thus qualification of an additional material is not their top priority - from Union Carbide's standpoint - this equates to time - and the plant is producing 30 tons per month.

Next let us address the complexity of qualifying a new carbon fiber in an established program. To represent the complex testing program that can result, I will use a qualification program which has been completed with a commercial airplane company as an example:

QUALIFICATION MATRIX

GRADE/TOW OR STYLE		SUPPLIER A			SUPPLIER B			SUPPLIER C		
		SPEC 1	SPEC 2	SPEC 3	SPEC 1	SPEC 2	SPEC 3	SPEC 1	SPEC 2	SPEC 3
95	3K	X	X	X	X	X	X	X	X	X
	6K	X	X	X	X	X	X	X	X	X
	12K	X	X	X	X	X	X	X	X	X
145	3K	X	X	X	X	X	X	X	X	X
	6K	X	X	X	X	X	X	X	X	X
	12K	X	X	X	X	X	X	X	X	X
190	3K	X	X	X	X	X	X	X	X	X
	6K	X	X	X	X	X	X	X	X	X
	12K	X	X	X	X	X	X	X	X	X
3K-70-PW		X	X	X	X	X	X	X	X	X
3K-135-8H		X	X	X	X	X	X	X	X	X

If the complete test matrix had been followed, and assuming three representative lots of carbon fiber, there would have been 297 qualification test series. By judicious selection of a representative test matrix, the number of qualification test series was reduced to about 100. For qualification, all test series had to be successful - all were - qualification of the complete matrix was granted. Regarding this particular qualification, there were seven qualified prepreg suppliers. To keep the qualification in any reasonable perspective, the commercial airplane company had to select a reasonable few.

Getting to what I believe to be the point of this talk - what can DoD do to reduce its dependence of foreign sources and sole sources of carbon fiber?

Let me again use the commercial aircraft company as an example. They determined that it was in their interest to have a domestic source of carbon fiber. They encouraged Union Carbide to build a domestic plant. They took the lead in establishing a qualification program. They financed their own qualification program. Qualification was accomplished in less than one year.

I would liken DoD to the commercial airplane company. If a material source ceases to exist - the cost is to DoD, not the prime contractor. For the commercial aircraft company, the cost is out of their own pocket. The most positive step that DoD can take to insure domestic and dual sources of carbon fiber is to contractually require its prime contractors to establish such sources. Yes, it will cost money, but would it be preferable to pay the initiation fee now or risk buying the club later - as in the case of the IRC rayon and Enka rayon stockpiling programs.

CARBON & PRECURSOR FIBERS

James Burns
Hercules, Inc.
(Presented by Jon Poesch)

CARBON & PRECURSOR FIBERS

James Burns
Hercules, Inc.
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I thought Mr. Townsend's speech was quite stirring. The cost of some of this is astronomical. The investment is pretty large and I think Hercules has some of the same thoughts as Union Carbide as far as the investment and paying off that investment is concerned.

The title of this talk is: Precursors and Carbon Fibers. Hercules is in the precursor business, the carbon fiber business, the prepreg business and the structures business, so my remarks will probably cover a broader range than just carbon fiber and precursor. I think there has been a lot of discussion about domestic supply and I will be expressing some of Hercules' comments on that. I'll talk about material specification and standardization, some of our qualification experiences and, at the end, I'll make a couple of comments about economics and suggestions for the working group to consider.

We have been domestic carbon-fiber manufacturers since 1971; we use two different precursors at the present time - one that we manufacture through a joint venture in Japan by Sumika Hercules, and one that we purchase from Courtaulds. Our present fiber capacity is about one-half million pounds and we are installing a fifth line that will bring that to a little over 2¼ million by the first quarter of '85. The facilities produce state-of-the-art fibers as well as some of the new fibers that are being introduced - such as AM6 and IM6.

On the issue of domestic precursor, we have responded to the DoD request. Present production today is in Japan; as I said, its a joint venture with Sumika Hercules

(Sumitomo Chemical Co.); the technology is jointly owned and we are in the process of transferring that technology to the U.S.. Actually, we started in December of last year and we have now a Hercules engineer located in Japan. We estimate production start in the U.S. in 1987. We anticipate putting that fiber into the present customers that we have; fortunately we are in the prepreg business so we don't have quite the problem that Mr. Townsend had. We will be putting this precursor into a carefully planned qualification program, jointly developed with our customers. Basically, I think the solution to DoD domestic source on carbon fiber precursor is in hand.

On material specifications for the precursor to date, the specifications have been controlled by the fiber manufacturer. The carbon fiber itself has been mostly controlled by the manufacturer but, as M. Katsumoto said, there is increasing interest in the control of the process by some prime contractors and, to date, nearly all the prepreg has been customer-controlled. As for the specifications for polyacrylonitrile that we manufacture with Sumika-Hercules, there are incoming ingredient specs and there are in-process controls. We measure about 10 to 15 items on every incoming lot, including items such as chemistry, diameter, denier, tenacity, moisture content and a lot of work on just controlling chemistry, particularly chemistry of heavy metal ions. We control the test methods, we certify and introduce these products in a controlled manner to our customers and we introduce them in the various product forms. We actually went through two qualifications where we took AS4 developed from Sumika-Hercules prepreg and put it into qualification for the F16 with General Dynamics and with the F18 with McDonnell Aircraft in St. Louis. Both of those programs went very well.

For the certification of carbon fiber, as well as in-process controls on the process itself which are carefully checked by quality people, we measure density, weight per unit length and then mechanical properties on every lot. Here, we have taken a step that is different from most of the other fiber suppliers and has caused some confusion in the industry. Our primary method for generating listed properties for the fiber is to make a prepreg, manufacture a laminate and then test for tensile strength, flex strength and short beam shear on that laminate. To date, this has been done with 3515A resin. We also run tensile tests but our primary method of certification is in laminate tests. We found that this was a better control for the type of properties you could actually get in a finished prepreg or finished structure and it gave us a much better handle on the fiber to resin interaction through the short beam shear test. That test has been very good at detecting problems and we have rejected lots based on this laminate test method. Unfortunately, it has led to multiple methods of testing. I do think we've got to get together and standardize these tests because it does confuse the industry and it also costs money. We must find a way to reduce the testing costs to get everybody in a more economically viable position.

In the prepreg area, the customers have total control and, unfortunately, every customer has a different specification at the present time. In the test laboratory, we must have five different ways to run a flexure test which is one of the simpler tests, the difference being whether you run a three-point or four-point specimen, put a rubber pad under the specimen, the diameter of the loading noses, etc. We have a group of five people to make sure that we do test each different lot the right way per the customer's specification. This just lists a few of the things that we find varying from customer to customer.* We heartily endorse the fact that we've got to figure out a way to standardize test methods. It costs a lot of money just in re-tests if we make mistakes, if we run the flexure test

*p. 303.

per the Lockheed method instead of the General Dynamics method, for example. It takes a lot of compromise; the industry has to really grow up. Everybody cannot go their own way; new tests are coming in, but we have got to get together on this and I know ASTM has been trying. I was in ASTM in 1970 and I think they are still trying to solidify some of the methods we talked about then, such as compression testing.

The other problem is the rapid advance in technology. We have discovered that, in the carbon fiber field, there is a lot of room for growth in both modulus and strength, so there are going to be new precursors, new fibers, and of course, there's a whole new set of resins about to come out. We're going from epoxies to BMI's to thermo-plastics to phenolics and polyimides. This is probably going to make it impossible to standardize on a product for a while. We can standardize on test methods and standardize on some specifications but that may be as far as we can get for a while. This is a very dynamic industry right now and probably ought to stay that way. We are making some great advances in technology so I think the final material specifications cannot be really totally standardized yet, but the way we measure them and specify them, I think, can be.

Our qualification experience is really dependent upon where you stand. If you have a new technology or a new technical lead, the program itself will qualify you, normally. If you have an existing product being introduced into a new program, you will usually be qualified if you are there first. If you are an alternate source, if you are fifth or sixth, it becomes very expensive to the material supplier because, in general, it is required that the supplier pay the cost. We do a lot of qualifications that many people don't hear about. If you make prepreg fabric on one machine and change to another machine, there is a re-qualification required. In some cases, if you make AS4 on line 3 and want to supply it from line 4, you've got to qualify line 4 for that customer. If you just want to mix resin differently, in many cases, you have to requalify; and of course, if you have a new plant site, that's a major requalification. I don't have the total numbers but I know that, to date, Hercules has spent over a million dollars in the requalification phase alone. In general, we find that the customer has been very fair with this entire thing. Maybe, we've been lucky in that joint payment or joint funding has been possible. It does depend on whether you have a new technology and where you are in the system, however. You are much more likely to get cost-shared qualifications if you are first or second supplier.

To summarize, I think we can standardize on test methods. I think we can standardize some of the specifications. We do need to get more data sharing betwen the primes and the manufacturers. That final item gets back to what Bud Townsend talked about. It costs a lot of money to put in facilities, especially for precursor and carbon fiber manufacture and, if you then have to supply to a DD633, the government really doesn't recognize all that development and cost that you put in. This may not be the right place to bring it up, but I think some review by the DoD of the government pricing regulations for this industry could be beneficial.

PRECURSORS AND CARBON FIBERS

J.N. BURNS

HERCULES

OVERVIEW

- DOMESTIC SUPPLY
- MATERIAL SPECIFICATIONS/STANDARDIZATION
- HERCULES QUALIFICATION EXPERIENCE
- ECONOMICS
- SUGGESTIONS FOR WORKING GROUPS

HERCULES

0232o/2/Burns-2

DOMESTIC CARBON FIBER SINCE 1971

- 1-1/2 MILLION POUNDS NOW
- 2-1/4 MILLION POUNDS BY 1985
- FACILITIES PRODUCE
  - STATE OF THE ART FIBERS--LIKE AS4
  - ADVANCED FIBERS--LIKE IM6

HERCULES

DOMESTIC PAN PRECURSOR BY 1987

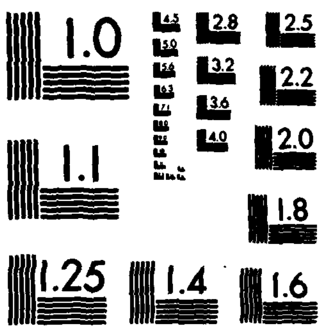
- PRODUCTION PLANT IN JAPAN TODAY
- SUMITOMO/HERCULES JOINT VENTURE
- J/V NAMED SUMIKA-HERCULES
- TECHNOLOGY TRANSFER TO U.S. STARTED
- PRODUCTION AT U.S. PLANT--1987

SOLUTIONS TO DOD DOMESTIC
CONCERNS UNDER WAY

HERCULES

AD-A149 039 PROCEEDINGS OF COLLOQUIUM/WORKSHOP ON COMPOSITE MATERIALS AND STRUCTURES..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA S L CHANNON JUL 84 IDA-D-70 4/6

UNCLASSIFIED MDA903-84-C-0031 F/G 11/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MATERIAL SPECIFICATIONS

- PRECURSOR--SUPPLIER CONTROLLED
- CARBON FIBER-- MOSTLY SUPPLIER CONTROLLED
- PREPREG--CUSTOMER CONTROLLED

HERCULES

PAN PRECURSORS PRODUCED TO SUMIKA-HERCULES REQUIREMENTS

- SPECIFICATIONS
- PROCESS CONTROL DOCUMENTS
- TEST METHODS/PARAMETERS
- CERTIFICATION PRACTICES
- PRODUCT FORMS

CARBON FIBER USERS ONLY INDIRECTLY AFFECT REQUIREMENTS

HERCULES

FIBER CERTIFICATION TESTS BASED UPON IN-HOUSE DEVELOPED METHODS

- DENSITY
- WT/UNIT LENGTH
- LAMINATE
  - TENSILE
  - FLEX
  - SBS

  (TENSILE, FLEX, SBS: SHOWS FIBER TO COMPOSITE CONVERSION)
- TOW TENSILE--AS REQUIRED

FIBER SUPPLIERS DO NOT TEST NOR CERTIFY TO SAME METHODS

CUSTOMER SPECIFICATIONS PLAY MAJOR ROLE AT PREPREG LEVEL

- FIBER TYPE--MANY TO CHOOSE FROM
- SIZING--DIFFICULT CHOICE
- AREAL WEIGHT--95 TO 190 g/m2
- RESIN TYPE--MANY AVAILABLE
- RESIN CONTENT--30 TO 42%
- BACKING MATERIAL--DEPENDS ON PART FAB METHOD
- SPOOL DIA--3 TO 24 in.
- WIDTH--1 TO 60 in.
- SPECIAL PACKAGE--YOU NAME IT
- TEST PARAMETERS--EACH CUSTOMER HAS OWN VIEW
- TEST METHODS--TO MANY TO COUNT
- TEST VALUES--BASED UPON FIBER/RESIN SELECTION
- OTHER

STANDARDIZATION WILL BE DIFFICULT--
TEST METHODS BEST PLACE TO START

HERCULES

RAPID ADVANCES IN TECHNOLOGY ALSO MAKE STANDARDIZATION DIFFICULT

- NEW PRECURSORS
- NEW FIBERS
- NEW RESINS
- NEW PRODUCT FORMS
- NEW EVALUATION CRITERIA
- NEW EVALUATION METHODS
- DIFFERENT PROPERTIES

HERCULES

QUALIFICATION EXPERIENCE

- QUALIFICATION
  - NEW PRODUCT FOR NEW PROGRAM
  - EXISTING PRODUCT FOR NEW PROGRAM
  - ALTERNATE SOURCE
- REQUALIFICATION
  - PRODUCT CHANGE
  - PROCESS CHANGE
  - NEW EQUIPMENT--UPGRADE/EXPANSION
  - NEW PLANT SITE

HERCULES

QUALIFICATION COST EXPERIENCE

- FIRST MATERIAL QUALIFIED
  - MOST CASES CUSTOMER ABSORBED COST
  - SOME CASES COST SHARED
- SUPPLIER INITIATED CHANGE
  - PAID
  - COST SHARED
- ALTERNATE SOURCE
  - CUSTOMER ABOSRBED COST
  - PAID
  - COST SHARED

CUSTOMER NEED DETERMINED
FINANCIAL ARRANGEMENT
--GENERALLY FAIR--

HERCULES

SUGGESTIONS FOR WORKING GROUPS

- DEVELOP PLAN TO STANDARDIZE TEST METHODS
- FORMULATE PLAN FOR COMMON MATERIAL SPECIFICATION
- DEVISE PLAN FOR USER TO SHARE DATA BASES
- ASSESS GOVERNMENT PRICING GUIDELINES

HERCULES

ARAMID FIBERS

Paul Langston
E.I. DuPont de Nemours & Co., Inc.

ARAMID FIBERS

Paul Langston

E. I. DuPont de Nemours & Co., Inc.

My job is to give you some background here and impress upon you, that where carbon fiber and advanced composites are not synonymous, there is another product called Kevlar. I want to tell you some of our trials and tribulations and some of the opportunities that it presents. In addition to Kevlar with which you are familiar, such as Kevlar 49 which is typically a high modulus and high strength material, there is another material which is higher modulus, higher strength also, Kevlar 29 which is used in ballistics which I will be addressing some today because there is some interest in DoD on composites in that area. We also have NOMEX honeycomb. It is an area of vital concern to designers today. Within the light aircraft industry, there is a debate between rib and stringers and sandwich structures, and we see a lot that has to be done from our standpoint in that area. We also have the ceramic fiber, aluminum oxide, which has low dielectric properties and good radar transparency and can be used in combination with Kevlar for stealth technology.

Kevlar is a domestic source material, a domestic product and a national resource. We are not importing this technology; we tend to export the technology that we've developed there. For those who are not familiar with Kevlar, you will recognize it in the missile cases of the MX (all three stages), the Trident II, the Pershing II, the IUS, and the Andrean missile motor cases.

We have talked a lot about military aircraft today and we're very familiar with the structures there but if you look at what's happening to the commercial segment and also what's happening to general aviation, you see a different type of thing happening; you see a lot of hybridization. Neither Kevlar nor carbon is being used extensively and one of the challenges I want to present here is that, in addition to Kevlar and carbon fiber, there is potential for a combination of the two materials. As we look at the metal industry and see what they are doing from an alloy standpoint, we had better look at what we can do from an alloy or hybrid standpoint. You will recognize many of the structures in hybrid form on the Boeing 767; 33% of their wetted surface is advanced composite; 23% of it is a hybrid structure. In the helicopter market and ACAP, there is a real move toward hybrid structures throughout the aircraft. The same thing is true in the general aviation area. The AVTEC uses honeycomb, predominately Kevlar (72% aramid fiber, 18% carbon fiber). Why is one fiber chosen over the other? We are all familiar with compressive strength and stiffness, but are we familiar with the contributions that can be made by a hybrid structure? We'll look at that a little bit more. One other product line that we provide in the thermoplastic area includes K polymer and J polymer which is very much like the PEEK product.

What is our problem? We are a basic material supplier. We saw some of the others earlier and the kind of matrix they had in getting to the marketplace. Many people are involved in qualifying Kevlar for different products. In the DoD area, we have Kevlar in aircraft, ballistics structures, the new specified helmet for the Army, and more efficient patrol boats, as examples. There is also filament winding. So we have a complex matrix going to market if we also count the number of weavers involved (at least three majors and seven smaller ones), the number of prepreggers (at least eight) and product forms (tapes, woven products). I don't want to get into debate on which is the better product here, but this chart shows that both products have advantages and disadvantages and I think you are familiar with all of them. There is an opportunity to marry these fibers which this industry hasn't pursued extensively and I think it is the opportunity of the future.

From the fiber standpoint, getting a product certified is not a major problem at DuPont. It may be a problem with our customers. It has been around long enough that it is pretty well identified but the question is how to make the best use of combinations of materials available to us. Recently, we gathered 32 designers in a conference and we confronted them with the following problem. If we had a blank sheet of paper and we're going to design an airplane (any type of aircraft), how would you design it? Surprisingly, the all-composite wing was a hybrid of Kevlar and graphite and the fuselage was predominately Kevlar. So this told us that we are missing a data base; there's something else we need to be looking at to make use of both types of products.

As we look at ways that we can implement quality control, we have a statistical quality control management system that not only controls our product but it controls the raw materials coming into our plants. This system is established so that it can be applied all the way down to the aircraft manufacturer because the system is set up to identify what variables must be maintained and controlled and which ones must be tested. I think we'll see more effort in that direction. We've got to optimize the system and strike a balance between static properties and dynamic properties. Today, we almost said crash worthiness. The general aviation and helicopter people are talking about crash worthiness and dynamic properties. Kevlar has some very good attributes to contribute there in combination with carbon fibers but we've got to identify them. We've got to include them in our design considerations. There is a current debate in missiles as to whether carbon or Kevlar should be used. With the available data base, you'd probably come up with a hybrid missile utilizing both fibers. The goal of a magic fiber that does everything and a matrix to complement it is something that we should always keep in our mind but, from a practical viewpoint, that is a long way off. In the meanwhile, I suggest that we optimize what we have and I'd like the panels to consider that question in the next two days.

THE CERTIFICATION CHALLENGE

COMPOSITES CONFERENCE

MAY 8-10, 1984

PAUL LANGSTON

DUPONT COMPANY

ADVANCED COMPOSITES

- o PRODUCTS
  - o KEVLAR® T-49
    HIGH STRENGTH - HIGH MODULUS
    HIGHER STRENGTH - HIGH MODULUS
  - o KEVLAR® T-29
    HIGH STRENGTH - INT. MODULUS
  - o NOMEX® - HONEYCOMB
  - o FIBER FP - EXTREMELY HIGH MODULUS

POSITION

KEVLAR®

VS. GRAPHITE

+	-
Higher Strength/Weight	Less Stiff
Tougher	Lower Compressive Strength
Lower Cost	Organic, will burn
Non-Conductive	Tougher to Fabricate
Thermal Insulator	

VS. GLASS

+	-
Higher Strength/Weight	Cost
Tougher	Organic, Will Burn
Stiffer	Tougher to Fabricate
Thermal INsulator	

NOMEX®

VS. ALUMINUM

+	-
Lightest Weight Core	Lower Shear Properties
Tough, Non-Brittle	Cost
Corrosion Resistant	

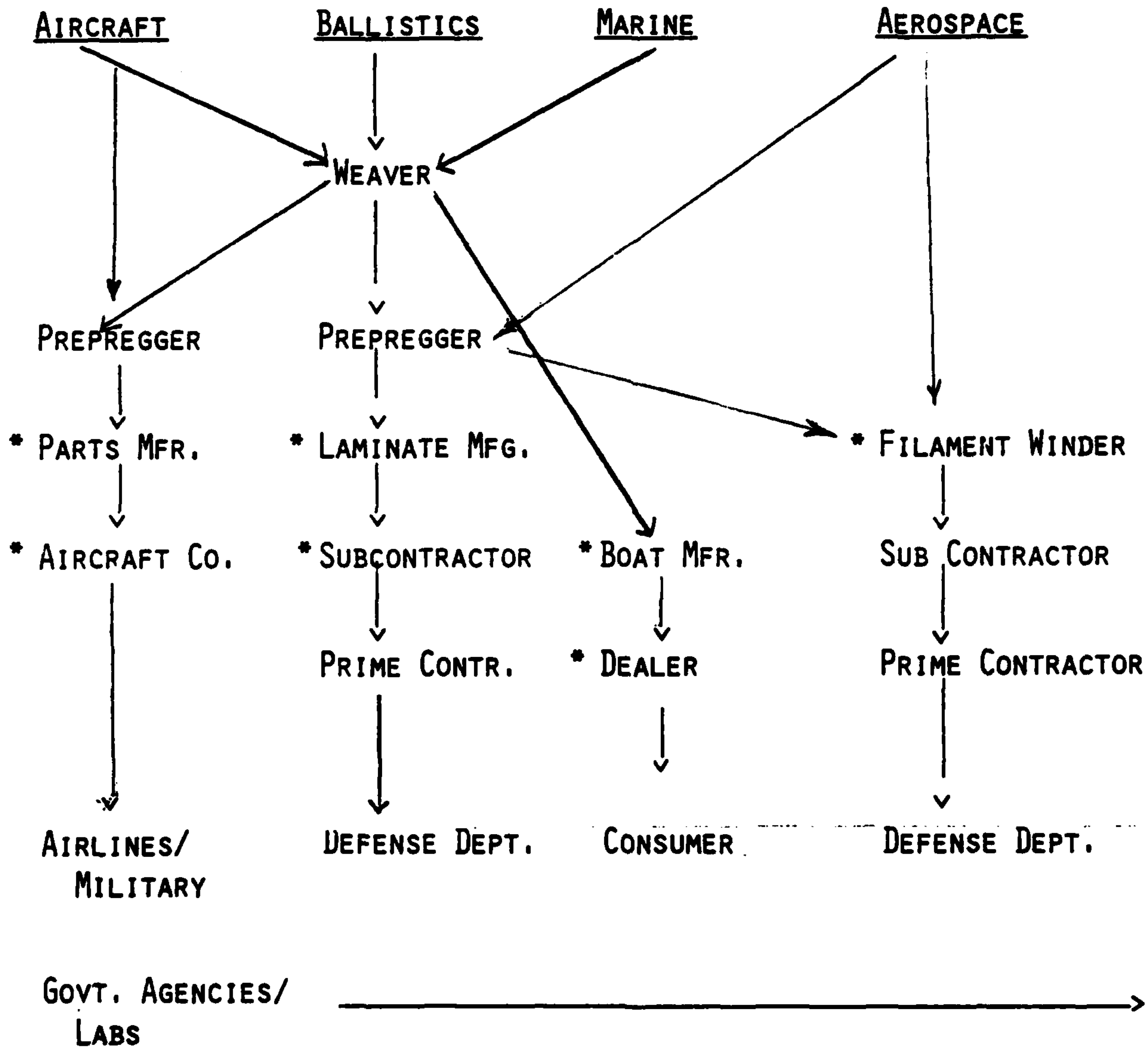
VS. FOAMS

+	-
Lightest Weight Core	Cost
Tough, Non-Brittle	Ease of Fabrication
Proven Product	Closed Cell Structure

VS. PAPER

+	-
Lightest Weight Core	Cost
Tough, Non-Brittle	
Flame Resistant	

INDUSTRY STRUCTURE



* MATERIALS SPECIFIER

CERTIFICATION

- GETTING CERTIFICATION IS NOT THE MAJOR PROBLEM.

- BUT GETTING THE COMBINATION OF MATERIALS OF (HYBRIDS) IDENTIFIED AND CERTIFIED IS.

  o THE MAJOR NEEDS ARE:

    - IDENTIFICATION OF PRODUCTS AND HYBRIDS FOR THEIR POTENTIAL CONTRIBUTION (SECONDARY).

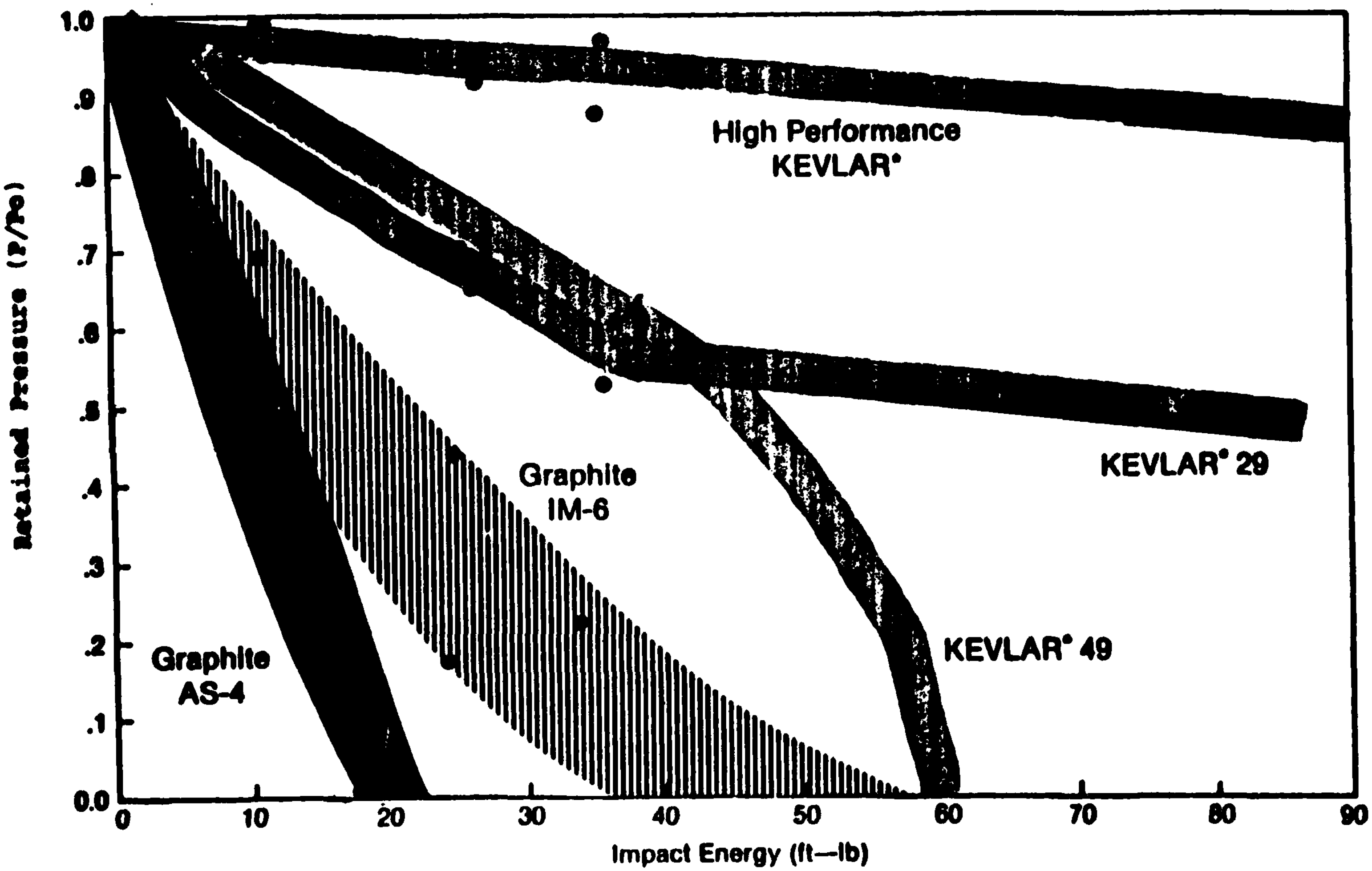
    - CRASHWORTHINESS

    - MOVE ON FROM COMPOSITE STATIC PROPERTIES TO DYNAMIC PROPERTIES.

    - UNDERSTANDING AND IDENTIFICATION OF HYBRIDS, AND GENERATION OF A DATA BASE.

    - GOAL OF A MAGIC FIBER AND MATRIX IS O.K., BUT MORE REALISTIC IS OPTIMIZE WHAT WE HAVE.

Pressure Vessels
Damage Tolerance



P=Burst Pressure; Po=Virgin Burst Pressure

HIGH STRENGTH GLASS FIBERS

Michele Abraham
Owens Corning Fiberglas

HIGH STRENGTH GLASS FIBERS

Michele Abraham

Owens Corning Fiberglas

If most of you are anything like me, about this point in the afternoon, you've had enough lunch and sat here for long enough that you're about ready to fall asleep. Unfortunately, I was appointed to come to this fairly much at the last minute so I don't have pretty pictures or a nice presentation to show you. What I will do to try to maintain your attention is to make this as short and sweet as possible. What I want to do is to give you an introduction of where we stand with glass fibers today, talk a little about any dependence we might have on foreign materials that go into glass fibers, standards and specifications that we see used with glass primarily today, and any requirements and recommendations we might have. I want to talk a little bit about customer specifications with which we get involved and problems that we see there and I will touch on the status of testing standards that are used today and finally summarize with some recommendations.

First of all, there seems to be some confusion about the glass fibers so I will clarify where we stand. S-2 glass products today are primarily used in the industry as a high strength fiber reinforcement. The product that was originally developed was called S-glass which was designed for the defense industry back in the 60's. Over the years, we found that many of the companies were finding the cost of S-glass to be prohibitive for the types of applications in which it was being used, so we developed a modification of that product called S-2 glass. That is the product that, for years now, most people have been qualifying into specifications. It has the same glass composition but there are some minor changes in it, and it is much less expensive.

S-glass fiber was discontinued about a year ago. We are continuing to support a couple of major programs where S-glass has been qualified and where requalification using S-2 glass was going to be extremely expensive. So, on a contract basis, we are supporting those programs. We have seen very little problem in the industry with the discontinuance of that product. If there are any questions on that, I will be glad to address those individually later. For new applications, the product being qualified and specified is S-2 glass.

Today, we currently have sufficient capacity to support the industry. We are in the process of expanding our production capacity to the point that we feel that we can easily accommodate the projected requirements up through 1990. We are also in the process of looking at how to expand beyond that to meet any additional growth that would happen further out, so we are committed to supply sufficient material to the industry to support it. We are sensitive to the fact that we are basically a sole source supplier of the high strength glass reinforcement in the industry today. We feel confident that we can supply enough material to support the needs in the marketplace where the S-2 glass is primarily used, and today, the quality control and testing that we do as a normal function of our business is sufficient to meet most of the specifications that are used in the industry. The commercial grade product that we sell primarily into the commercial industry is E-glass. There are some instances where there are military applications that are more cost-sensitive where reliability or performance requirements are not quite as high as the S-2 glass. A good example would be a launch tube system, for example, the multiple launch rocket system being used on some of the new systems that are coming out. These are utilizing an E-glass reinforcement which is more cost-effective and offers enough performance capability for that type of application.

Basically, we have qualified domestic sources for all raw materials that go into S-2 glass products. Where there are foreign sources being used, we have an alternate domestic source, so we have virtually no concern about materials that go into fiber-glass as foreign material sources.

In talking about specifications, I'm going to take this from a little bit different perspective. When you talk about military specifications today, there are primarily four different specifications on the glass reinforcement product itself that our customers use and to which we are asked to certify. We qualify and certify to these specifications on a regular basis and have no problems with them. The Mil-Y1140 specification on yarn products is specifically for E-glass products. As far as I'm aware, there is no military specification on an S2-glass yarn product. There are a lot of cloth and woven roving specifications but nothing on the fiber itself. We would suggest that this specification be modified to incorporate S-2 glass. We have a lot of requests from customers who don't really have a good basic document to work from when they need a military specification. We meet the quality control testing standards that are brought to our attention most often in the industry. This is a normal part of our production operation and we basically have no concern with these as general specifications. There has been a lot of reference to the ASTM shear test method, and I would say that we share some of those concerns. One of the problems that we've run into is that the method is general enough that there are some specific details that are not defined. As different suppliers use the tests (the ASTM shear methods), they follow different details, such as the exact resin system, and there is some inconsistency. We agree that some standardization would be helpful.

I want to talk about customer specifications rather than military specifications for a moment. Our greatest problem or obstacle in adequately certifying to specifications is in the actual customer specifications that are generated. We are several steps removed, like an aramid or graphite supplier; we may sell to a weaver who sells to a prepregger who sells to a fabricator who sells to a contractor and, by the time it flows down to us, those specifications get a little muddied in the process. We often don't know what is going on until after those specifications have been written, then somebody comes to us (either after the material has been purchased or is in the process of being purchased) and says, "Oh, by the way, we have the specification we need to have you meet", then we have to find out whether we can certify to that specification. We have difficulty with some of the requests that are included in individual customer specifications. Examples are an interest in higher frequency testing, extra or different tests from those normally used, added labelling or handling requirements that are not standard practice, and an extensive list of data to be provided with every shipment. Some of these efforts can increase the price of the product by as much as two or three times. We sell a lot of S-2 glass to commercial operations today for non-military type applications. When we get a different set of requirements for every customer, it becomes very difficult to adhere to all of those. We would recommend that we become involved in the program at the time the specifications are developed, so that we can have some input and work out a program that is mutually acceptable to everybody involved. One example in which this procedure was followed was the MX Missile. We were able to get involved with the contractors when they wrote the specifications. They wanted a considerable amount of data supplied with each certification and the stated reason was a need for traceability. What we were able to do was to give them a data base, background and history, and then to demonstrate that we have the capability of tracing back any material that they use so that in the event that they have a requirement for data, we are able to supply it. We maintain the data over the life of the program so there's no problem there.

In summary then, what we're saying is, we'd like to have a better dialogue established between us, the pre-preggers and the fabricators as the development is being done and the specifications are written so that the process flows more smoothly and more quickly than it has in the past. Another suggestion that we would have, is the use of a generic description for a product rather than putting an actual product name in. Obviously, in some cases, that's not possible. However, there is a Navy shell program which uses glass and the specification describes the glass composition, the fiber diameter, the resin compatibility, and several other descriptive items, and does not include a specific commercial product that had to be used. The program was in production and we developed a product that met all of these criteria but which, we felt, was superior to the one being used. Because of the way the specification was written, we were able to successfully substitute for the other product without going through an extensive program of requalification and testing. That's not always possible but, where it is, its something that might be considered. As changes are made in programs, we would just ask for better dialogue between the different tiers of people involved in the program.

WORKSHOP

COMPOSITE MATERIALS

AND

STRUCTURES

STANDARDIZATION,

QUALIFICATION,

CERTIFICATION

OWENS-CORNING FIBERGLAS CORPORATION

MICHELE D. ABRAHAM

PRODUCT/MARKET MANAGER

MAY 8-10, 1984

DISCUSSION AGENDA

I. INTRODUCTION

II. OVERVIEW GLASS FIBER REINFORCEMENTS

III. DEPENDENCE ON FOREIGN MATERIALS

IV. STATUS CURRENT STANDARDS/SPECIFICATIONS

REQUIREMENTS/PROBLEMS MEETING SPECIFICATIONS

V. CUSTOMER SPECIFICATIONS

REQUIREMENTS/QUALIFICATIONS COSTS

VI. STATUS/TESTING PROCEDURES

VII. SUMMARY/RECOMMENDATIONS

INTRODUCTION

S-2 GLASS PRODUCTS ARE THE PRIMARY REINFORCEMENTS SOLD TO THE AEROSPACE/DEFENSE INDUSTRIES TODAY.

WE CURRENTLY ARE EXPANDING MANUFACTURING CAPACITY TO INSURE AMPLE SUPPLY IS AVAILABLE TO THE MARKETPLACE THROUGH THE LATE 1980'S. IN ADDITION, PRODUCT DEVELOPMENT WORK CONTINUES TO BETTER SATISFY GROWING AND CHANGING NEEDS IN THE INDUSTRY.

OWENS-CORNING FIBERGLAS CORPORATION IS TOTALLY COMMITTED TO SERVICING THE MARKET NEEDS FOR S-2 GLASS FIBER AND OTHER REINFORCEMENT PRODUCTS.

OVERVIEW

GLASS REINFORCEMENTS

I. S-2 GLASS PRODUCTS

- PRODUCT LINE PRIMARILY USED IN ADVANCED COMPOSITES
- SUPPLY ASSURANCE
- QUALITY CONTROL AND TESTING SUFFICIENT TO MEET CURRENT SPECIFICATIONS

II. E GLASS PRODUCTS

- COMMERCIAL GRADE PRODUCTS BEING USED IN CERTAIN COST CRITICAL APPLICATIONS
- EXTRA Q.C/TESTING IMPOSED WHERE NECESSARY TO MEET REQUIREMENTS

III. S GLASS PRODUCTS

- DISCONTINUED FOR GENERAL INDUSTRY USE BECAUSE COST WAS PROHIBITIVE

DEPENDENCE

ON

FOREIGN MATERIALS

VIRTUALLY NONE

NOT A CONCERN FOR GLASS

REINFORCEMENTS

STATUS

CURRENT SPECIFICATIONS

ONLY A LIMITED NUMBER OF SPECIFICATIONS AND STANDARDS ARE COMMONLY USED FOR GLASS REINFORCEMENTS:

1)	MIL-R-60346C	ROVING
2)	MIL-C-19663C	WOVEN ROVING CLOTH
3)	MIL-M-43248C	MATS
4)	MIL-Y-1140H	E GLASS YARNS

BEING CONVERTED TO ASTM STANDARD.

ALL OWENS-CORNING PRODUCTS MEET REQUIREMENTS OF THESE SPECIFICATIONS.

BASICALLY NO PROBLEMS OR CONCERNS WITH THESE DOCUMENTS.

STATUS

CURRENT STANDARDS

QUALITY CONTROL, TESTING AND CERTIFICATION PROCEDURES OF OWENS-CORNING MEET REQUIREMENTS OF MOST STANDARDS NOW USED.

TWO MOST COMMONLY REFERENCED:

1) MIL-Q-9858A
2) MIL-STD-105D

THESE PROCEDURES ARE AN INTREGAL PART OF S-2 GLASS FIBER PRODUCTION. THE ADDITIONAL TESTING NEEDED FOR E GLASS SOLD INTO AIRCRAFT/DEFENSE INDUSTRIES IS DONE AT MINIMAL COST ON AN AS NEEDED BASIS.

SPECIFICATION

NEEDS

- MILITARY SPECIFICATION FOR S-2 GLASS YARN PRODUCTS WOULD BE USED FREQUENTLY BY THE INDUSTRY.

- MIL-Y-1140H (OR ASTM REPLACEMENT) COULD BE MODIFIED TO INCORPORATE S-2 GLASS YARN PRODUCTS.

CUSTOMER SPECIFICATIONS

- THESE DOCUMENTS ARE MUCH MORE STRINGENT AND SPECIFIC ON FIBER REQUIREMENTS

- TYPICAL REQUESTS INCLUDE:
  - HIGHER FREQUENCY TESTING
  - EXTRA OR DIFFERENT FIBER TESTS
  - ADDED LABELING REQUIREMENTS
  - SUPPLY OF DATA WITH EACH SHIPMENT

- SUCH ADDITIONAL EFFORTS CAN INCREASE PRODUCT COSTS AS MUCH AS TWO FOLD

- OCF WORKS WITH INDIVIDUAL CUSTOMERS AS REQUIRED TO ESTABLISH ACCEPTABLE PROGRAM
  - EXAMPLE: OCF CAN MAINTAIN TRACEABILITY AND PROVIDE DATA ON AS NEEDED BASIS

CUSTOMER SPECIFICATIONS

RECOMMENDATIONS

I. WORK WITH GLASS SUPPLIERS DURING DEVELOPMENT/SPECIFICATION STAGES TO INSURE DOCUMENTS ARE MUTUALLY ACCEPTABLE.

II. UTILIZE GENERIC DESCRIPTIONS ON PRODUCTS WITHIN SAME CLASSIFICATION TO ALLOW CHANGES/MODIFICATIONS WITHOUT EXTENSIVE REQUALIFICATION EFFORT.

III. MAINTAIN DIALOGUE ON NEEDS AND IMPROVEMENTS DESIRED.

STATUS

TESTING PROCEDURES

- STANDARDIZED ASTM TEST METHODS USED AND ACCEPTED FOR MOST GLASS REINFORCEMENT PROPERTIES.

- NO IMMEDIATE NEEDS OF WHICH WE ARE AWARE.

SUMMARY/RECOMMENDATIONS

- GLASS REINFORCEMENT SPECIFICATIONS AND PERFORMANCE REQUIREMENTS WELL ESTABLISHED AND ACCEPTED.

  CHANGES NEEDED ONLY FOR S-2 GLASS YARN AND ENTRY OF GLASS INTO NEW AREAS SUCH AS BALLISTICS.

- TESTING PROCEDURES ALSO STANDARDIZED AND ACCEPTED

- SUPPLY OF S-2 GLASS FIBER IS SUFFICIENT TO HANDLE PROJECTED DEMAND.

- PRIMARY NEED IS BETTER DIALOGUE AND AGREEMENT BETWEEN GLASS SUPPLIERS AND CUSTOMERS ON INDIVIDUAL SPECIFICATIONS.

ORGANIC MATRIX MATERIALS

Dr. Gail DiSalvo
Ciba-Geigy Corp.

ORGANIC MATRIX MATERIALS

Dr. Gail DiSalvo

Ciba-Geigy Corp.

I'd like to thank IDA for asking us here today to speak on these critical and important issues. Ciba-Geigy is a world-wide organization with facilities both in the United States, Europe and Japan and we consider this to be one of our strengths. As you see on the slide, we manufacture resins, prepreg, honeycomb, panels, etc. We have a wide range of products that are sold throughout the composites industry. In the U.S., the resins department is based in Hawthorne, N.Y. and we have our resin manufacturing in New Jersey and in Alabama. We have adhesives and prepreg manufacture in Fountain Valley, Ca., in Miami and Lansing, Michigan so we're pretty well spread out over the U.S. Since we're talking about high performance aerospace, I'll restrict my comments to those resins which are pertinent to these issues.

We sell the standard of the industry, MY720, and have been manufacturing it for ten years. We have a large manufacturing experience and data base established. We also manufacture some other multi-functional epoxy resins with which you are probably familiar; 0500, 0510, EPN, ECN and 0163. However, we don't just make epoxy resins although, certainly, we are very happy to make these epoxy resins. We also make bismaleimide resins and have recently introduced a product to the market about which we have been hearing very good news and we certainly see some future there. We also make high performance hardeners, like the DDS, and high performance thermoplastics as well which are receiving increasing interest and use in the aerospace industry. We also make a full-line of basic liquid resins and hardeners and we also manufacture polyester resins in the U.S. These resins are used on a number of commercial and military aircraft in graphite, Kevlar and glass prepregs as well as in adhesives. So we understand the strategic nature of our products and are very aware of the concerns that are raised from time to time, such as the ones that are being raised here.

In the high-performance resin areas, Ciba-Geigy is committed to three main issues: - quality and consistency and maintenance of supply of its products. We have expended a fair amount of time, energy and money to make sure of these issues. I'll talk about each one of these in detail. We are also committed to the domestic manufacture of strategic products.

Our commitment to quality starts with the starting materials. We have tight quality control over the materials that we buy and we also buy to narrow specifications from our suppliers. We have an extensive series of in-process controls using the latest analytical techniques, so that we know all the way through the process what the product is like, not just at the end; and we have an extensive product quality assurance program. We have narrow product specifications, i.e., manufacturing specifications. We have under development statistical analysis methods to analyze our production and to spot any trends ahead of time in case any problem should occur. We also have product sales specifications. We draw these up in cooperation with our customers so that we know what they want to see in our products and we encourage our customers to tell us what product sales specifications are important to them.

In terms of supply, we are very concerned about supply and maintaining adequate supply and this is not brought about by a single method but by a series of steps. For example, supply involves forecasting. We have developed annual forecasts for each customer, by product, with our customer's help. On a quarterly basis, we also ask our customers for their projections for the coming year. I am happy to say that most of our customers are very cooperative in this and they tell us, on a quarterly basis, what they anticipate they will be needing over the year. We internally review this information monthly to make sure that our product management and our production are all in tune with what the needs of the marketplace are. In terms of spare capacity, we are committed to a 50% spare capacity situation in case of an emergency and, in 1985, we will be expanding our specialty plant in New Jersey. This has been allowed by the fact that we have come on stream in Alabama with a new basic liquid resin plant, giving us more capacity.

In terms of inventories, we maintain a four-months' supply of inventory of these critical products for our customers. We consider that to be necessary. In terms of distribution, we have multiple warehouses throughout the country which we maintain for our customers (East coast, West coast, middle of the country) so that our stock is available when our customers need it and it is not concentrated in one place.

We have multiple manufacturing sites. In the U.S., we have one in New Jersey and another in Alabama. In Europe, we have capacities to produce multi-functional resins in Duxford, England and in Basel, Switzerland, In Japan, we have capacity to produce multi-functional resins, as well.

With respect to strategic products, we are committed to U.S. manufacturing capability and I am happy to say that, in all these areas, we have a U.S. manufacturing capability and, in the case of DDS, this was recently demonstrated. In case of our bismaleimide resin, we will possibly be announcing the U.S. manufacture of that next year. In all of these cases, we understand the need for domestic manufacture and we are committed to it, in the terms of intermediates as well as those basic raw materials from which our resins are made.

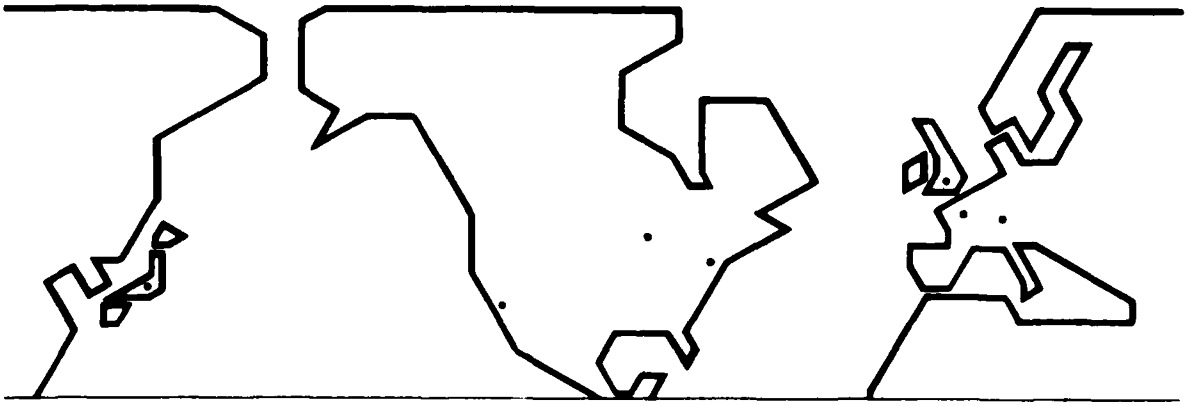
In conclusion, considering the very important and strategic nature of our products and the concerns that are expressed by various people in the military and commercial aircraft areas, we are committed and welcome the comments of our customers and their customers about any additional steps that we should be concerned about. During the next couple of days, we would be happy to hear from you if there are any items that you feel that we should consider or that you would like to discuss further with us.

Finally, we are committed to quality, consistency, to U.S. manufacture of all these products and to maintaining an adequate supply, including an excess capacity in case of any emergency.

CIBA-GEIGY Corporation
Plastics and Additives Division
Hawthorne, NY 10532

G. DiSalvo, Ph.D.
Market Center Manager, Matrix Resins
Resins Department

CIBA-GEIGY Composite Materials Worldwide Capability



United States — **Resins Department**
- Resin Manufacture
- Resin Research & Development
- Composites Research
- Engineering
- Prepregs
- Laminates
- Honeycomb Panels
- Film Adhesives
- Advanced Composites
- Honeycomb
- Potting and Edge Close-Out Materials
- Tooling Materials
- Woven Products

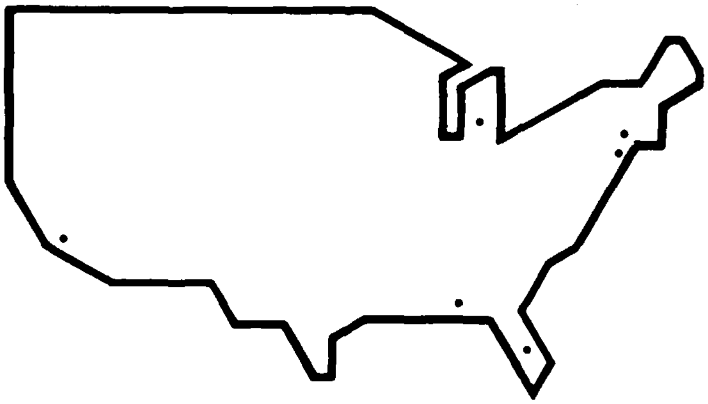
Japan ACC

United Kingdom — **Bonded Structures Division**
- Composite Research
- Plastics Research
- Honeycomb Manufacture
- Film Adhesives
- Panels
- Prepregs
- Advanced Composites
- Resin Manufacture

France — **Brochier**
- Weaving Research
- Woven Prepregs
  - Graphite, Boron
  - Glass, Kevlar
  - Aramid
- "3 Dimensional" Weaving
- Advanced Composites

Switzerland
- Specialty Resin Research
- Resin Manufacture
- Tooling Materials
- Composites Engineering

CIBA-GEIGY Domestic Facilities



Ardsley/Hawthorne, New York	Basic Resin Research
Toms River, New Jersey	Specialty Epoxy Resins
McIntosh, Alabama	Basic Liquid Epoxy Resins
Fountain Valley, California	Prepregs Laminates Film Adhesives Advanced Composites Panels Cargo Liners Woven Products Research and Development
Miami, Florida	Nomex® Honeycomb Fiberglass Honeycomb Detailed Parts
Lansing, Michigan	Adhesives Potting and Edge Close-Out Materials Formulated Epoxies and Polyurethanes

CIBA-GEIGY Resins Department
Manufacture/Sales

High Performance Multifunctional Epoxy Resins

Araldite® MY 720	Tetraglycidylether of methylenedianiline
CIBA-GEIGY Epoxy Resin 0500	Trifunctional epoxy
CIBA-GEIGY Epoxy Resin 0510	Super high purity 0500
Araldite EPN	(Epoxy Phenol Novolac)
Araldite ECN	(Epoxy Cresol Novolac)
CIBA-GEIGY Epoxy Resin 0163	Tetrafunctional epoxy

CIBA-GEIGY Resins Department Manufacture/Sales

Bismaleimide Resins	XU 292
High Performance Hardeners	Hardener HT 976 - Diaminodiphenylsulfone
High Performance Thermoplastics	XU 218 (Thermosettable)
Basic Liquid Resins/ Hardeners	Araldite 6010, etc.

CIBA-GEIGY Resins
Qualified in Major Aircraft Specifications

Commercial Aircraft	Graphite prepregs Kevlar prepregs Adhesives
Military Aircraft	
Airplanes	Graphite prepregs Glass prepregs Kevlar prepregs
Helicopters	Graphite pregregs Glass prepregs
Space Shuttle	Graphite prepregs

CIBA-GEIGY Resins Department
Major Emphasis in High Performance Resins

Quality/Consistency of products

Maintenance of supply

Domestic manufacture of strategic products

CIBA-GEIGY Commitment to Quality

Starting Materials	Narrow specifications Tight quality control
In-Process Controls	
Product Quality Assurance	Narrow product specifications Statistical analysis development Product sales specifications

CIBA-GEIGY Resins Department
Supply Philosophy

Forecasts
Annual Forecasts
Quarterly rolling forecast with each major customer
Monthly review internally

Spare Capacity
1985 plant expansion in U.S.

Inventories
At least 4 month supply

Distribution
Multiple warehouses nationwide

Multiple Manufacturing Sites
U.S. (one used, others available)
Europe
Japan

CIBA-GEIGY Resins Department Commitment
U.S. Manufacturing Capabilities/Strategic Products

Resins/Hardeners

Araldite MY 720 - Multifunctional epoxy (TGEMDA)
CIBA-GEIGY Hardener HT 976 (DDS)
CIBA-GEIGY Epoxy Resin 0500 - Trifunctional epoxy
CIBA-GEIGY Epoxy Resin 0510 - Superpure 0500
CIBA-GEIGY Bismaleimide Resin XU 292

Intermediates

Methylenedianiline
p-Aminophenol

CIBA-GEIGY Resins Department
Aircraft/Aerospace Applications

Commercial Aircraft
Primary and Secondary Structures

Military Aircraft
Primary and Secondary Structures

CARBON-CARBON COMPOSITES

Jay Baetz
Atlantic Research Corp.

CARBON-CARBON COMPOSITES

Jay Baetz

Atlantic Research Corp.

I represent a little bit different viewpoint, perhaps, than production might have presented. We are not a fabricator, we do not manufacture carbon-carbon composites; however, we do use carbon-carbon composites. I'd like to pose a question relative to carbon-carbon composites specifically, although the same question could be addressed to metal matrix composites and organic composites. And then, I'd like to propose what will happen if the question is not answered in a positive sense from a user's standpoint. The question is this. How can you possibly reconcile the goals of standardization, qualification and certification with something that is the absolute antithesis of homogeneity, i.e., carbon-carbon composite? In fact, I would suggest that there are those who would call carbon-carbon composites "defects held together with string", and perhaps that's true. Let's take a look at it for just a second. We have structures composed of steel alloys, titanium alloys, aluminum alloys; we have ablatives that are made of graphite materials. All of these are what I call recipe materials. They are amenable to definition and specification by ASTM, AMS, etc. Even the precursor materials are amenable to specification and once the recipe is defined, I can order from this menu. Composites, on the other hand, are heterogeneous at best and, by definition, they form more complex structures. Of those composites, we have the organic composites which are fairly mature in their state of development and there have been specifications that we, as a customer, do use in ordering materials, whether it be a filament-wound motor case or some other organic composite used as an ablative in a rocket motor. On the other hand, there are metal matrix composites which are in their infancy and are just developing through feasibility studies and, with their growing pains, will have to develop these standards and specifications.

I liken carbon-carbon composites to the adolescent age and that is that they are growing out of control. In fact, as I said earlier, the carbon-carbon composites do bring true meaning to the word non-homogeneity. For example, we have precursor reinforcement; we have several, some foreign and some domestic; we have rayon precursor used mostly in 2D cloth; we have PAN and pitch. We have many producers of fibers and precursor manufacturers in the U.S. and we have foreign precursor manufacturers who supply fibers for the matrix. We have processing which is dictated and driven by both the end component and the individual processor. We have proprietary processes involving densification with CVD or pitch or resin or combinations of these. We have not only U.S. processors but we have a very strong and aggressive French campaign in the U.S., an outgrowth of the fact that they make more material than they can sell internally to their own government, so they're over here selling to us and they have a very persuasive sales pitch.

With all these combinations and permutations.we are faced with the problem of non-destructive inspection of the material. We know that we have variability. The two consecutive PAM failures demonstrate what variability will do to you. Tag end tests don't represent a true part and there is question about the usefulness of co-processed specimens. In fact, the entire validity of the test methods is in question. We therefore come back to the question of how the goals of standardization, qualification, and certification can be realized with all these negatives.

If carbon-carbons are to be fully used, and there are areas where we're retrenching, then I don't think any element can drive or dictate the terms. A cooperative effort involving compromise between the fabricator and the user is needed to settle on standards and certifications. On many occasions, there will be a state-of-the-art advancement in the materials. The systems requirements will be defined on the basis of the improved performance which these material improvements offer. Somewhere along the line, the material will get into trouble; it will not be qualified. Having committed the material to the system, the system requirements are legislated away. We've all seen this happen many times before. A fallback position will be taken up and that fallback position will be qualified by the contractor, such as Atlantic Research Corp., Lockheed, Hercules or Thiokol, and the system will be frozen. IOC dates will be set and met and the system will be frozen and the advanced material may never be used. The scenario that I just proposed is not unrealistic and I've seen it happen too many times. Therefore, if we can't answer the questions as to how we will standardize, qualify and certify this complex material that is called carbon-carbon, then I suggest that we will probably use it to only about 20 percent of its capacity.

ORGANIC PREPREGS

Juan Chorne
Hexcel Corp.

ORGANIC PREPREGS

Juan Chorne

Hexcel Corp.

I think it is safe to say that the concerns and the problems that have been mentioned by the previous speakers certainly apply to the organic resin matrix composites. I'd like to summarize some of these. To begin with, there is a high dependence on foreign and sole sources. All of the high performance resin systems that are currently qualified on major programs have components which are both sole sourced and foreign sourced. One example of a sole source is the TGMDA which is the generic abbreviation for MY720, the trade name for Ciba epoxy; it represents about 80% of the military and commercial aircraft. Ciba does have two U.S. plants which reduces the risk of disruption. There are at least three companies, Dow, Shell and Reichold, which are potential domestic alternates but none of these is in production at this point. The alternate MY720s that are in production come from Japan.

You have also heard about DDS, a common curing agent for the MY720. The sole source for this material in the U.S. was Ciba. It is also a foreign source material because it is produced by a French company for Ciba. There are about five domestic alternates possible but, at this point, none of these is in production.

Of the high temperature systems, the bismaleimides (BMI) have been receiving much attention because of their improved temperature and environmental resistance compared to the current epoxies; however, most of the recent candidates have formulations which are based on foreign sourced starting BMIs or BMI blends from companies such as Rhone Poulenc (French), Technochemie (German) and about two or three Japanese companies that are starting BMIs and BMI plants.

The BT resins which are very similar to the BMIs are currently sole source from Japan.

There are available alternate prepreg systems and components for these formulations. The prepregs are severely restricted by the persistent practice of reverting to the established data base. This is a user restriction, usually reacting to the role of the government agency acting as the gate keeper, as was expressed earlier this morning. The supplier restriction is one of high cost of qualification and the associated risk to the return on investment, particularly in a highly competitive situation where there are several suppliers qualified or a user who has a history of qualifying several sources but using only one or two sources. The raw material alternates are also available and these are being restricted by the user specifications which freeze the original sources. In other words, they are qualifying brand names rather than generic materials. The high cost of requalification of the alternate sources is prohibitive when several multiple specifications have to be requalified. Finally, even when the user is receptive to qualifying alternates, the lack of standards for equivalency may impede the progress in this area. We feel that excellent progress has been made with chemical characterization that provides a sound basis for proving or providing equivalency.

A recommended road map or methodology has been proposed for demonstrating equivalency of alternate raw materials for formulations. It is based heavily on chemical analysis. It is a sequential type of approach in which the next level of testing is not pursued until the criteria from the previous one have been met. It starts out with chemical analysis of the raw material component which is to be qualified, which is compared against a control which is usually the qualified source. The raw material component is then incorporated into the resin formulation and the neat resin (the unreinforced resin) is also again tested chemically. In addition, some mechanical and fracture toughness screening is very helpful in determining whether the alternate source is indeed equivalent. All of this is done before getting into the more expensive prepreg laminate mechanical test which are usually not as extensive as the original qualification. Depending on the nature of the resin then, fracture toughness tests, if applicable, will also be run. The point to be made here is that this may not be the way it happens. We have run some alternates that did'nt run exactly like this but if there is good communication between the user and supplier, usually some agreement can be reached; at least, it breaks down the barriers.

The high cost of qualification seems to be the recurring theme today and you have already heard mention of the high cost inherent in the large number of specimens for "A" & "B" basis allowables and also on the sub-component and full-component testing which is part of the building block approach. Manufacturing verification can use up large quantities of material. The non-interchangeability of engineering data bases leads to considerable investment redundancy. One can get a rough estimate of the cost by trying to quantize the redundancy of investments for the current state-of-the-art MY720 and DDS type systems by counting the number of specifications in these various sectors and then multiplying them by some factor which takes into account the number of times the investment has been duplicated for different product forms and different suppliers. On this basis, at an average cost of $50,000 to a quarter million dollars for the test matrix which would include some sub-component testing, you get an investment of $4-20 million. The raw material and fabrication costs are additional. The total cost will reach from five to twenty-eight million dollars, probably skewed to the high end.

Some specifications do require excessive testing and what we recommend is that these accumulated data bases be reviewed periodically. If, after years and a considerable number of batches, there is no correlation showing that it is controlling or it is correlating with performance, then these should either be eliminated or replaced by more effective testing. There is a growing need to develop technical bridges and multiple supplier test pooling.

I'd like to re-touch on the redundancy of qualification. The commonality in formulations of some of the resin systems is shown in the table. These are somewhat in order of how they appeared in the marketplace and you can see that they are all based on the TGMDA building block cured with DDS, with or without the catalyst, BF_3. Even in the case of the minor epoxy diluents which were added for handling characteristics, there is some commonality. The point to be made is that if we could not get test correlation with all that redundancy using systems that were fairly familiar or fairly common, and which have been repeatedly proven to be equivalent, I should say, it is not very likely to happen in the next generation of fracture tough resins.

A set of curves shows the trade-off between hot, wet service temperature and fracture toughness. These are some of the programs which are either being proposed or are underway. Each line represents a program, the lower fracture toughness representing the base line system and the end of the line representing the program goal; it is apparent that there is more than one envelope there. All of these systems have different building blocks, different converters and different curing agents; some have as many as 8 or so epoxy resins in them. These developments are in direct opposition to the concept of fairly similar resin systems.

The introduction and qualification of new materials and sources is very difficult. The inflexible attitude toward changes is stifling incentives to develop new technology, to qualify these alternate sources and ultimately expand applications. While the military and the governmental agencies sponsor most of the R&D, historically, they have also been the most reluctant to qualify these improved products and technology. This is illustrated in the graph which shows a time scale from about 1965 to 1985 and the attendant technology that has been available during these time periods. The aerospace industry started with 250°F curing systems before the pitfalls of the moisture resistance were discovered, at which time the 350°F curing systems were introduced. More recently, there is an improvement in these types with controlled flow, easier to process resins which are incrementally tougher but not as tough as required for primary structures. Even more recently, the trend has been toward the systems with higher T_g such as the BMI's and systems which show more damage tolerance, high strength, etc. In the military missile and space applications, there has been more reluctance to use the incremental improvements. These are various major programs. The D 5 program is looking at new systems but production has not started yet. The AV8B has accepted BMI and has it in production in certain sections. The commercial aircraft industry has been more receptive to the introduction of improvements in technology as they have become available.

I think everyone agrees that sole sources are expensive. On the other hand, the market and the general economy must be able to support multiple sourcing. All the non-sole-source suppliers are saying the same things in different ways. Over-sourcing, coupled with lowest bidder awards, creates a profit squeeze which is discouraging suppliers from developing improved technology and expanding their capabilities. The high probability of some prepreg suppliers falling by the wayside is real. We feel that the solution to the high dependence on foreign and sole sources is economic and probably requires some government intervention, including direct or indirect incentives.

Finally, in summary, the organic prepregs are currently dependent on foreign and sole sources but there are alternate materials and sources available. The situation is not as critical as other structural materials, such as metals, and minerals. A partial list of the strategic minerals and the countries from which they are imported shows that this is not exactly a list of the most politically stable countries. The high cost of qualification and certification can be reduced probably most significantly by eliminating the redundant testing by multiple users. I did not collude with Ray Palmer but this parallels what he suggested. Possible solutions are to establish government criteria for joint Services qualifications, to establish an approved testing laboratory and to establish an interchangeable engineering data base, through testing standards. Finally, and perhaps more important, is that economics by choice may be considered a strategic item and will certainly have a bearing on the industry in the very near future. Other items which are important to the U.S. industrial base include alternate domestic sources of development, introduction of new and improved products, capital investments made by suppliers to improve the quality and reliability of prepreg products (industry is certainly hammering on us to do that), and ultimately, the expanded application for advanced composites.

INTERMEDIATE PRODUCTS

ORGANIC PREPREGS

J. CHORNE'

HEXCEL CORPORATION

HIGH DEPENDENCE ON FOREIGN & SOLE SOURCES

- CURRENT HIGH PERFORMANCE PREPREGS RESINS HAVE "SOLE SOURCED" FORMULATION COMPONENTS.

  EXAMPLES:

  - MY720 (TGMDA) - CIBA GEIGY (2 US PLANTS)
    ~80% MILITARY & COMMERICAL AIRCRAFT
    DOW, SHELL, REICHOLD POTENTIAL ALTERNATES
  - DDS - CIBA GEIGY

- COMPONENTS FOR HIGH PERFORMANCE RESINS ALSO "FOREIGN SOURCED".

  EXAMPLES:

  - ALTERNATE MY720 - 2 JAPANESE CO'S IN PRODUCTION
  - DDS - PRODUCED BY FRENCH (ROUSSEL) FOR CIBA
    ~5 DOMESTIC ALTERNATES POSSIBLE
  - BMI's - MOST RECENT CANDIDATE FORMULATIONS BASED ON FOREIGN SOURCED BMI OR BMI BLENDS
    - RHONE-POULENC - KERAMIDS
    - TECHNOCHEMIE - H795 ET.AL.
    - JAPANESE COMPANIES - BMI, BMI BLENDS
  - B.T. - RESIN CURRENTLY SOLE SOURCE FROM JAPAN

AVAILABILITY OF ALTERNATE PREPREG SYSTEMS & SOURCES

- ALTERNATE PREPREG SYSTEMS AND/OR SOURCES ARE AVAILABLE BUT SEVERELY RESTRICTED BY:

  1. PERSISTENT PHILOSOPHY/PRACTICE OF USING "ESTABLISHED DATA BASE"

  2. HIGH COST OF QUALIFICATION & ASSOCIATED RISK
     ~ $20K - 200K (S.L. CHANNON)

- ALTERNATE FORMULATION RAW MATERIALS ALSO AVAILABLE BUT RESTRICTED BY:

  1. USER SPECIFICATIONS FREEZING ORIGINAL SOURCES QUALIFIED
     I.E., BRAND VS. GENERIC

  2. HIGH COST OF REQUALIFICATION; PROHIBITIVE FOR MULTIPLE SPECIFICATIONS

  3. LACK OF STANDARDS FOR EQUIVALENCY
     - EXCELLENT PROGRESS W/CHEMICAL CHARACTERIZATION PROVIDES SOUND BASIS FOR ESTABLISHED CRITERIA

HEXCEL RECOMMENDED RAW MATERIAL

EQUIVALENCY TEST METHODOLOGY

CHEMICAL ANALYSIS
RAW MATERIAL COMPONENT

↓

NEAT RESIN
CHEMICAL/MECHANICAL/FRACTURE TOUGHNESS
SCREENING

↓

PREPREG LAMINATE
MECHANICAL TESTS

↓

LAMINATE FRACTURE
TOUGHNESS IF APPLICABLE

HEXCEL RECOMMENDED

RAW MATERIAL EQUIVALENCY

1. CHEMICAL ANALYSIS - RAW MATERIAL COMPONENT & QUALIFIED CONTROL

   A. HPLC/PRODUCTION SIZE 3 BATCHES

   B. PHYSICALS

2. NEAT RESIN FORMULATION

   C. RHEOLOGICAL FINGERPRINT (η vs. T, t)

   D. DMA - G' , G'', vs. T, Tg

   E. TENSILE & COMPRESSIVE MECHANICALS @ RT (σ , E , ϵ)

   F. FRACTURE MECHANICALS K_{IC}, G_{IC}

3. LAMINATE - WOVEN

   G. TENSILES

   H. COMPRESSIVES

   I. FLEXURES

   J. SHORT BEAM SHEAR

   @ R.T./T_S

   K. FLEXURE (WET) - RT, T_S

   L. SHORT BEAM SHEAR (WET) - RT, T_S

4. LAMINATE - UNIDIRECTIONAL

   DITTO #3

5. LAMINATE FRACTURE TOUGHNESS IF APPLICABLE

MOST RECENT ACTUAL

W/MY720 ALTERNATE

1. CHEMICAL ANALYSIS - RAW MATERIAL COMPONENT & QUALIFIED CONTROL

   A. HPLC

   B. PHYSICALS

   C. EPOXY EQUIVALENT

   D. DMA - G'

2. NEAT RESIN FORMLUATION

   NONE

3. PREPREG & LAMINATES

   E. IR

   F. LC

   G. PREPREG PHYSICALS

   H. LAMINATE PHYSICALS

   I. TENSILES - RT

   J. COMPRESSIVES - RT 160oF

   K. SBS - 65,RT,270oF

   L. COMPRESSIVE - (WET) RT,270oF

   M. COLOR

   N. STORAGE LIFE

4. SHOP EVALUATION

HIGH COST OF QUALIFICATION & CERTIFICATION

- INHERENT IN LARGE NUMBER OF SPECIMENS REQUIRED FOR "A" AND "B" BASIS ALLOWABLES.

- INHERENT IN ASSOCIATED SUB-COMPONENT AND FULL COMPENENT TESTING & MFG. VERIFICATION.

- NON-INTERCHANGEABILITY OF ENGINEERING DATA BASES LEADS TO CONSIDERABLE INVESTMENT REDUNDANCY.

- EXCESSIVE TESTING REQUIRED FOR CERTIFICATION BY SOME SPECIFICATIONS.

    - ACCUMULATED DATA BASE SHOULD BE REVIEWED PERIODICALLY FOR POSSIBLE STREAMLINING OF TESTING REQUIREMENTS.

- GROWING NEED TO DEVELOP "BRIDGE-BUILDING" AND "MULTIPLE SUPPLIER TEST DATA POOLING" PRACTICES.

ROUGH ESTIMATE

QUALIFICATION INVESTMENT REDUNDANCY

MY720/DDS - CARBON FIBER PREPREG SYSTEMS

SECTOR	ESTIMATED NO. OF SPECS.	EST. TOTAL QUAL. UNITS*
COMMERCIAL AIRCRAFT	16	37
MILITARY AIRCRAFT	8	16
SPACECRAFT	11	16
HELICOPTERS	4	6
A/C ENGINES	4	6
	43	81

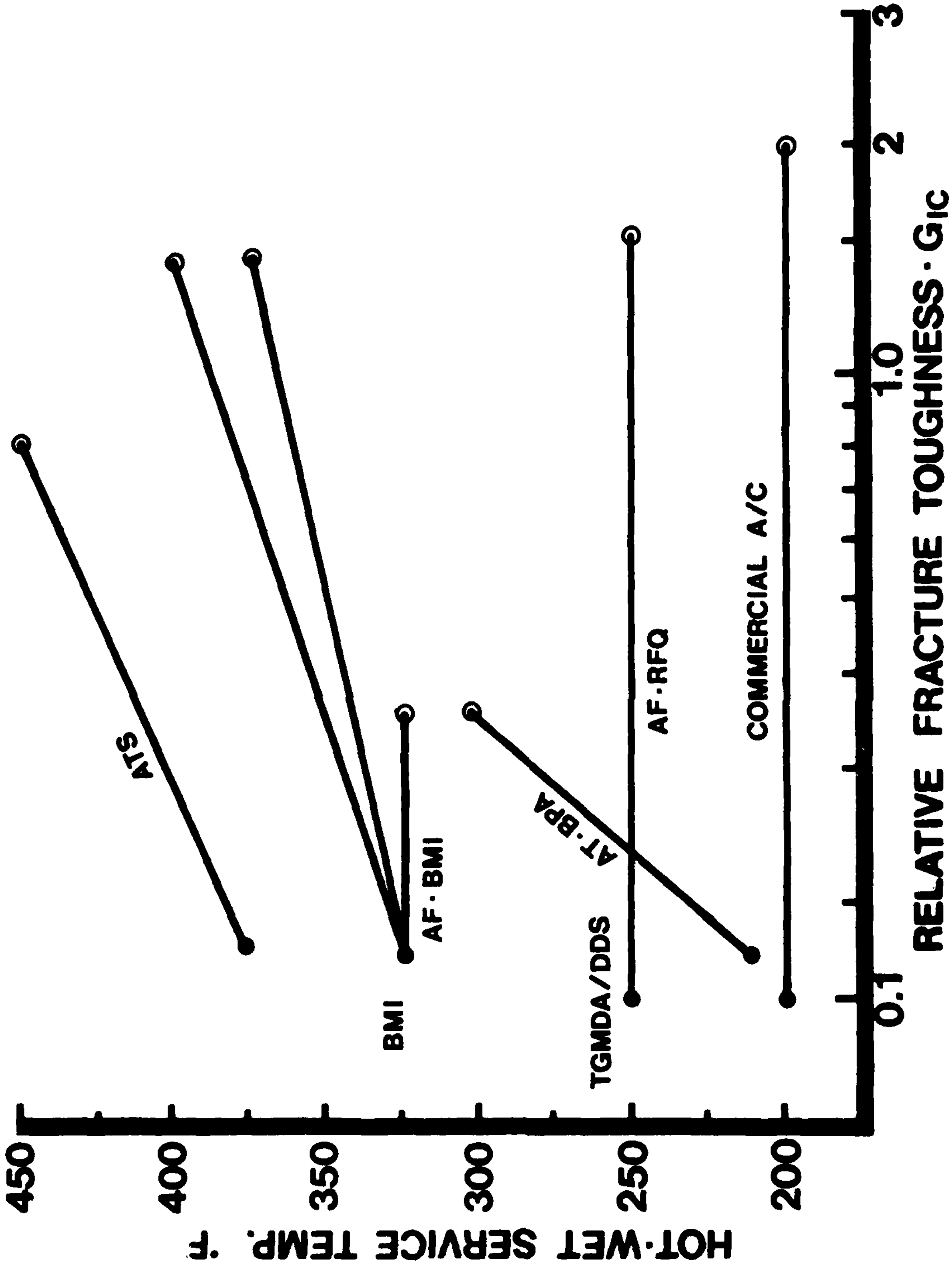
EST. COST - TEST MATRIX (@ $50K - $250K)	$ 4 - 20 MILLION
EST. COST - RAW MATERIAL & FABRICATION (@ $5K - $100K)	$0.4 - 8.1 MILLION
TOTAL ESTIMATE	$4.4 - 28 MILLION

* ESTIMATE ACCOUNTS FOR DIFFERENT PRODUCT FORMS AND MULTIPLE SOURCES QUALIFIED

STATE OF THE ART: 350°F CURING EPOXY

RESIN FORMULATIONS FOR CARBON FIBER PREPREGS

SYSTEM	TGMDA (MY720)	DDS	BF3	MINOR EPOXY A	MINOR EPOXY B	MINOR EPOXY C
5208	X	X			X	
3501	X	X	X	X		
934	X	X	X			X
F263	X	X	X	X		
3502	X	X			X	
976	X	X			?	



HOT-WET SERVICE TEMP. °F
450
400
350
300
250
200
RELATIVE FRACTURE TOUGHNESS · G_{IC}
0.1
1.0
2
3
ATS
BMI
AF · BMI
AT · BPA
TGMDA/DDS
AF · RFQ
COMMERCIAL A/C

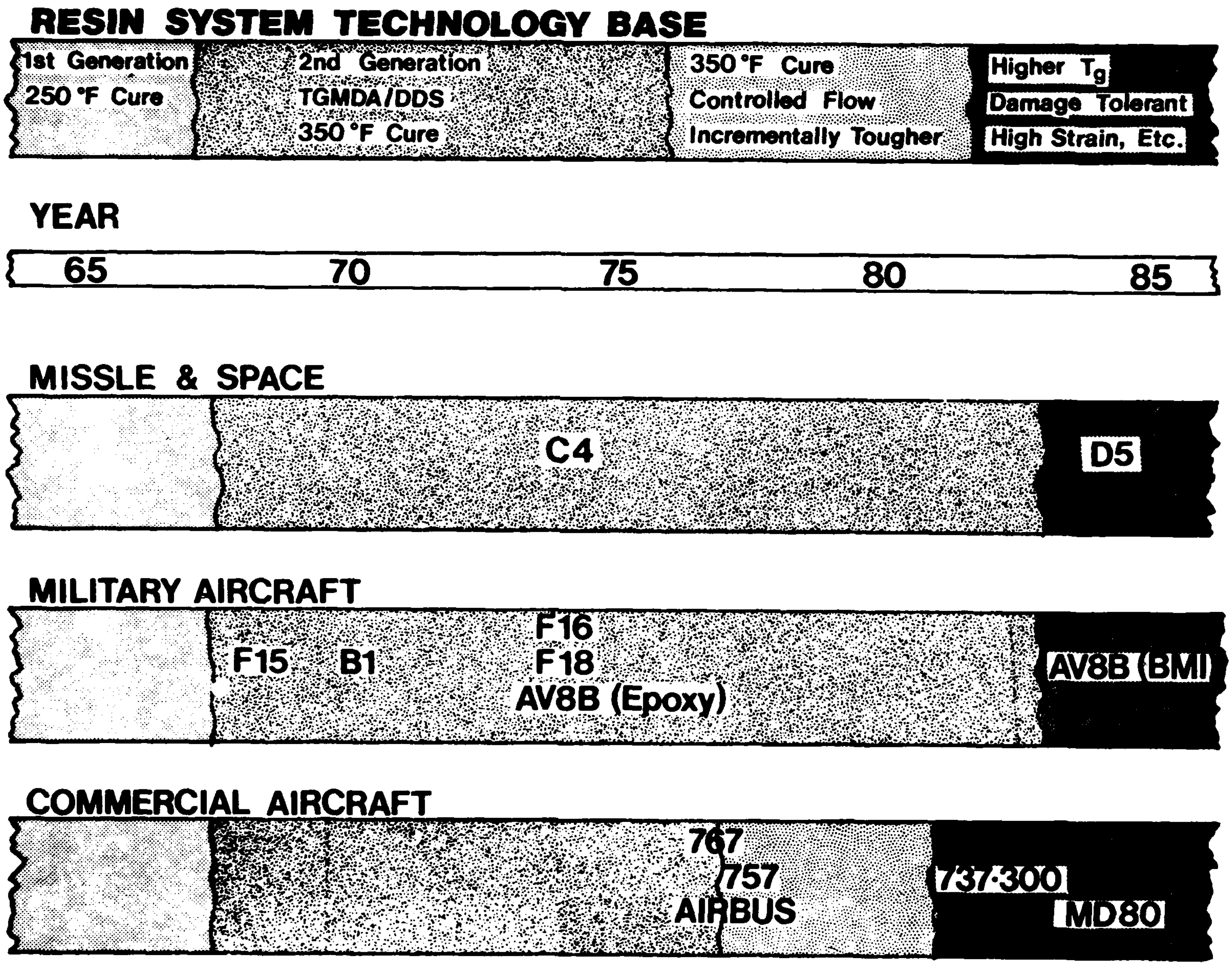
MULTI-SUPPLIER "POOLED" QUALIFICATION TESTING CONCEPT

	SUPPLIER A	SUPPLIER B	SUPPLIER C
CONTROL: QUALIFIED SYSTEMS	RESIN A/FIBER 1	RESIN B/FIBER 1	RESIN C/FIBER 1
ALTERNATE FIBER QUALIFICATION	RESIN A/FIBER 2	RESIN B/FIBER 2	RESIN C/FIBER 3
NUMBER OF SPECIMENS	1/3 TOTAL	1/3 TOTAL	1/3 TOTAL

INTRODUCTION AND QUALIFICATION OF NEW MATERIALS AND SOURCES

- INFLEXIBLE ATTITUDE RE: CHANGES IN PRODUCT STIFLING INCENTIVES TO:
  - DEVELOP NEW TECHNOLOGY
  - EXPAND APPLICATIONS
  - QUALIFY ALTERNATE RAW MATERIALS

- MILITARY SECTOR HISTORICALLY MORE RELUCTANT TO QUALIFY IMPROVED PRODUCTS AND TECHNOLOGY THAN COMMERCIAL SECTOR.


RESIN SYSTEM TECHNOLOGY BASE
1st Generation
250 °F Cure
2nd Generation
TGMDA/DDS
350 °F Cure
350 °F Cure
Controlled Flow
Incrementally Tougher
Higher T_g
Damage Tolerant
High Strain, Etc.
YEAR
65
70
75
80
85
MISSLE & SPACE
C4
D5
MILITARY AIRCRAFT
F15
B1
F16
F18
AV8B (Epoxy)
AV8B (BMI)
COMMERCIAL AIRCRAFT
767
757
AIRBUS
737-300
MD80

ECONOMIC ISSUES

- SOLE SOURCES EXPENSIVE.
- MARKET AND GENERAL ECONOMY MUST SUPPORT MULTIPLE SOURCING.
- "OVER SOURCING" COUPLED WITH "LOWEST BIDDER AWARDS" CREATES A PROFIT SQUEEZE DISCOURAGING SUPPLIERS FROM DEVELOPING IMPROVED TECHNOLOGY OR EXPANDED CAPABILITIES.
- SOLUTION TO HIGH DEPENDENCE ON FOREIGN AND SOLE SOURCES WILL PROBABLY REQUIRE GOVERNMENT INTERVENTION INCLUDING INCENTIVES.

S U M M A R Y

- ORGANIC PREPREGS ARE CURRENTLY DEPENDENT ON FOREIGN & SOLE SOURCES BUT SITUATION NOT AS CRITICAL AS OTHER STRUCTURAL MATERIALS SUCH AS METALS.

- HIGH COST OF QUALIFICATION & CERTIFICATION CAN BE REDUCED MOST SIGNIFICANTLY BY ELIMINATING REDUNDANT TESTING BY MULTIPLE USERS.

  POTENTIAL SOLUTIONS:

  - GOV'T - SET CRITERIA FOR JOINT SERVICES QUALIFICATIONS.
  - INTERCHANGEABLE ENGINEERING DATA BASES VIA. TESTING STANDARDS.

- ECONOMICS DRIVE CHOICES - EVEN STRATEGIC!

  - ALTERNATE DOMESTIC SOURCES.
  - DEVELOPMENT AND INTRODUCTION OF NEW, IMPROVED PRODUCTS.
  - CAPITAL INVESTMENTS TO IMPROVE QUALITY & RELIABILITY OF PREPREG PRODUCTS & EXPAND MANUFACTURING CAPABILITIES.
  - EXPANDED APPLICATION FOR ADVANCED COMPOSITES.

NET IMPORT OF SELECTED CRITICAL

MINERALS AND METALS

MATERIAL	AMOUNT IMPROVED	MAJOR SOURCES
COLUMBIUM	100%	BRAZIL, THAILAND, CANADA
MANGANESE	98%	BRAZIL, GABON, S. AFRICA
COBALT	97%	ZAIRE, ZAMBIA, FINLAND
TANTALUM	96%	THAILAND, CANADA, MALAYSIA
BAUXITE	93%	JAMAICA, AUSTRALIA SURINAM, GUINEA
CHROMIUM	92%	S. AFRICA, USSR, TURKEY ZIMBABWE

METAL MATRIX COMPOSITES

Stan Paprocki
Materials Concepts, Inc.

METAL MATRIX COMPOSITES

Stan Paprocki

Materials Concepts, Inc.

I have taken the liberty to extend the talk to graphite continuous fiber reinforced metal matrix composites. This field is probably trailing behind the organic composites by ten or fifteen years so the tribulations, the problems and the joys that you had in the organic composites field 15 years ago are being experienced by us at the present time.

The prime materials in metal matrix composites today include graphite-aluminum, graphite-magnesium and graphite-copper. From a fiber standpoint, we have investigated, or have in current use today, Celanese GY70, Hercules HM, FMI Microfil and Union Carbide pitch fibers. The greatest concentration today is on the Union Carbide pitch fibers, primarily because they give you a spectrum of modulus values from 55 to more than 100 Msi. The primary applications in DoD are for space structures and some high performance missiles. In the space area where zero thermal expansion is important, high specific properties and high modulus fibers are needed. All of the fibers that we have investigated are domestically produced, but the PAN precursor is primarily a foreign product. The composite precursor materials (graphite-aluminum, graphite-magnesium) are available commercially; graphite copper is available domestically on an experimental basis. Secondary fabrication of sheet and structural materials, is performed domestically by DWA, Amercom and MCI, at the present time.

When we talk about organic composites, we are talking about the picture moving very fast. In metal matrix composites, we are in an emerging technology and things are moving so fast that, when we think of qualification, certification and standardization, we wonder what it all means; we're not there, yet. We have insufficient data base in any specific composite material. There is a variability of fiber properties, and the fabrication processes are in the constant state of development and improvement. However, I think we are reaching a point where we can begin to think about qualification. There is a joint Navy-Air Force program that has been initiated which involves characterization, testing and evaluation of 500 pounds of P100 fiber. That does not seem to be a lot of material but one has to remember that, two years ago, there was no P100 material. This will be used to produce 200 - 300 pounds of prepreg graphite-aluminum precursor, and then there are going to be composite structural shapes made. The objectives of the program are to generate a data base for a run of material and see what kind of consistency the material displays. The structural forms that will be produced will be tested by about a dozen aerospace companies that are involved in space technology, so we'll get some idea of whether there's a correlation in test methods. Up until now, there have been a lot of questions as to what type of test methods should be used for tubes, sheets and those types of products. We will also determine the current state of technology in control of the processing. By processing 500 pounds of P100 fiber, we expect to determine the uniformity throughout the lot and how closely the modulus and tensile strength can be controlled. As the precursor wire is made, we will determine the uniformity in the precursor wire and make the same determination in making sheet and shapes. So, we are starting to develop some criteria for these materials so that maybe in that development we can begin to think of how we qualify these materials.

One of the topics of this meeting was to consider how the DoD can establish a stable, domestic source of supply. Right now, all of these metal matrix materials are fabricated domestically, and if this is a critical material of the future, how do we maintain that? I think DoD should have a sensitivity to problems that are experienced by the primary suppliers. I am extremely interested in the well-being of Union Carbide and their production of P100orP120 fiber; it is a source of supply and the entire metal matrix industry, as it looks into space, is dependent on that supply. Consequently, I am as concerned about their well-being as I am about my Company's well-being. In order to have a domestic supply, we must have a viable economic situation; whether one does that by stockpiling or in some way keeping the industry viable, that's going to be necessary. I like to think that it is desirable to have an integrated strategy. I look at the Japanese and see that they have a focused integrated strategy in any area they pick, and I think that's going to be required. But above all, I think there should be an orientation to external rather than internal competition. What do I mean by that? One day, I ran a tally of all the precursor wire that I sold in the last 12 months; it amounted to $150,000 and I was very happy. That afternoon, I was asked if it wasn't time to set up multiple sources. I think there may be a time to set up multiple sources, but not at a time when we are wondering whether we'll exist from month to month. In the metal matrix area, there are some restrictions on export. There is a restriction of high modulus fiber export, and also a restriction on metal matrix export. As a citizen, I am all for that; I think we ought to protect our technology but I also want to pose a question. The Japanese are talking about coming out with high modulus fiber at the end of the year; they may be coming out with metal matrix composites. Do we allow them to import in this country?

and do we restrict us from exporting? and is that going to develop a good, stable, domestic base? I don't know; that's a question I'd like to pose.

GRAPHITE CONTINUOUS FIBER REINFORCED METAL MATRIX COMPOSITES

STAN J. PAPROCKI

MATERIAL CONCEPTS INCORPORATED
Columbus, Ohio

GRAPHITE CONTINUOUS FIBER REINFORCED METAL MATRIX COMPOSITES

Composite Materials:	Graphite-Aluminum Graphite-Magnesium Graphite-Copper
Graphite Fibers:	Celanese GY 70 Hercules HM FMI Microfil™ Union Carbide-Pitch Fibers P55-P120
Matrix Materials:	Commercial Alloys
Prime DOD Applications:	<u>SPACE</u> High Performance Missiles

SOURCES OF SUPPLY

Graphite Fiber:	50 to 100 Msi	Commercial - Domestic Sources - Hercules, Celanese, FMI, Union Carbide
	120 - 140 Msi	Experimental - Domestic Source - Union Carbide
Composite Precursor:	Gr-Al, Gr-Mg	Commercial - Domestic Source - MCI
	Gr-Cu	Experimental - Domestic Source - MCI
Secondary Fabrication:	Sheet and Structural Shapes	Commercial - Domestic Sources - DWA, Amercom, MCI

CURRENT STATUS RELATIVE QUALIFICATION, STANDARDIZATION AND CERTIFICATION

As A Consequence of Rapid Advances In Technology:

- Insufficient Data Base Exists For Specific Composite Systems
- Variability of Fiber Properties Experienced - In Process Of Optimization
- Fabrication Processes In State of Optimization

However:

- Technology Has Reached a Point of Sufficient Maturity To Permit Initiation of Programs Leading To Development of Required Data For Qualification and Standardization

JOINT NAVY (NAVSEA) - AIR FORCE (AFWAL) PROGRAM ON DEVELOPMENT OF DESIGN DATA FOR P100 GRAPHITE - 6061 ALUMINUM COMPOSITE

Program Involves:

Characterization, Testing, and Evaluation of -

- 500 Pounds of P100 Graphite Fiber
- 200 - 300 Pounds of P100 Graphite - 6061 Aluminum Precursor Wire
- P100 Graphite - 6061 Aluminum Composite Sheet and Structural Shapes

JOINT NAVY (NAVSEA) - AIR FORCE (AFWAL) PROGRAM ON DEVELOPMENT OF DESIGN DATA FOR P100 GRAPHITE - 6061 ALUMINUM COMPOSITE

Program Objectives:

- Data Base Generation
- Evaluation of Test Techniques
- Determination of Current State of Technology Relative To Production and Quality of -
  - P100 Graphite Fiber
  - P100 Graphite - 6061 Aluminum Precursor Wire
  - P100 Graphite - 6061 Aluminum Sheet and Structural Shapes
- Establish Criteria For Future Qualifications and Specifications of Graphite - Aluminum Composites

DOD ACTIONS INFLUENCING THE DEVELOPMENT AND MAINTENANCE OF STABLE DOMESTIC MATERIAL SUPPLY SOURCES

Sensitivity To Problems of Critical Suppliers

Sufficient Demand To Sustain Economic Viability

Integrated Strategy

Orientation To External Rather Than Internal Competition

METAL MATRIX COMPOSITES

Joe Dolowy
DWA Composite Specialties, Inc.

METAL MATRIX COMPOSITES

Joe Dolowy

DWA Composite Specialties, Inc.

I appreciate the opportunity to be here and I'm going to try to follow on in the vein that Mr. Paprocki just began; changing things a little bit from the resin matrix emphasis that you heard during the rest of the day.

I want to remind everybody that we are in a position of whether we have the chicken or the egg. We are the new guys on the street. With the exception of the carbon-carbon composites, metal matrix composites have been coming along behind the resin-matrix systems. So we are not as far along as much of the technology you heard about this morning. I'll try to give you some background and insight to set the pattern for where we're going with this system. The topics addressed in Mr. Channon's letter are all key items that should be addressed as far as produceability, data base and industrial base for composite materials are concerned. I think everyone agrees with that; however, the more I looked at this list, the more I began to realize that one extremely key item had been left off which is _especially_ important in composites, where you do, in fact, have a designable system. You also have to have some idea of the type of market, the shape and the form of the finished product. If you are talking about industrial bases, specifications, standard qualifications, you'd better be sure you understand which market you're going after because the automobile industry doesn't care about half of the criteria that the commercial aircraft people require. That was a difficult lesson for me to learn and the lesson I learned is that I should stop going to Detroit.

What is the status or rationale today in metal composites? There is no broad, qualified domestic industrial base for metal matrix composites, simply because there is no market to justify it. I don't really need more competition when I don't have enough business to keep my people busy. Metal matrix composites are a unique business. I'm going to talk about three systems. In every case, (and I think I'm making true statements for Stan, Jack and probably half the rest of you here who are producers), I've got capacity which amounts to 5 - 10 times the market for any of these systems. If you set up any reasonable capacity that is going to be efficient, it has to be well beyond the market level of today and the last ten years. So we're caught up in a vicious cycle. We don't have the industrial base because there isn't enough market to justify it or the system isn't far enough developed. The costs are too high because the market's not large enough; therein lies the vicious circle. I'm going to particularly talk about three forms of metal composites. I've selected these three as characterizing the basic forms of the materials in the marketplace. Continuous fiber systems are best exemplified by boron-aluminum. This is the original system that was developed nearly 20 years ago; now there are various forms of SCS-aluminum and Borsic-aluminum also. We can also reinforce titanium. In all cases, we end up with a highly directional anisotropic material. The second type of composite that I'm going to address generally is the continuous tow system such as graphite reinforced metal, FP reinforced metal, and silicon carbide (Nicalon) reinforced metal. There's a whole range of these systems with different reinforcements which are anisotropic. And finally, I'll say a few words about the discontinuous reinforced systems which are unique because they tend to be isotropic. DWAL20 is my company's trademark for a ceramic powder reinforced metal matrix which fits into this group.

The present status of each of these systems, from the standpoint of specifications and qualifications will be discussed under the following headings. I want to look at the raw materials, in-process or precursor or intermediate forms, and then comment on the finished product form and where technology stands. In the case of boron-aluminum, boron has been produced for 20 years and specifications exist for the fiber. It is a sole source material and it is produced domestically; unfortunately, it is not very popular these days and probably less than 1000 pounds a year are used for this 20 year-old material with unique properties. There are instances where there is an intermediate form. My personal feeling (and many other people seem to agree with it) is that the most efficient way to produce the composite is not to create a precursor (or intermediate) form but rather go directly to a finished product form. There are selected product form specifications that exist for the system and it is domestic, yet we still don't have a market developing for that particular system.

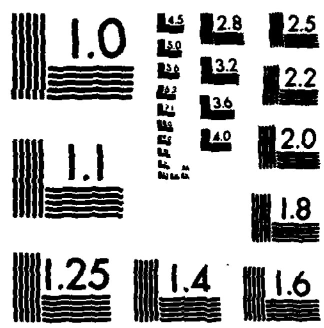
In the case of the graphite metals systems, carbon fibers and metal fibers have been available for a while and all the producers (Union Carbide, Hercules, Celanese, FMI, etc.) have specifications for carbon; it is pretty well understood. There are intermediate forms. Mr. Paprocki reported on his form, the liquid metal infiltrated system. There are specifications that exist and they are becoming tighter. When you get to the finished product forms (sheet, simple shapes), the users are developing the specifications.

On the discontinuous materials, (the isotropic systems), in our particular case, ceramic particulates have been around 40 to 50 years or more. They are used in the cutting tool business. They are well qualified and well understood. There is no intermediate stage involved in the production of particulate reinforced metals. At present, we and others who are making discontinuous systems are working with the users to develop specifications and qualifications.

What are the problems? Why aren't these systems getting into use? Keep in mind, of course, that these material systems, for the most part are very new. The oldest, boron-aluminum, is about 18 years old; graphite-metal is about 12 years old; discontinuous reinforced metals, (DWAL and the whisker systems that Jack Cook will tell you about next) are both about 6 or 7 years old; they are relatively new systems. Jay Baetz referred to carbon-carbon as being in adolescent stage. Well, I'm afraid discontinuous material is still in the pre-adolescent stage. The major problems that we've come up against are listed and I think they're all pretty self explanatory.* In the last couple of years, we've clamped down on our technology and our ability to sell composite materials abroad. During that time period, we've seen several foreign suppliers enter the market and go right on past the state of development while we sit here in the U.S. Now, I'm all in favor of protecting useful and strategically important technology but, if foreign users are going to outsmart us because we won't work with them, then I think we're making a big mistake. We are missing a tremendous opportunity. A lot of technology and development exist but they aren't being used for these reasons and many others. If I compare the U.S., Japan and European people that I've had occasion to speak with in the last two or three years, from the standpoint of metal composites, I see differences in their primary aim and the way they approach the problems at

*p. 418.

AD-A149 039 PROCEEDINGS OF COLLOQUIUM/WORKSHOP ON COMPOSITE 5/6
MATERIALS AND STRUCTURES..(U) INSTITUTE FOR DEFENSE
ANALYSES ALEXANDRIA VA S L CHANNON JUL 84 IDA-D-70
UNCLASSIFIED MDA903-84-C-0031 F/G 11/4 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

hand. In the U.S., we are notorious for spending anything to get another two percent of performance out of the material system, even if it doubles the cost. When I go to Detroit and say "I've got the greatest material in the world - a metal matrix spring for your car", the answer is "Great, I'm using steel now and it's killing me, it's costing me a $1.78 a pound". The Japanese, in the meantime, take the exact opposite point of view. They find the simplest, most direct, most expeditious approach to meet the minimum requirements to satisfy the job and that is the product form they go after. The best example of that is the Toyota piston with which I think everybody is familiar. The Europeans tend to be between those approaches, depending on the particular company, but I have yet to find one that pushes quite as hard as we do here in the U.S. to maximize everything. There is a place for maximizing everything; if you want to put a great system into space that's going to last forever, you may want to refine that system to the nth degree. That is where you maximize all your properties. If you want to build a fin for one of the small rockets or missiles, it is almost as bad as going to Detroit to talk about the prices of these materials.

In the U.S., because we are putting so much emphasis on the maximum properties, the composite forms that we select tend to be somewhat specialized, which aggravates the situation by making it even more costly to produce a finished product. The Japanese always try to utilize existing facilities and existing technologies first. The Europeans, again, are intermediate.

One of the necessary conditions to expand the industrial base for metal matrix composites is to define some markets. We have to create or somehow encourage initial application experience. Metal composites will have to go through the same evolutionary steps that graphite epoxy or other resin base systems did. Even though it may not be cost-effective initially, it is important that everyone sees what can be done and then, hopefully, the customers will come to us. Finally, I would like to emphasize a very important point, in the necessary conditions for expansion of the industrial base. If we continue to act as though we have all the greatest secrets in the world and watch our foreign colleagues pass us by, producing items that do the same job and, in many cases, do a better job than the items we're producing here, we are making a serious mistake. In the case of the Toyota piston application, each piston has nominally one-tenth of a pound of metal matrix composite in it. In 1983, that application exceeded my best guess at the total production of metal composites in the U.S. Based on conversations with Japanese visitors to my plant and other Japanese companies, the Japanese were also working on other applications and they were building connecting rods which use a whole lot more composites.

I would recommend that we select some key application areas, carry out the demonstration and then move the system into a real application. I think that's the key. Obviously, some of these things would help. It would be nice if this could be done with manufacturing technology support; it would be nice if it could be done under OUSDRE support; however it has to be done. Until that step is accomplished, I think we are going to continue to progress slowly. And finally, I think it is imperative that we adopt an intermediate point of view or at least consider other points of view in our material design philosophy. I believe that will help us come to standardization and help these technologies grow much more quickly.

IDA COLLOQUIUM /WORKSHOP

on Composite Materials and Structures

May 8 - 10, 1984

National Academy of Sciences

PRESENTATION ON METAL MATRIX COMPOSITES:

by: J. F. Dolowy, Jr.
President, DWA Composite Specialties, Inc.

dwa composite specialties, inc.

"Where concepts become reality"

composite specialties, inc.

"Where concepts become reality"

OBJECTIVE

Formulate Recommendations leading to development of broad, qualified, domestic, industrial base for composite materials.

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SUGGESTED ITEMS FOR DISCUSSION

A) Standards

B) Specifications

C) Qualification Procedures

D) Material Sources

E) Availability

F) Costs

G) Problems

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A SIGNIFICANT AREA HAS BEEN LEFT OUT:

H) *Market Type/Size;*
Application Type

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RATIONALE

TODAY, NO BROAD, QUALIFIED, DOMESTIC INDUSTRIAL BASE FOR MMC'S BECAUSE:

- Demand / Market is ill-defined, or lacking.
- Present MMC's use available, lower cost raw materials.
- Lack of Complete MMC characterization complicates selection, specification preparation...
- MMC's costs have been too high.

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THREE TYPES OF MMC SYSTEMS I WILL ADDRESS:

Reinforcement	"Generic" Systems	Mechanical Response
Continuous Fiber:	B-Al or SCS-Al	anisotropic
Continuous Tow:	Gr-Metal, Al_2O_3-metal	anisotropic
Discontinuous:	DWAl 20®	isotropic

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PRESENT STATUS OF EACH "LEVEL" FOR MMC SYSTEMS

Spec. Levels	Continuous Reinforcement: Fiber (B-Al Type)	Continuous Reinforcement: Tow (Gr-Al Type)	Discontinuous Reinf. DWAl 20®
1. Raw Materials	Fiber spec. exists.	Tow spec. exists.	Ceramic particulate spec. & aluminum P.M. spec. exist.
2. In-process/ Intermediate forms	N.A.	L.M.I precursor forms developing specs.	N.A.
3. Product Assurance	Selected product-form specs. exist.	Prototype users' specs. now being developed.	Manufacturers' process controls exist; specific product form specs. developing.

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PROBLEMS ENCOUNTERED IN GETTING MATERIALS USED

- Lack of user experience / familiarity
- Lack of program support to apply material technology to structural areas
- Widely varying requirements / criteria
- Many U.S. potential users fail to realize that higher performance, specialized materials will (at least initially) cost more than "conventional" materials.
- Foreign usage of U.S. MMC impeded by uncertainty of availability, re: Munitions Control status.

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<u>TODAY'S:</u> <u>TECHNOLOGY AREAS OF MMC PROGRAMS</u>

- MATERIALS SYSTEM REFINEMENTS
- MATERIAL MECHANISMS
- MATERIALS CHARACTERISTICS
- PROTOTYPE STRUCTURES

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OVERLAY

BASIC & APPLIED RESEARCH-TYPE PROGRAMS (6.2) .

EMPHASIZING PROPERTY OPTIMIZATION.

LIMITED: FEASIBILITY OF SECONDARY PROCESS SCHEMES (6.2 & 6.3A).

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MMC INDUSTRY COMPARISONS

	USA	JAPAN	EUROPEAN
AIM:	Maximize Properties	Create simplest material to do job.	Intermediate
APPROACH:	Utilizes often developmental, higher cost reinforcement.	Seek least costly reinforcement	Both schemes
	Emphasizes specialty fabrication.	Utilizes existing facilities and equipment.	Utilizes existing facilities and equipment.

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<u>" NECESSARY CONDITIONS " TO ENHANCE MMC INDUSTRIAL BASE</u>

1. DEFINED MARKET.

2. INITIAL USAGE EXPERIENCE--WILL CREATE USER CONFIDENCE AND NECESSARY SPECIFICATIONS.

3. ENHANCED INTERNATIONAL COOPERATION, TAKE ADVANTAGE OF FOREIGN-DEVELOPED MARKETS AND TECHNOLOGIES.

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RECOMMENDATIONS

o Select Key Application Areas by Material System or Structure Type, and accomplish via M.T. Funding.

A) Complete Material Characterization

B) Demonstrate Material Applicability to Real Structures

C) Create "Preliminary" Specification Documents

O Adopt an Intermediate Material Design Philosophy:

A) Select available, cost-effective material & processes.

B) Encourage joint ventures with commercial and foreign users.

C) Maximize usage of available facilities / equipment.

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on Composite Materials &
Structures, May 8-10, 1984

WHISKER/METAL COMPOSITES

Jack Cook
ARCO Metals, Inc.

WHISKER/METAL COMPOSITES

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I'm going to specifically focus on one set of the metal matrix composites, namely the discontinuous metal matrix composite. We build our whisker reinforcements out of the rice hulls. It is a by-product of the rice manufacturing industry in the U.S. We would use about one-tenth of one percent of the rice husks generated if we were producing a million pounds of whiskers, so we're not even touching that source today. Beer cans represent a commercial product which might be an application for an improved aluminum product. If you think qualification in Detroit is interesting, you ought to try to put can stock into that industry which uses 6 billion pounds of aluminum per year. It dwarfs what we are trying to do and puts you back in perspective when you are a company that is trying to make that kind of material. We are making some high performance materials out of these reinforcements and I will now try to direct my remarks to some of the issues concerning the industrial base and qualifications.

This is basically a high performance material so the standards and measurement techniques have to be focused in that direction. High stiffness, high strength materials are not tested in the same manner as a ductile metallic system. This is a non-strategic material; none of the elements in the composite (silicon carbide or aluminum), are dependent on a volatile foreign source. We do have competition, however. The specifications look very much like the same words that are used in the resin composite system. They are very much in their infancy. Current RFPs which are released for metal matrix materials are requesting assurances on material properties, processing and uniformity. We don't stand a chance of meeting those requirements today with the small quantity of material that is being produced.

I will give you a status report on what I believe are some of the critical issues. The raw material source is domestic, made from rice hulls; the capacity in 1984 is somewhere around 10 - 16 thousand pounds. We expect to double this capacity in 1985 and we have proven the scaleability of each step of the process; it is a continuous process. Pre-alloyed, high performance aluminum powders are available on the open market in 5 - 10 thousand pound lots. The present capacity for that type of material in this country is only about 150 tons and we don't see that expanding at a very significant rate. We have just started construction on a 300 - ton plant that will be on stream in 1985 but that, in itself, is not a very large portion of what would be required for one cargo aircraft.

The whiskers are short, about half a micron to a micron in diameter and probably 50 to 100 microns long. When combined with the aluminum powder, we are really dealing with a powder metallurgy type composite. There is a good competitor for this product in Japan, with about the same capacity. He is marketing in the U.S. and has also been trying to sell whiskers to me.

With regard to the status of process controls and reproducibility, I think that we are doing the best that we can with the quantities of materials that are being produced today. We have had the fortunate experience of working with a major air-frame company for some time and this customer is a hard task-master. They have insisted that we provide documentation, even in the early days, when we were making only a few pounds of material. We have our standards traceable back to NBS and we have a lot of our analytical tools in place, but they are not yet sufficient. We are putting computerized controls on our processes wherever possible. We still have to provide certification. We are learning about storage of materials in the process without degradation. This is not as bad as the moisture problem with some of the intermediates in the polymer systems, but there are places where you would not like to store either the whisker raw materials or the powder raw materials.

I'd like to cover a few of the highlights of our quality assurance techniques. We think that the issue in inspection is detecting the flaw size that may cause a problem in mechanical testing. We are trying to work out NDE techniques that will provide an in-process inspection tool for early rejection of material. We want to be able to reject material early in its life so that it is not processed even close to the finished article. Later rejection drives up the cost of the total spectrum of products. We can trace our material from raw material source to the product that goes out the door; we are starting to computerize that record management so that it will be acceptable and available to the customer. We have qualified a number of different sources of raw material to date. We don't have any better MIL specifications than the MIL 45208, but we'd like to go to the higher levels of qualification such as contained in MIL/9858A as quantity demands and programs increase to the size that will afford it. That is a very expensive procedure in order to become a qualified supplier.

There is almost no data being generated through prototype testing; the testing is limited to one or two articles. We are, indeed, in our infancy. You heard earlier about statistical analysis being applied to small populations of data. We think that is a viable thing to consider; we've used it on some of these test data and it compared very well against larger populations. The table* shows comparison between the metal matrix material (SXA) with a modulus of 17 million psi versus an aluminum alloy with a modulus of 10 million. The yield strength and ultimate strength are significantly higher and the elongation is much lower for the metal matrix material. Tests at Mellon Institute and Silag are representative of about 60 specimens each and the standard deviations show fairly close correlation between the two testing sources. Other test data shows the comparison of properties from rod to rod in extruded material. Most of the data came from mid-sized billets which weigh about 100 pounds. However, this is not typical of the sizes that we will have to produce when we are producing material at a higher production rate. Larger billets of 600 pounds have been made. Toyota piston represents a considerable amount of material; I believe 25,000 engines were built in 1982, with that type of material.

It is our intention to be a reliable, available source of material but we are also in business for a profit. Multiple sourcing is great but, if you over-source, you are likely to discover that you may not have one of those sources when you need it; it will go out of business for a different reason.

I'll conclude by just reminding you that we do have a domestic source. We convert that domestic source into a cost-competitive material that, we think, can make its way into the aerospace air-frames of this country in the near future. It's going to take an effort on the part of the prime contractors, the government and the suppliers to see that we do everything that we can to get the volume up so that the price reduction will be realized.

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*p.439.

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

STANDARDIZATION QUALIFICATION AND CERTIFICATION

PRESENTED

TO

NATIONAL ACADEMY OF SCIENCES

MAY 8-10, 1984

ARCO METALS COMPANY
SILAG OPERATION
GREER, S.C.

ARCO METALS COMPANY

SILAG OPERATION

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

- ATTRIBUTES -

HIGH PERFORMANCE

- ° LOW DENSITY
- ° HIGH STRENGTH
- ° HIGH STIFFNESS
- ° NON-STRATEGIC ELEMENTS
- ° HIGH DIMENSIONAL STABILITY
- ° HIGH ELEVATED TEMPERATURE STRENGTH
- ° HIGH ELEVATED TEMPERATURE STABILITY

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

- RAW MATERIALS -

SILICON CARBIDE

- 10 - 16,000 POUNDS/YR - 1984
- 30,000 POUNDS/YR - 1985
- CONTINUOUS PROCESSING

PREALLOYED ALUMINUM

- PURCHASED IN 5 - 10,000 POUND LOTS
- PRESENT CAPACITY - 150 TONS
- 1985 CAPACITY - 300 - 500 TONS
- SEMI-CONTINUOUS INERT PROCESSING

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

- TYPICAL REQUIREMENTS -

- ... GENERATE A TECHNICAL DATA PACKAGE TO INCLUDE DESCRIPTION OF MANUFACTURING PROCESSES AND MATERIAL SPECIFICATION

- ... CONDUCT A FULL MATERIAL CHARACTERIZATION TO DEFINE CRITICAL MECHANICAL PROPERTIES IN ADDITION TO MATERIAL FAILURE MODES

- ... DOCUMENTATION OF PRODUCTION PROCESSES

- ... ASSURE THAT THE ACTUAL MATERIAL IS DEFECT FREE, CONSISTENT IN PHYSICAL PROPERTIES FROM LOT TO LOT, ETC. (I.E., MATERIAL SPECIFICATIONS MUST BE GENERATED.)

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

- CRITICAL ISSUES -

- RAW MATERIAL SOURCES
- RAW MATERIAL CAPACITY
- PROCESS CONTROL/REPRODUCIBILITY
- Q. A. TECHNIQUES AND INTERPRETATION
- TRACEABILITY
- CONFORMANCE TO MIL STANDARDS AND OTHERS
- DESIGN ALLOWABLE DATABASE GENERATION

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

- STATUS OF PROCESS CONTROL AND REPRODUCIBILITY -

- NBS TRACEABLE CALIBRATIONS
- STANDARDS FOR ANALYTICAL ANALYSIS
- PROCEDURE DOCUMENTATION
- COMPUTERIZED CONTROL AND PROCESS ANALYSIS
- OPERATOR TRAINING, TESTING, AND CERTIFICATION
- STORAGE LIFE DURING PROCESSING

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

-STATUS-

Q. A. TECHNIQUES AND INTERPRETATION

- DETECTION AND CHARACTERIZATION OF FLAWS
- ASSESSMENT ON PERFORMANCE PROPERTIES

TRACEABILITY

- TRACEABLE PROCESSING AND TESTING DOCUMENT
  - RAW MATERIAL TO PRODUCT
- RECORD MANAGEMENT THROUGH COMPUTERIZATION

CONFORMANCE TO MIL STANDARDS AND OTHERS

- ASSESSMENT: VALIDITY OF MIL STANDARDS TO MMC MATERIALS
- CONFIGURATION OF Q.A. SYSTEM TO MEET MIL STANDARDS

SILICON CARBIDE REINFORCED ALUMINUM COMPOSITES

-STATUS-

DESIGN ALLOWABLE DATABASE GENERATION

- COMPUTERIZED DATA ACQUISITION AND ANALYSIS
- DATABASE GENERATION
- PROTOTYPE TESTING

DATABASE PROGRAM

INITIAL RESULTS

- STRENGTH AND STIFFNESS OF ALUMINUM ALLOY 6061 IS SIGNIFICANTLY INCREASED BY ADDITION OF SILICON CARBIDE WHISKERS.

	MEAN TENSILE PROPERTIES[1]			
	ELASTIC MODULUS (MSI)	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE TENSILE STRENGTH (KSI)	ELONGATION (%)
ALLOY 6061 (TYPICAL)	10.0	40	45	17
SXA 61/20 VOLUME PERCENT F9 (60 TESTS)[2]	17.20	66.20	86.99	1.98

1 ARTIFICIALLY AGED TEMPER.

2 FOUR 1 INCH DIAMETER EXTRUSIONS FROM 6 INCH DIAMETER BILLET; FIFTEEN TESTS PER EXTRUSION.

RELIABILITY OF MECHANICAL PROPERTIES

SXA 61-T6 EXTRUSIONS

EXTRUSION	E(MSI)	FTY(KSI)	P.L.*(KSI)	FTU(KSI)
C6201Z	17.12	64.70	50.61	85.59
C6202Z	17.09	63.76	49.75	84.00
C6203Z	18.01	62.23	48.17	82.89
C6204Z	17.61	63.65	49.55	82.14
C6205Z	18.04	64.38	50.63	85.17
C6207Z	17.98	65.07	50.81	84.44
ALL 150 TESTS	17.46	64.83	50.55	85.22

*PROPORTIONAL LIMIT

DATABASE PROGRAM

(SXA 61-20)

TEST LAB TO TEST LAB COMPARISON - MEAN (STANDARD DEVIATION)

Test Lab	Elastic Modulus (MSI)	0.2% Offset Yield Strength (KSI)	Ultimate Tensile Strength (KSI)
MELLON	17.19 (1.33)	66.27 (1.80)	85.97 (3.81)
SILAG	17.21 (0.64)	66.14 (1.09)	88.00 (1.54)

DATABASE PROGRAM

(SXA 61-20)

ROD TO ROD COMPARISON - MEAN (STANDARD DEVIATION)

ROD	ELASTIC MODULUS (MSI)	0.2% OFFSET YIELD STRENGTH (KSI)	ULTIMATE TENSILE STRENGTH (KSI)
C6156Z	18.01 (1.08)	66.03 (1.54)	87.59 (2.39)
C6157Z	16.29 (0.87)	66.58 (1.85)	85.22 (3.70)
C6158Z	17.36 (0.88)	66.38 (1.32)	86.69 (2.05)
C6159Z	17.14 (0.45)	65.82 (1.13)	88.45 (1.36)

WORKING GROUP SUMMARY REPORTS

WORKING GROUP 1

FIBERS AND REINFORCEMENTS

T.J. Reinhart, Chairman

Working Group I. Fibers and Reinforcements

T. J. Reinhart, Chairman

In Working Group 1, we did not limit our discussion to fibers alone. The recommendations and options pretty much cover the gamut of composites, so let me apologize in the beginning if we have stepped on anyone's toes.

These recommendations are not presented in any specific order. The first one I would like to present relates to DoD showing increased sensitivity to the business and economic problems of the material suppliers. Several of the members think that composites technology is an international technology in that things are developing all over the world and that the U.S. has very little to "hold close to the vest", so to speak. Many of the members thought that the embargo on certain technologies was penalizing our industry in allowing the foreign competition to leap ahead. Any of us who have travelled overseas at all really can see that there is tremendous progress being made in places like Japan, Germany and England. DoD has an option here to look at what we are doing to ourselves and make sure we don't shoot ourselves in the foot. Certainly, there are areas where we are leading and the embargo could do some good for us. In addition, many of the members thought that, by restricting the business base, (for instance, Union Carbide trying to sell overseas has to get a license from the Commerce Department), the time delay allows the Japanese to have a stockpile in place and sell materials. That seemed to be unfair. Also, restricting the export of our technology also restricts the import of similar technology from other countries; it has to be a two-way street. DoD has to take a look at this technology list that the State and Commerce Department are using and do something about it. It is understood that a group met several years ago and recommendations were made with no resulting action in DoD, Commerce, State or anywhere. (Comment from G. Lubin that SAMPE is addressing this problem). Maybe that group should also focus a recommendation to DoD or to IDA and transmit it to DoD.

The eloquent plea that we heard from Joe Dolowy about his feelings really hit home. There is really no big market for metal matrix composites even though we have flown some on the Shuttle, there are a few pieces flying here and there and the Air Force is building some big pieces. There is no impact of metal matrix on any of our systems today. There is no market competition, so controls are probably not needed in a case like that. We all heard Paul Langston's plea for the use of hybrid materials especially in damage-tolerant systems and damage-tolerant design. In a military environment, especially the military repair environment, we see a lot of ground-handling inflicted damage. If we can keep our airplanes flying and if we can keep them away from the dropped wrenches and dropped tool boxes, we are in good shape. Our planes spend most of their life on the ground, either practicing loading weapon systems or opening them up to get at the electronics. We desperately need damage-resistant composite systems as well as damage-tolerant designs, and repairable designs. The resin community is working on tougher resins and we are looking at thermoplastic materials like PEEK but they are several years away - maybe more than that. Meanwhile, hybrid composites may be able to add to the toughness and durability of our systems. DoD should explore an option here, whether it is a tri-service activity or assigned to one activity/agency to look at hybrid composites to see what they can do.

The next recommendation impacts on the way DoD implements new technology into the systems. In a system that is in production, it is very difficult to get a new material introduced. For instance, we are buying F-15's from McDonnell Douglas; those F-15's have a horizontal stabilator that was designed by the laboratories back in '68 or '69 - using 5505 boron fiber skins with metal honeycomb core. Now, the Air Force is going to buy another 500 of these aircraft and they are going to have the same structure. Although we could have verticals and horizontals of high modulus fibers in a high impact resin, there is no way that the SPO people are going to stand still and have us put a new material on there. They are concerned about cost and schedule rather than what we might do for ourselves. In the future, if we had a system that had better serviceability, damage tolerance and damage resistance, there is high pay-off in this area for the DoD. Yet, those of us in the labs are unable to push new technology into a system that is in production. If that system isn't ready five years or four years before production, and the material is frozen, there is no hope of getting it in. This area is a candidate for a future meeting either by IDA or some other organization. The labs have been sponsoring meetings like this for years in SAMPE with talks on materials but we don't get the SPO people there who can make decisions about putting a new material in a block change in production when it makes sense to do so. We may be missing a good bet here and this is something that DoD should explore - how it implements new technology into systems that are in production now.

We all heard Wayne Stinchcomb and Paul Doyle talk about standards and the time that it takes to get things done. It is recommended that DoD explore options as to what increased leadership or increased funding would make sense in working with the people that are developing the specifications and standards. It was felt by the members of the working group that the initial activity or initial focus might be with NASA, since they are engaged in an activity with Boeing, Lockheed and McDonnell-Douglas related to a new specification for 350°F curing resins. Maybe we should keep that going and have them work on other things, too.

Stan Channon put up a slide early in the session which indicated that there was some thinking or some advantage to having a DoD/Industry Composites Association. I'm not sure DoD should play a part in that but the Composites industry needs an Association; it needs a focus where the group can get together and work on high priority problems that are sufficiently common throughout the group. This may be done under NASA, SAE, or it could be an independent group, something like the Aluminum Association or the Concrete Association. This, also, we feel, could be a possible topic for a future workshop or a future seminar.

With respect to Mil-Handbook 17, you saw Paul Doyle's presentation and you understand that two DoD laboratories are involved in generating design information. The budget for this is somewhat less than a half million dollars a year provided by Army, Air Force and NASA, with zero dollars from the Navy. The schedule that he showed for that Handbook indicates that it is years away from having systems in it that we'd like to consider for our aircraft today. DoD should explore ways to accelerate this. A strong Mil-Handbook 17 is good for composites and it is good for the industry. We should learn from the way the metals people are running Mil-Handbook 5. They have a full-time contractor and they are not in the business of generating data. The data for Mil-Handbook 5 comes from the material suppliers, the fabricators, the forgers, and it comes from the aerospace prime contractors. Until the Composites industry learns that its going to have to share its data base, we are not going to have a Mil-Handbook 17 in any kind of a time period that will make it a useful document. I was chairman of Mil-Handbook 17 when the Air Force had it; we had something like $25,000 a year to put into Mil-Handbook 17 and that's exactly what I have today to put into Mil-Handbook 17. We need 10 to 20 times that amount if we are going to do anything in a reasonable time. Personally, I feel that DoD should not be in the design data business; we shouldn't have Government labs generating design data.

Several of the members felt that they had great difficulty trying to determine what the DoD requirements were for fibers to go into advanced composites, (Carbon, S2-glass and Kevlar). I'm not sure whether the capability exists within the DoD to rectify that but DoD should explore ways to better apprise the industry of DoD requirements so that they can better plan their facilities expansion. Some of the members said it takes up to a year just to get top management's interest and then another year to get money (or not get money). They mentioned that the Japanese can do this in about a month, so you can see that we have a response time problem here.

Many of the members felt that DoD should explore ways to accelerate the activity in some other areas such as ASTM and the SAE Specifications. There are certain problems in ASTM. There is voting, there are comments and it can take several years unless a concerted effort is made by a special interest group before a method is voted on and is published. Several of the members thought that, if DoD wanted standard test methods, they should press for them and give them support.

We had quite a bit of discussion on dual sourcing. Where dual sourcing is required for national security, the group felt that it should become a contractual requirement and it should not be done after the fact. DoD should be willing to step up and pay the money required to do that up front and not try to artificially create or build up a second source after production has begun. The group felt that DoD should refrain from creating artificial economic situations that they are unwilling to support, and that market factors should dominate to the extent, of course, that they are consistent with national security. Also, it was felt that DoD should take into account the significant efforts by the material suppliers in the area of domestic sourcing of carbon fibers, as well as the resin suppliers that we are presently using.

The group felt that they have spent considerable time and corporate funds coming to this meeting; they would greatly appreciate DoD's feedback at some point in time as to what was the overall result of the conference. We did not come to any agreement as to how that feedback might be supplied - whether it would be a letter report or another meeting-so we will leave that option open but they felt that future participation in workshops could be enhanced if there were some feedback and not just dropped after the final report was out.

The group felt that, in listening to the papers the first day and listening to all the discussion in our Working Group, the lack of universally accepted standards, procedures and certification was not a major problem in getting composites on military aircraft because we have been flying parts , (structural, highly loaded components) since 1970 - 1972 very successfully. From a strategic material standpoint, we are probably in a lot better shape than the metals industry is today as far as the economic and political stability of our off-shore supply sources are concerned.

WORKSHOP 1

FINAL REPORT WORKING GROUP 1

FIBERS AND REINFORCEMENTS

WORKSHOP 1

DoD OPTION:

DoD SHOULD PROVIDE FEEDBACK TO ATTENDEES ON STATUS OF OPTIONS RECOMMENDED BY THIS WORKSHOP AT AN APPROPRIATE FUTURE DATE.

- INDUSTRY CONCERNS WHICH SURFACED DURING THE WORKSHOP AFFECT THE WAY IN WHICH THE INDUSTRY OPERATES. MAXIMUM BENEFITS OF THE WORKSHOP DEPEND UPON TIMELY FEEDBACK.

WORKSHOP 1

DoD OPTION:

DoD SHOULD SHOW INCREASED SENSITIVITY TO BUSINESS/ECONOMIC PROBLEMS OF MATERIALS SUPPLIERS.

- COMPOSITE MATERIALS/PROCESSING/UTILIZATION ARE DEVELOPING ON AN EQUIVALENT BASIS WORLDWIDE (E.G., WESTERN EUROPE, JAPAN). UNNECESSARY EXPORT RESTRICTIONS WHERE U.S. TECHNOLOGY IS NOT UNIQUE IS STRENGTHENING FOREIGN COMPETITION AT THE EXPENSE OF DOMESTIC SUPPLIERS.
- RESTRICTED BUSINESS BASE WILL INHIBIT U.S. SUPPLIERS FROM REALIZING FULL ADVANTAGE OF ECONOMIES OF SCALE.
- RESTRICTED EXPORT OF COMPOSITE MATERIALS WILL LIMIT EXPERIENCE AND INFORMATION FLOW FROM ABROAD IN THIS RAPIDLY DEVELOPING MATERIALS AREA.

WORKSHOP 1

DoD OPTION:

DoD SHOULD EXPLORE APPROACHES FOR THE UTILIZATION OF HYBRID COMPOSITES (CARBON, KEVLAR, GLASS) TO IMPROVE COMPOSITE COMPONENT SUPPORTABILITY IN THE MILITARY MAINTENANCE ENVIRONMENT.

- DAMAGE RESISTANT/TOLERANT MATERIAL SYSTEMS AND DESIGNS ARE REQUIRED.
- TOUGH RESINS
- REPAIRABILITY DESIGNED IN?

WORKSHOP 1

DoD OPTION:

DoD SHOULD EXPLORE WAYS TO PROMOTE THE DEVELOPMENT AND INTRODUCTION OF NEW AND IMPROVED COMPOSITES SYSTEMS. MECHANISMS FOR THE INTRODUCTION OF NEW MATERIALS SYSTEMS INTO WEAPON SYSTEMS NOW IN PRODUCTION SHOULD BE DEVELOPED (WHERE IT MAKES SENSE TO DO SO)

- PROPRIETARY DEVELOPMENTS SHOULD NOT BE DISCOURAGED
- PRIMES, SUBCONTRACTORS AND MATERIALS SUPPLIERS SHOULD BE INCLUDED IN EXPLORATORY DEVELOPMENT EFFORTS TO OPTIMIZE UNDERSTANDING OF MATERIALS REQUIREMENTS.
- THIS AREA HAS HIGH PAYOFF FOR DoD PARTICULARLY WHERE NEW MATERIALS CAN SAVE COSTS IN THE OPERATIONAL/MAINTENANCE ARENA.
- THIS AREA IS A CANDIDATE FOR A FUTURE WORKSHOP/SEMINAR WHERE WEAPON SYSTEMS PROJECT OFFICE (SPO) PERSONNEL ARE INCLUDED.

WORKSHOP 1

DoD OPTION:

EXPLORE DoD LEADERSHIP ROLE/FUNDING IN ADDITION TO EXISTING ACTIVITIES TO ACCELERATE GENERATION AND ACCEPTANCE OF STANDARDS.

- CONSIDER NASA AS THE INITIAL FOCUS FOR THIS ACTIVITY. CURRENT PROGRAM WITH BOEING, DOUGLAS, AND LOCKHEED TO GENERATE A COMMON SPECIFICATION (RELATED TO ACEE) IS ALREADY UNDERWAY.

- FURTHER CONSIDERATION SHOULD BE GIVEN TO A DoD/INDUSTRY COMPOSITES ASSOCIATION. COULD BE ORGANIZED/ADMINISTERED THROUGH SAMPE/SAE (A LA ALUMINUM ASSOCIATION).

- POSSIBLE TOPIC FOR A FUTURE WORKSHOP -- "COMMON STANDARDS ORGANIZATION"

WORKSHOP 1

<u>DoD OPTION:</u>

DoD SHOULD EXPLORE WAYS TO ACCELERATE REVISION AND PUBLICATION OF MIL-HDBK-17.

- SHARING OF THE DATA BASE POSSESSED BY INDUSTRY WILL BE CRITICAL TO THE SUCCESS OF THIS EFFORT.
- DoD CANNOT GENERATE ALL THE PROPERTIES DATA NEEDED--TOO EXPENSIVE--TAKES TOO LONG.
- A STRONG/VIABLE MIL-HDBK-17 WILL BE GOOD FOR THE COMPOSITES INDUSTRY.
- SHOULD REDUCE THE AMOUNT OF INDUSTRY TESTING REQUIRED.
- WE SHOULD LEARN FROM THE METALS INDUSTRY AND MIL-HDBK-5.

WORKSHOP 1

DoD OPTION:

SELECTIVE FEEDBACK TO SUPPLIERS OF PROJECTED DoD MATERIALS USAGE OVER TIME (REQUIRED FOR PROPER INDUSTRY PLANNING).

- o EXCESS CAPACITY OF FIBER/RESIN FABRICATION FACILITIES EXISTS FOR DoD NEEDS. HOWEVER, SURGE IN REQUIREMENTS MUST BE DEFINED TO ENABLE INDUSTRY TO RESPOND. CAPACITY EXPANSIONS CAN TAKE UP TO THREE (3) YEARS (CORPORATE APPROVALS TAKE TIME TO OBTAIN).

- o OVERCAPACITY CAN RUN UP COSTS DUE TO INEFFICIENCIES OF LOW PRODUCTION LEVELS.

WORKSHOP 1

DoD OPTION:

EXPLORE WAYS TO WORK WITH EXISTING/ON-GOING STANDARDIZATION ACTIVITIES TO ACCELERATE DEVELOPMENT OF NEEDED SPECIFICATIONS AND STANDARDS. DEVELOP PERFORMANCE BASE SPECIFICATIONS WHERE FEASIBLE.

- NASA/BOEING/LOCKHEED/McDONNELL DOUGLAS SPECIFICATION ACTIVITY
- AMMRC--MIL-17
- ASTM TEST STANDARDS
- SAE/AMS SPECS/AIRs/ARPs

WORKSHOP 1

DoD OPTION:

DoD SHOULD CONSIDER MAKING DUAL/DOMESTIC SOURCING A CONTRACTUAL REQUIREMENT IN THOSE INSTANCES WHERE NATIONAL SECURITY WOULD DICTATE DUAL SOURCING.

- DoD SHOULD REFRAIN FROM CREATING ARTIFICIAL ECONOMIC SITUATIONS
- MARKET FORCES SHOULD BE ALLOWED TO DICTATE TO THE EXTENT POSSIBLE/CONSISTENT WITH NATIONAL SECURITY CONSIDERATIONS.
- DoD SHOULD TRACK THE VERY SIGNIFICANT EFFORTS BY THE FIBER/RESIN SUPPLIERS TO PLAN/DEVELOP DOMESTIC MATERIALS SOURCING.

CONCLUSIONS

- THE LACK OF UNIVERSALLY ACCEPTED STANDARDIZATION AND QUALIFICATION PROCEDURES FOR COMPOSITES HAS NOT BEEN A MAJOR PROBLEM IN THEIR APPLICATION ON MILITARY SYSTEMS.

- FROM A STRATEGIC MATERIALS STANDPOINT COMPOSITES IN GENERAL ARE NOT IN A CRITICAL/PANIC SITUATION AND ARE PERHAPS IN BETTER SHAPE OVERALL THAN ARE THE STRUCTURAL METALS.

WORKING GROUP 2

MATRIX MATERIALS

Bernard M. Halpin, Chairman

Working Group 2. Matrix Materials

Bernard M. Halpin, Chairman

We opened the day with about 14 attendees in the room with a pretty wide range of experience not only in time but in materials with which they were dealing. We opened the discussion with many issues that were present among those folks in attendance. It was very easy to talk about all kinds of problems while it was very difficult to pin down anything on which we all agreed. Most people agreed that there is a broad matrix material base in the country as far as ordinary commercial products and even low performance military products were concerned. Nobody wanted to build a business based strictly on providing materials to the strategic military market.

It was difficult to agree on what would be a common nomenclature. The pros were, of course, that perhaps if there were some kind of friendly sounding name or coding system for epoxies or any other matrix material, it would increase the acceptance not only in the design but also the purchasing end of the business. The worries were, of course, that this would tend to lock in any of the already well-known systems and, of course, it would be difficult to devise a system that would be all-inclusive as an identifying mechanism. There were some interesting anomalies during this discussion. For example the International Union of Pure and Applied Chemistry, UPAC, was mentioned as a source for nomenclature although we spent the entire morning discussing chemical names without once using the UPAC designations.

We then discussed specifications. This also produced some interesting comments. Everyone said they wanted performance of the material rather than the material specifications, the argument being that the end items were being bought to performance specifications which are locking in these materials. This produced quite a bit of discussion. If you're going to buy an airplane, it doesn't say that it will be made of MY720 but somehow, down through the chain of people who purchase things, that gets locked in and that, of course, is a restriction. This led to the very pointed issue that came up - can a market really support one source for a really special item? This again led to a very long discussion and then we had a pragmatic suggestion that if, in fact, there is a proprietary material specified, perhaps one way around this at the beginning of a contract for a piece of equipment is that an agreement be reached that, after a certain amount of time or certain number of ship-sets, the original proprietary manufacturer would license his technology to other capable competent suppliers. This would give them the option of being able to recoup some of their original investment. Given that no problems will come up in qualification, it will shorten the qualification cycle but it won't necessarily do away with it.

On test methods, everybody agrees that, in recent years, the chemical analysis of various resin constituents has made tremendous improvements. There is a lot of concern with the effect of rheology and processing history not necessarily showing up in most of these chemical tests. If the correct sensors are used, you can, with the *finger-printing technique*, determine some of the previous history of the material that you are investigating. Along the mechanical lines, the need for resin-sensitive tests to determine the mechanical behavior of composites (to determine the effect of the resin while it is in the composite) was raised, although we don't propose to open up this forum to the discussion of yet another shear test.

Everyone really liked the idea that was proposed during the first day of some sort of an "underwriters lab" which would be a facility or facilities certified to conduct screening tests so that, if somebody had a material which they thought would meet the requirements as set forth by the prime manufacturers or the Government, they could take their material there and the prime or Government would buy off on the fact that the material did meet these specifications. Once again, that lab does depend on common specifications and that has, to date, been a ve: severe problem. Perhaps this toughened resin cooperativ effort might be a first step in reaching an agreement on laboratory such as an underwriters laboratory for composi testing.

In the qualification issue, we didn't get very in clearing any of the mine fields that have come up prev in discussions surrounding one supplier's resin versus an Everybody did agree that if we had a resin which was the chemically as another resin, there would have to be some qualification although no one was very clear as to who sh or would pay for that qualification. Once again, the ne a common data base came up several times during the day. one would have to agree as to what is going to be common the common data base before you start setting one of thos

The other issues which arose during the day inc sole source versus multiple source. This came up from s the resin suppliers in attendance. Does this mean that company having two plants making the same resin, would be considered a multiple source? In some people's minds, i would be. Others say it has to be different companies. interesting point here is that, in ordinary resin manufac we have situations today where materials are different on the label that's on the can and, in fact, one manufacture the same curing agent for all resin suppliers. Is that source or a multiple source? One brave soul recommended alternate materials rather than alternate sources. Of c this does create serious qualification issues.

With regard to foreign dependency on matrix ma we didn't really feel that that was too bad. Ciba-Geig more or less gone on record to say that they will make D the U.S. This seems to be about the only major source of the accelerated 250°F curing resins rely on herbicide not manufactured in the U.S. any more, but nobody seems t about that one.

On incentives to industry, they varied, of course, that a lot more money would do it; I'm not quite sure where that money would come from - maybe sponsoring research programs which would entice additional suppliers into the marketplace. The industry-wide association was suggested as a means of promoting commonality in specifications, nomenclature, etc. The stockpile was also discussed. If you really knew how many of everything you needed, you could store them someplace - maybe set up under Title 3 as is being done, I think, in PAN base fibers. Several issues along those lines were raised.

At the conclusion of the presentation, Dr. Gail DeSalvo, Ciba-Geigy, reported that Ciba-Geigy has gone on record that it is able to produce DDS in the U.S. when required and it is prepared to certify that the domestic material will be equivalent to the imported DDS.

WORKING GROUP 2

MATRIX MATERIALS WORKING GROUP

QUESTION: IS THERE A BROAD, QUALIFIED, DOMESTIC INDUSTRIAL BASE IN MATRIX MATERIALS?

MARKET AREA	BROAD INDUSTRIAL BASE IN U.S.
STANDARD COMMERCIAL	YES
"LOW-PERFORMANCE" MILITARY	YES
HIGH PERFORMANCE COMMERCIAL/MILITARY	?
STRATEGIC MILITARY	NO

WORKING GROUP 2

NOMENCLATURE:

DIFFICULT TO AGREE ON AT THIS STAGE OF DEVELOPMENT

PRO: WOULD HAVE BENEFIT OF INCREASING FAMILIARITY

MAY INCREASE ACCEPTANCE OF COMPOSITE MATERIALS

CON: MAY LOCK IN EXISTING SYSTEMS MORE RIGIDLY

CAN NOT BE CONCLUSIVE AS AN IDENTIFIER

WORKING GROUP 2

SPECIFICATIONS:

- "PERFORMANCE VS MATERIAL SPECS?
- RESTRICTIVE VS BROADENING
- CAN MARKET SUPPORT MORE THAN ONE SOURCE FOR HIGHLY SPECIALIZED ITEMS?
- LICENSE ARRANGEMENTS TO SPREAD THE TECHNOLOGY FOR SPECIAL MATERIALS AFTER PRESET TIME/ NUMBER OF ITEMS, ETC.

WORKING GROUP 2

TEST METHODS

- TEST METHODOLOGY HAS MADE RAPID GAINS IN ABILITY TO DETERMINE THE CONSTITUENTS OF MATRIX MATERIALS
- EFFECT OF RHEOLOGY, PROCESSING HISTORY CAN NOT BE IGNORED
- STILL NEED RESIN SENSITIVE TEST FOR COMPOSITES
- NEED FOR AN "UNDERWRITERS LAB" TO CONDUCT INITIAL SCREENING TEST TO SHORTEN QUALIFICATION CYCLE

WORKING GROUP 2

QUALIFICATION

HOW MUCH QUALIFICATION IS NECESSARY FOR MATRIX MATERIALS?

NOT CLEAR WHO SHOULD OR WOULD PAY FOR THE QUALIFICATIONS.

NEED FOR COMMON DATA BASE TO EASE QUALIFICATION.

WORKING GROUP 2

OTHER ISSUES

SOLE SOURCE VS MULTIPLE SOURCES (PLANT VS COMPANY)

ALTERNATE MATERIAL RATHER THAN ALTERNATE SOURCE (RAISES ADDITIONAL QUALIFICATION ISSUES)

FOREIGN DEPENDENCE--HOW BAD IS IT IN MATRIX MATERIALS?

INCENTIVES TO INDUSTRY

INDUSTRY WIDE ASSOCIATION--COULD IT FILL THIS ROLE?

STOCK PILES

WORKING GROUP 3

INTERMEDIATE PRODUCTS (PREPREGS)

Ray M. Juergens, Chairman

Working Group 3. Intermediate Products (Prepregs)

Ray M. Juergens, Chairman

The group was asked to address prepreg materials or intermediate products and that's what we concentrated on to the exclusion of any consideration of fibers or matrices or structure qualification practice. We didn't have time to address metal matrix at all and I don't believe there was representation in the latter part of the afternoon. The group that we had was a mixed group of the prepreg industry and some agency people and most of the users were represented. It was a very active and a very vigorous group and I was assisted by Dave Forest and also by Frank Traceski of the Army. The interest of the group was directed toward these topics which were prompted by Channon's initial recommendation. We voted on what was most important and these topics showed up in the order of priority shown and we addressed them in that manner.

As you can imagine, this group is faced with a great deal of the frustration associated with qualification test methods and standards because the prepreg industry really is where it all comes together. The poor prepregger has to smile at everybody, make everybody happy, do all the tests that we lay on him industry-wide and still stay in business, and God help him if he makes a mistake. So they are very sensitive to market conditions and they are very sensitive to doing what their customers want. There is not a whole lot of compassion directed toward the prepreggers and they probably don't need it because they are a very creative group.

Our methodology was to address the topics listed,* to identify problems that the community thought arose from that topic then, after some discussion, we would suggest solutions to those problems, discuss it some more and come up with a recommendation.

On qualification** the problems were the lack of consensus on the test procedures, the multiplicity of test

*p. 493.
**p. 495.

organization groups move and that's part of the voluntary consensus process. However, it seems as though that should be accelerated in some manner and, if not in an organization like ASTM, perhaps in some other way. If there is a funding constraint, the funding constraint should be addressed. Again, the Department of Defense seems to be the area that we felt was responsible.

The third solution is to establish a certified test laboratory and centralized data base. A centralized test laboratory would provide an independent centralized test facility that is blessed and everybody would agree to it. The group felt that the concept was good; however there should be some additional study on how you are going to make that work, where is it going to be, how many there are going to be, who's going to pay for it, how you are going to price it, all those real world constraints that are contained in a blessed laboratory of some kind. However, the study should be conducted and it was felt that, since some of the suggestions originated via FAA associated discussion, we put FAA down as an action agency. The centralized Data Base was a minor variant on this topic in that implicit in a centralized laboratory, would be the storage and acquisition of the data that resulted from that testing that would be available again to minimize redundancy of repeated testing qualification. We thought that also should be part of the study.

The last suggestion relates to standardized materials which means that you would not have to requalify every material. This is analagous to the practice that is used in metals and the recommendation would be to develop standard material specifications. The lead organization for the specifications publication, at least the effort directed toward writing the specification, might be the AMS committee of the SAE.

Similar to the previous speakers, some of the recommendations revolved around Mil-Handbook 17 and the following items are addressed to Mil-Handbook 17. The solution to some of the qualification problems would be to get Mil-Handbook 17 up to Mil-Handbook 5 status. This is not a short range goal, obviously, but when that occurs, much of the qualification work that we are doing will not be done any more. The recommendation on all of these is to accelerate the Mil-Handbook 17 activity in concert with the other recommendations, perhaps shared by DoD and FAA. A suggestion also would be to publish interim data in Mil-Handbook 17 as opposed to the relatively long cycle time for revision of that document. A suggestion was also made to use a generic approach; maybe the materials in Mil-Handbook 17 could be covered generically and not as specifically as we have covered some in the past. That would mean that you would cover a class of carbon epoxy or reinforced material in a manner that has been done in the past with fiber-glass. The last item is Data Sharing. It would be desirable to share data once it is generated, particularly those data which are proprietary. The recommendation here is to require data reporting as a contractual item.

Test Methods and Testing were the second main topic of discussion.* The problems are non-standardized testing practice. That means not only non-standardized test methods but non-standardized use of test methods. Some individuals in the community, for reasons other than technical reasons, will use test methods which are not appropriate and partially or largely inadequate. The practice is not consistent and perhaps driven by provincial interests. Many test methods are recognized as being inadequate and should be improved; they don't do what they are supposed to do. We need better test methods. In the prepreg area, predominately the prepreg industry and the user, it was felt that there was lack of a good engineering and scientific data base or understanding relevant to prepreg products. There is a lot of testing done on fibers,

*p. 498.

procedures, the non-transferability of the data that is generated by qualification programs and the processing method variations that were required to be incorporated in the qualification process. In the last item, an evaluation of the variability in the processing might be another additional requirement in characterization or qualification of a material and perhaps it ought to be separated or handled in a different manner. All of these problems really stem from an awareness or recognition by this community of excessive cost in time being devoted to redundant multiple retests that look like they were identical to the ones that were done last week or the year before or for a different company. There was a tremendous amount of waste that took place in this multiple qualification activity and somebody ought to do something about it. The solutions that were suggested were to develop some sort of consensus of a test matrix for qualification and test processing. The recommendation there would be to identify some sort of focal point (some organization or somebody) who could make some sense out of the conflicting and multiple requirements for qualification. As part of our strategy, what we decided to do when we made a recommendation was to try to identify an action organization or person or group that we felt was in a lead position to do something about that recommendation. In this case, it was the Department of Defense.

We heard also in the previous discussions, the desirability of developing standard test methods. The prepregger who is trying to qualify or conduct any kind of testing relevant to a multiplicity of customers is faced with non-standard tests or very slight differences that occur in the test methods that he has to perform and obviously the test method standardization would greatly improve that. It could result in less frustration and an improvement in cost or price. To do that, the group felt that the acceleration of funding, e.g. the consideration of funding the ASTM activity, would be desirable. We all know how slowly voluntary consensus standard polymers, resins and a great deal of testing on cured laminates which has not been well explored or addressed. That lack was identified. There was considered to be a lack of adequate analytical laboratory instrumentation relating to the testing of the prepreg (uncured product), other than the fiber or the polymers or cured laminate.

Processability test development addresses the multiplicity of the processing that the prepreg product is forced to fit into in terms of the user communities. There should be some way of handling that variability in processability and processing requirements. The production variables of the prepregging manufacturer are also part of this concern.

Solutions for these topics were to use one set of standard test methods. Everybody should use the same set of standards. The recommendation would be to establish and require the use of ASTM test methods, particularly those recommended by the D30 committee. This would have to be done by some sort of non-voluntary method, perhaps by action arising from the Department of Defense and the FAA. Another improvement relating to test methods would probably be to come up with a standard method of data reduction. Our data reduction practices vary from company to company and are imposed upon the prepreg industry. Our normalization practice should be standardized and there is a recommendation that the ASTMD30 look into a standard normalization practice and method. There was concern by some members that many of the tests that are done on prepreg are not really relevant to the development of an engineering data base and the question was raised - are the tests that we run on prepreg relevant to prepreg? It was suggested that ASTM review this topic and take it under consideration. The solutions to testing problems are additional research and development and instrument development relevant to prepreg and the understanding of the processability and data generation. This is a neglected area and the responsibility would again fall to the Department of Defense and on industr itself to do the internal work necessary to support its products.

The prepregger sits in the middle between the fibe supplier, the resin supplier and the user and there is a general unawareness in the industry of his needs. One of t recommendations was to form an industry association which wo address the industry-wide awareness problem.

The next topic we addressed was Specifications* problems are very simple. There are too many, they cover almost identical or similar materials, they are too complex they are too demanding for some applications. That latter comment applies to the intermediate or medium or low technol applications - non-structural, secondary structure or others The solution would be to achieve the same status as metals. If we can get to that point, our specifications will be simp we would use either industry or government or association specifications which is the state-of-the-art today. We nee to establish industry-wide specifications in some manner. T ASTM and the specification writing groups, supported by industry, are the organizations that will have to accomplish that and again we are addressing really a voluntary standard tion effort here. The solution to the complexity of the specifications would seem to be in stratification of specifi cations, i.e. specifications that would be directed more tow a spectrum of requirements in terms of complexity and struct requirements from non-critical secondary structure, primary structure, to super critical. A recommendation would be th a performance specification could be used in some of those c areas, the non-critical areas. The action here seems to fa within the jurisdiction of the groups listed, SAE, ASTM ar industry.

We had two more topics to address. One was Indus Preparedness** and, in this overall topic, we tried to addres

*p. 501.
**p. 503.

the industrial capacity, emergency conditions and also foreign dependency. Again, I'd like to remind you we are talking about the prepreg industry; we did not address fibers, matrices, resins and other aspects. I guess it was a fairly clear consensus from the prepreg industry representatives that there was not a problem with industry preparedness. They felt that there was plenty of capacity and hoped for a larger market. They indicated that they have the ability to scale up and react very quickly. On Foreign Dependency, it was not felt that that was an issue at all as far as prepregs were concerned.

We also addressed standard form and nomenclature.* The problem is that there are too many almost identical forms, areal weights differ very slightly in the carbon fiber content or reinforcement content and the resin content. One specification may be one percent different than another and this has cost and price impact on the producers. Of course, there is tremendous variation in woven material such as cloth. The obvious solution is to standardize the products and the recommendation is to include specification ranges and tolerances and composition uniformity in the existing specifications and other specifications that are new or being written. The action here falls upon ASTM and SAE and on the industry and the specification writing groups. Another way that this could be done is to form an Industry Association and the action there is relegated to industry.

Comments & Questions

Tom Brayden, Vought Corp.

On one of your slides, you showed a need for more analytical instrumentation for characterization of the prepreg. For my information, I would like to know what kinds of instrumentation you are thinking of. There is a wide gamut of analytical instrumentation available today, from nuclear magnetic resonance to dynamic spectrometers for rheology to

*p. 504.

thermal/mechanical analyzers, dynamic scanning calorimetry - the list goes on and on. Why isn't this array adequate?

Juergens: Your comment was also expressed at the meeting and there was not unanimous feeling on that topic. One of the items which was mentioned, for instance, was the rheometrics spectrometer which cannot work on a fiber-filled prepreg. It is adequate for neat resin but you can't run it on prepreg. The other comment was that there were a lot of questions about tack and the instrumentation relevant to tack. Some of the tack methods and tack instruments were considered to be inadequate. While they did measure tack, they should be improved. I think it addresses those kind of comments that address some characteristic of prepreg.

Brayden: So you are looking for methods to quantify tack and the interaction of the resin with the reinforcement?

Juergens: No, I don't think so, I think it is directed toward the need for instrumentation development.

Reinhart: We also discussed the possibility of standardizing materials in product forms. If you do that, then you would tend to stifle the creativity and innovative ability of the industry which we should explore ways of increasing as opposed to stifling.

Juergens: That specific question came up and I guess the most pointed answer to that was "We're not worried about that. It's not going to slow up the progress from such a dynamic group as we have assembled here. No one's worried about that."

John McCarty - (Boeing): I would like to ask a question about what you called stratification requirements for different levels of utilization. Does that really enhance standardization and reduction of the amount of products on the market or does it make it worse? As each individual use is identified, you have a different product and another qualification. In addition, the user has an extended inventory because he has different materials, so is that really a viable improvement to this leveling or would one product that was used across all lines be better?

Juergens: If there's anyone on the committee who would like to talk to that subject, I'd be glad to defer to them. If not, I'll try to reflect what I recall of that discussion. The suggestion that we have made would try to address not so much the multiplicity of specifications but the co·plexity. It was felt that we try to get too much performance improvement where there is perhaps not a substantial requirement for that improvement. I think it was to address that aspect of it. Whether that would simplify or complicate things, I don't really think I know. Obviously, it would complicate it in terms of having another tier of specifications; however, it might simplify it in that you could treat those specifications differently or those materials differently. Maybe you could use a performance specification for that class of material or simplify your testing or use a generic approach or other things of that manner. I'm not so sure I know whether that would improve or worsen things but I can see the rationale for the suggestion.

DiGiovanni - (Raytheon): With regard to the problems we have with the prepreggers and the qualifications, in the missile industry which is lagging the aircraft industry in use of advanced materials, there are many areas which we, in our own Company, are looking at advanced materials to replace some of the more standard, heavier materials, steel and titanium. It is really difficult, in most cases, to reduce aluminum because of cost. We are finding that, with this problem of qualifications, prepreg is simply not meeting our needs. When we have major research and development programs with company supported and advanced materials and we have to wait 6 and 9 months for 20 - 50 pounds of a relatively standard prepreg, (and we have, over the past three years, had to wait very long times for delivery of that material), it undermines our whole goal. I think you folks should begin to realize that there's another marketplace out there that is extremely high volume that does not need the kind of specifications needed by man-rated aircraft. Those needs are not being met and, on many of ourrather extensive applications, we currently are using titanium and steel where we believe some of the newer material could be used. I don't think we're getting the kind of help we should be getting from the prepreggers and the resin fabricators and fiber manufacturers. If we continue on this way, I can tell you what the response of upper management is going to be. They simply are not going to be impressed with the advanced materials in spite of their use on man-rated aircraft because we can't utilize it fast enough and we will continue using traditional materials. Once the decision is made to use a traditional material on a system, it is very difficult to replace it after it goes into production.

Juergens: I would like to pose a question to you. How do you buy your titanium?

DiGiovanni: To a standard Mil. Spec.

Juergens: And where do you get it?

DiGiovanni: I just go to my buyers.

Juergens: Right! And he gets it, perhaps, from a warehouse.

DiGiovanni: Yes.

Juergens: Right!

DiGiovanni: Lots of times, we may have a sufficient stockpile from other programs to use in our R & D programs.

Juergens: Sure! And he probably gets a standard product out of the warehouse, and that's where we want to be some day too.

DiGiovanni: One of the difficulties is that we cannot use the buyer now. I have to do the buying because the buyer can't communicate the requirements well enough, so the engineer becomes the buyer.

Juergens: I don't think you could find a better example for why this meeting is being held. I think you've put it all together.

Forest: (Fiberite): Peter, are your requirements that much different than all of the prepregs that are available in the aerospace industry?

DiGiovanni: No. In fact, they are overspecified and that is a part of the problem, not a solution. Many times, we have to wait a long period of time. If the specs were relaxed, i.e. if there were different specs for non-man-rated material, we could get the material more quickly. Typically, what we hear is that we have a big run going for Boeing and, when we get that finished, we'll give you a lot of it. By that time, we can cancel our research program.

Juergens: Those materials are not really man-rated or non-man rated. Take the case of the titanium. That titanium which you bought to a Mil spec or an AMS spec can go into a submarine, an airframe, an engine turbine blade, armor, a desalination plant, or anywhere. What that spec really does is to characterize that material, and that is what material specs should really do.

Forest - (Fiberite): What specs do you buy to, Peter? If you are doing engineering work, or R & D work, where are you getting your specs?

DiGiovanni: We do not develop specifications because we are not sure what the specifications should say, so we use the specifications developed by one of the larger prepreg houses. I don't believe that is necessary for our kind of work.

Forest: Why do you do it? Why don't you buy to a prepreggers product?

DiGiovanni: We would be happy to. We prefer a generic product.

Forest: Any prepregger would be happy to sell you a generic product. I'm from Fiberite and if you'd like to buy one of our 500 generic products, let me know.

WORKING GROUP 3

PREPREG
(INTERMEDIATE PRODUCTS)

TOPICS ADDRESSED

QUALIFICATION

TEST METHODS/TESTING

SPECIFICATIONS

INDUSTRIAL PREPAREDNESS

STANDARD FORMS AND NOMENCLATURE

METHODOLOGY

IDENTIFY PROBLEMS

SUGGEST SOLUTIONS

RECOMMENDATIONS VIA CONSENSUS

REPORT

PREPREG

QUALIFICATION

PROBLEMS

- LACK OF CONSENSUS ON
  - TESTS
  - PROCEDURES
- NON TRANSFERABILITY OF QUALIFICATION DATA
- PROCESSING METHOD VARIATIONS

} EXCESSIVE COST AND TIME

} WASTE

PREPREG

SOLUTIONS	QUALIFICATION RECOMMENDATION	ACTION
DEVELOP CONSENSUS TEST MATRIX AND TEST PROCESSING	IDENTIFY CONSENSUS FOCAL POINT	DOD OUSDRE
DEVELOP STANDARD TEST METHODS	ACCELERATE AND FUND ASTM ACTIVITY	DOD OUSDRE
ESTABLISH CERTIFIED TEST LABORATORY AND CENTRALIZED DATA BASE	STUDY AND DEVELOP CONCEPT	FAA
STANDARDIZE MATERIALS	DEVELOP STANDARD MATERIALS SPECIFICATIONS	SAE/AMS

PREPREG

QUALIFICATION (CONT)

SOLUTIONS	RECOMMENDATIONS	ACTIONS
MIL-HNBK 17	ACCELERATE MIL-HDBK 17 ACTIVITY	DOD/FAA
GET TO MIL-HNBK 5 STATUS		
PUBLISH INTERIM DATA		
GENERIC APPROACH		
DATA SHARING	REQUIRE DATA REPORTING ON CONTRACTS	DOD/NASA

PREPREG

TEST METHODS/TESTING

PROBLEMS

- NONSTANDARDIZED PRACTICE
- INADEQUATE TEST METHODS
- LACK OF ENGINEERING/SCIENTIFIC BASE
- INADEQUATE ANALYTICAL LABORATORY INSTRUMENTATION
- PROCESSIBILITY TEST DEVELOPMENT
  - USER
  - PRODUCTION VARIABLES

PREPREG

TEST METHODS/TESTING

SOLUTIONS	RECOMMENDATIONS	ACTION
USE <u>ONE</u> SET OF STANDARD TEST METHODS	ESTABLISH AND REQUIRE USE OF ASTM METHODS (D30)	DOD OUSRE FAA
STANDARD DATA REDUCTION PRACTICE (NORMALIZATION)	RECOMMEND ASTM D30 TEST STANDARD	ASTM D30
CONSENSUS ON PREPREG TEST RELEVANCE	REVIEW BY ASTM	ASTM

PREPREG

SPECIFICATIONS

PROBLEMS

- TOO MANY SPECIFICATIONS FOR SIMILAR MATERIALS
- TOO COMPLEX/DEMANDING FOR SOME APPLICATIONS

PREPREG

SPECIFICATIONS

SOLUTIONS	RECOMMENDATIONS	ACTIONS
ACHIEVE "METALS" STATUS	ESTABLISH INDUSTRY-WIDE SPECIFICATIONS	SAE/AMS ASTM INDUSTRY
STRATIFICATION OF SPECIFICATIONS	ESTABLISH PERFORMANCE SPECIFICATIONS	SAE/AMS ASTM INDUSTRY

PREPREG

INDUSTRY PREPARDNESS

PROBLEM

NONE FOR PREPREG MANUFACTURE

FOREIGN DEPENDENCY

NOT AN ISSUE

PREPREG

STANDARD FORMS AND NOMENCLATURE

PROBLEM:

TOO MANY ALMOST IDENTICAL FORMS

- AREAL WEIGHTS
- RESIN CONTENT
- CLOTH STYLE

PREPREG

STANDARD FORMS AND NOMENCLATURE

SOLUTION	RECOMMENDATION	ACTION
STANDARD PRODUCTS	INCORPORATE STANDARD RANGES ETC. IN SAE/AMS ASTM & OTHER SPECIFICATIONS	INDUSTRY SAE/AMS ASTM
	FORM INDUSTRY ASSOCIATION	INDUSTRY

WORKING GROUP 4

COMPONENTS AND STRUCTURES

D. Mulville, Chairman

Working Group 4. Components & Structures

D. Mulville, Chairman

There were about 25 people who sat in on the discussions and they covered a broad range of interests. In fact, we got into the matrix systems, the fiber systems and the prepregs and everything, so I will try to distill out the essence of what we discussed and present this in the form of perhaps five or six specific problems or issues. First of all, let me say what we did do and did not do. We focused on the organic matrix systems almost exclusively and, in fact, focused primarily on aircraft applications with a limited discussion of missile systems. There was not a conscious decision to exclude metal matrix or carbon-carbon but the interests of the group of participants were such that the strongest motivation was to pursue the aircraft issues. The problems and issues that surfaced in the discussions are generic enough to apply to just about any kind of composite system, so you can read metal matrix or carbon-carbon when we discuss organic matrix. I would hope that, if people had a strong specific interest in these materials, we can bring them out during the discussion and see what specific component or structures problems are surfaced. There are not that many metal matrix components or structures at the present time and it may be that these are some of the potential stumbling blocks to get to that stage.

What we tried to do, as Stan Channon asked, was to identify problems, propose solutions and then discuss what potential government-industry actions might be. We've got the problems; I'm not sure we have the solutions. What came out of the government/industry discussion was a mixed bag in terms of who has the responsibility for carrying on some of these activities and who is going to pay for it. The initial cost was one that was discussed but very few real recommendations or conclusions were reached. These are not majority opinions;

there are some minority opinions here also.

There was a lack of clear definition of the data base needed to commit to full-scale development. I know the materials people out there are saying "I knew it all along; the structures people have no idea what they want. That's the problem. They have been making us go out and do all these tests and they really don't know exactly what they need; if we could get these people on track, we'd be in much better shape". The issue is that the structures people have a very clear understanding and definition of a structure. The concern is the availability of the total data base to support a commitment to a material when you get into a production program. There are a lot of factors involved in this. When you start a new design, there are very limited resources within DoD to explore a data base. When you are in the early stages of a program, you've got to rely on the data provided by the supplier, the data provided by the airframe industry, and whatever limited data is available from the government laboratories to be able to make a commitment. When you get into full-scale production, that is a different situation because there is more money to do a lot of testing of different items and components. The structures people do not like surprises. That's part of the problem because we don't know exactly how much data or exactly what kind of data we need for new materials as they come along.

There are differences between military production aircraft and commercial aircraft. On the commercial side, the commercial customers do not get as involved in the details in the materials design or the material selection process whereas, on the military side, we never know when to quit. We are getting as much data as we can and are tracking along very closely with the designers and with the industry suppliers. We try to project ahead in terms of what we see our mission to be, what the potential usage will be and where the problems are going to arise. This results in our request for a considerable amount of additional data. So, consequently, the materials data base is one of the areas that is of great concern to us, particularly when new materials (new fiber systems, new matrix systems, new prepreg operations) and new production techniques are introduced. This is an area in which the consumers could work a little more closely with the material suppliers and prepreggers to try to have better communication and integration of the process so that we could try to identify these items before we make the commitment.

The second issue is the Design Data Base and, by that, I mean the broad range of issues associated with the design of a new material. When we get to a point where we've got to make a commitment to a structure, we would like to have some tests conducted on large scale components. It's not enough to have coupon tests in the laboratory or a few small panels that have been made. If we're going to make a production wing or fuselage of an aircraft, we would like to have a wing box and a fuselage tested or something of that type; so, there is a big economic investment to carry that along. In many cases, the government does not have the resources at that stage to go through that process and so the data base itself is lacking. I'm not sure how you solve that problem. It is one that continues to surface every time you want to use these materials, whether on aircraft, missiles, ships, planes, tanks, or anything else. I think it is a problem that is not just industry's responsibility. It is the responsibility of DoD to identify what they see as the needs based on the applications. We have a couple of applications in which we would like to put new materials on aircraft. We've had discussions with the suppliers, with the industry and we have some data but there is still a concern because we haven't actually gone through the process of making the parts, testing them and assuring ourselves that we've got all of the bugs out of the system. This is viewed as a key concern.

We discussed the whole process of structural certification as opposed to certification of a material.

Both the Air Force and the Navy (and, I believe, the Army as well) pursue a building block approach which involves building a lot of sub-components to test certain aspects of the full-scale structure before you actually build the full-scale structure. It is cheaper to follow this course and you can apply selected loads (and environmental effects) to these small components that you may not be able to apply to the extent that you would like in the full scale structure. It is physically and economically impractical to take a large aircraft and put it in an environmental chamber and do a true lifetime fatigue test under hot wet conditions, even on the small military components. Consequently, there is great emphasis on doing sub-scale testing under hot wet conditions on a number of the components to look at the statistical variability. Those are the kinds of data that we feel are part of this needed data base that gets us to the point where we are ready to make the commitment to full-scale production.

Increased loads testing is another important step in the building block approach. There are a number of reasons for looking at enhanced load testing but that would be done on sub-components as opposed to the full-scale article. As you apply increased loads, you can account for scatter, you can account for environmental variability and you may account for processing variability. A final issue concerns scale-up. Concerns were expressed that a lot of coupon testing may not tell you anything about the way the material performs in the structure. Small coupons may give you design allowables from the point of view of tensile strength and compression strength. There are scale-up concerns with respect to defect significance and the effects of processing on the properties of large panels. Different properties may be found in the center compared to the edges of large panels which would not be detected in coupon testing. At the present time, we handle this analytically. We test some small components, we analytically model what is going to happen on the large structure and then test one or two large structures to verify the analysis. This is the most economical way of handling the scale-up effects. However, there must eventually be tests of larger components that satisfy the structures people that the structure can be built and perform satisfactorily.

Analytical procedures are basically used in the certification process. DoD does not do certification. Certification is really done by the airframe industry. DoD may prescribe certain requirements that it would like to have satisfied in terms of the specification and the analysis would be conducted by the airframe industry to project what the lifetime would be under a certain load spectrum. A few tests are conducted to validate these predictions on certification. It is somewhat different in the military than it is in the civilian airframe industry in terms of the load levels used but the process is the same. A final point on the certification is the question of whether fatigue testing is necessary or whether static testing is adequate. The consensus of the group was that, if you had a truly all-composite structure, it may be possible to avoid fatigue testing. You might be able to conduct a static test only. You might want to be concer ed about environmental considerations but a static test would probably be sufficient. For hybrid systems which include both metallic and composite components, it will probably be necessary to conduct a fatigue test just to interrogate the metal components and a static test to investigate the composite components. That is a sort of rough 'rule of thumb' that seemed to come out of the discussions.

There is a concern as to whether or not we have adequate analysis procedures for composite materials to enable us to use them in selected applications; there was a discussion of the items that are listed on the vugraph*. Postbuckling was one of the issues. In the past, NASA has done an outstanding job of putting together a design capability based on experimental verification of analytical models related to the postbuckling design, as an example. There was

*p. 526.

an expression of interest to pursue an activity of that type that would support the development of a design data base to look at some of these concepts. Impact damage is of great concern. The susceptibility of the composites to impact damage is dependent on the fact that it may not just be a property of the material but a property of the structure itself in terms of the response under impact loading. There are concerns about measuring the defects, and the acceptance criteria based on damage in the structure or defects included in the structure. Bolted and bonded joints are of major concern and although we have not talked about adhesive systems, they are also one of the key concerns. Adhesives that are compatible with the epoxy systems are of major concern. Adhesive systems that might be adequate for high temperature applications are also of major concern. For metal matrix composites or other kinds of composite systems, it is necessary to have compatible adhesives because, when the materials are combined, they must have overall structural performance which includes not just the composites but everything in the package. Transverse failure modes seem to be a unique issue in the composites area. It becomes very expensive to do 3D analyses on these composite systems but, unfortunately, that happens to be one of the critical areas because the transverse properties (potential for delamination) are a major concern. There are problems in being able to analytically model the transverse failure modes in a cost-effective manner. There is a significant amount of work going on at the present time, pursuing these various activities both within the DoD support, within NASA support, within the airframe industry as a whole (under IRAD). We feel that some progress is being made but we would like to be able to collect these data and present them to the industry in a form where they could be incorporated into production design.

Another issue that came out of the discussion was concerns about processing. There have been episodes in which materials have satisfied a "material spec" when they come into the company and yet, when parts are fabricated, they turn out to be different even though they are made from the same batch. There was interest expressed about having a processing specification as part of a material specification so that, when the material was received, a part would be built to demonstrate that it was the same or that it was adequate. There was concern that the analytical tools to measure the incoming materials may not be sufficient to assess the differences in the material in terms of its characteristics as a processed part. That is a real concern from the structures point of view because we would like to have these parts come off the assembly line as identical as possible. We would like to avoid the situation where every part was like a new product that we'd have to assess from a non-destructive point of view and see whether there were any differences. It would be ideal to have good control of materials and processing to the point where you had reliable products every time they were fabricated. There are a lot of different ways of making things. We use hand lay-up for many of the components we are fabricating and filament winding for the motor cases. There are many alternate kinds of fabrication procedures and a lot of new ones coming along all the time, e.g. pultrusion, and injection molded approaches. The factory of the future concept is trying to automate the process. We do not preclude use of those approaches in the vehicles because we don't really specify the way the components should be made. We may specify systems that are difficult to make using these other approaches, and one solution to that problem is for us to consider materials made in a different way. We've got to have a data base on those materials made in that way that is commensurate with the data base that we have on the materials made in the conventional way so that a selection can be made based upon the way that these materials will perform in the structure for a specific application. The challenge then is to build up the data base on these various kinds of processing schemes to present them in an equivalent

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manner to the current approaches so that a selection can be made on the basis of the merits.

There is an interest in having a standard set of qualification tests and methods for putting together a standardized data base. This is echoing what the matrix people, the fiber people and the prepreg people said because they'd like to have a standard set of tests as well. In some cases, these are not documented as well as they should be and it may be that there should be some effort put forth to have a documented set of tests collected as part of the data base so that you have a broad view of exactly what was conducted in the testing and to point the way to additional tests that would be required to bring a material along to the point where it could be committed to an application. Transferability of the data base is a major issue. We would like to be able to have a data base that is widely available to the industry so that there is a positive return from participation in an activity of this type, regardless of who pays the bill. Proprietary data is an area of concern and we certainly realize that this is a major concern for the producers and for the airframe industry. They have a big investment that they've put into developing these materials properties. We, of course, would like to get access to as much of that as we can when we are in the process of trying to make a commitment to use those materials. It turns out to be a negotiating session in terms of how much material data we can get and how much we really need in order to make a decision. There is probably a role for the proprietary data and some provision for protecting these data would have to be envisioned in a data base which was fully accessible to the industry.

The NASA program currently is in the process of trying to develop standard specifications and test methods and we would certainly endorse their continuation of that activity. We don't have as big an investment in that area but the payoff would be of benefit not only to NASA and the commercial side, but to DoD as well.

There was a discussion on the responsibilities for follow-up on some of the aforementioned suggestions. We came to no conclusion about what would be the best mode of operation for a process of this type and there may be no one best way of doing it; however it is a subject worthy of discussion and one that would have a high payoff from the application point of view.

In conclusion we have a number of components in service that have gone through the certification process and these are being fabricated on a continuous basis. We have not had any major structural problems to date so we feel comfortable in terms of the approach we have taken in the past. It may not have been the most efficient, it may not have been the biggest payoff in terms of design parameters that could have been used but it certainly has worked and it is basically the process that we are pursuing at the present time. There is going to be a much greater emphasis on composites in the future from the users' point of view and so, consequently, we have a strong interest in new materials and new processes and a data base to support these new applications. We don't build many airplanes that are different and once we make a decision to build one, there is a particular material (or maybe an alternate, but not always) that is selected. That product is going to be built for ten or fifteen years or longer. In many cases, every time we build a new airplane, a new material has to be considered and we have to basically go through the same process again. We try to learn and improve the specifications as we go along. There is going to be a much bigger emphasis on composites in the future. The common data base would be of benefit. There are a lot of opportunities in automation for future aircraft and I think that is an area in which the suppliers would work with the automated fabricators to come up with the data based on these new automation procedures. Finally, we feel that the government could lead in the implementation of some standard data-base development. By that, I don't mean that the government would do it or that the government would provide the money to support it, but we feel that the government has a strong, vested interest in the data base and could participate in it at some level.

Comments & Questions

T. J. Reinhart - (AFWAL): We filament wind a lot of motor cases and we make a lot of parts in production and I haven't heard processing expressed as a real concern. I wonder if the people from GD and McDonnell Douglas have a real concern today?

Dan Mulville - (Naval Air Systems): We had an opinion expressed by the Northrop representative that there was a concern about the processing. The concern was that the material would meet the specification on incoming but it would have to be processed differently in order to arrive at the same quality product coming off the assembly line. I won't present this as a general all-over concern. I was presenting views as expressed and the question can be raised as to whether that is, in fact, a universal problem or perhaps an isolated incident.

Ken Hutton - (Shell Chemical): My concern along those lines would be one of being able to develop new technology which can provide cost savings or some other method of improving the processing. From the standpoint of participating in the business, there are two options that a resin supplier has. One option is to try to develop a material that is comparable to the existing material that is in the industry and try to get specified on existing parts. This is essentially impossible. So the only way to do it is to develop a material and try to get specified on brand new parts and bring those into the industry. This gets back to the point made earlier with regard to the F15 tail section. That is a concern for us being able to participate in the industry as a resin supplier.

Mulville: There was a broad discussion on this and the issue was not just in this one isolated incident that we were talking about for any particular part but there was concern overall about being able to have good quality components in a process. Specifically, the compression properties were cited as being variable, but its more than that.

Harvey Mallory (DuPont): I would suggest that Ted Reinhart contact one of his associates at the Rocket Propulsion Lab., John Clark, who was discussing the issue of variability and processing in product consistency in filament winding. I know that that Lab is coming down very hard with some of their contractors who are winding bottles to achieve greater standardization in processing to insure that better product consistency results. That is an issue as far as they are concerned.

Mulville: There is a big economic factor in this production consistency because, when you start rejecting parts at the end of the line, that costs a lot of money. It's a little different to have a few coupons that did'nt make it but it's something else to have wing skins that did'nt make it. So we have a great concern about insuring that everything that goes through comes out the same at the end.

Reinhart: You know it is the laboratory man's job security to say that we have high product variability and we want to do better and we're going to show you how. However, I can't remember the last time we threw away a Minute-Man or Peacekeeper rocket motor because it didn't meet specifications, and I don't know whether Ray Juergens could tell us the last time they threw away an F18 wing skin or an F15 horizontal skin just because it didn't meet specifications.

Mulville: Without getting into details about that, we did have a lot of them in storage for a while because there was concern about defects in the skins themselves.

Reinhart: MRB actions notwithstanding, any part you make is never going to be perfect and you are going to have to rework it. I understand that.

Juergens: I don't think we're concerned about the inability to process material to make quality parts. I don't share those concerns. Any manufacturing operation is always faced with variability and flaws and defects which we're able to handle. I think also the structural integrity specifications have built into them a combination of this variability. There is always some sort of a temporal problem that you're chasing but I don't see it as being any fundamental or major problem. It is analogous to metals technology in which you have problems with forgings, castings, plate, sheet; the same is true with radars or with electronics.

Fran Hurwitz (NASA, Cleveland): May I suggest that there is a lot of room for work to be done between people who can do analysis of heat transfer and resin chemists because a large part of processing variability is brought about when you take a resin and make some complex shape or vary the thickness. The rate of curing of that resin changes through the dimensions of the material and since, in a thermoset product, the mechanical and physical properties of the material are very dependent on their thermal pre-history, you have a different material in the center of your part than you do at the surface. Most of the resin chemists don't have the analytical experience to work with heat transfer equations and I think there is a need for collaboration effort in that area.

Tom Brayden (Vought): I want to express an opinion about the processability and the uniformity of the starting materials and the mechanical properties of the finished product. We have done some work with phenolformaldehyde resins, taking 3 rolls from the same impregnation run and found quite different distributions of the constituent phenols in those resins extracted from those 3 different rolls. The consequent mechanical properties of panels made from those 3 rolls were different.

Mulville: That's another vote that the processing is a potential problem area.

COMPONENTS AND STRUCTURES WORKING GROUP

DAN MULVILLE - NAVAIR
JERRY WILLIAMS - NASA

COMPOSITE MATERIALS AND STRUCTURES

STANDARDIZATION, QUALIFICATION AND CERTIFICATION WORKSHOP

Composites & Structures
Working Group

INTRODUCTION

- FOCUS ON ORGANIC MATRIX COMPOSITE COMPONENTS AND STRUCTURES
- ITEMS NOT COVERED -- CARBON/CARBON, METAL MATRIX STRUCTURES
- IDENTIFY PROBLEM AREAS AND POSSIBLE SOLUTION
- SUGGESTION FOR GOVERNMENT/INDUSTRY ACTION

COMPOSITES AND STRUCTURES
WORKING GROUP

I. LACK OF A CLEAR DEFINITION OF THE DATA BASE NEEDED TO COMMIT TO FULL-SCALE DEVELOPMENT

- MILITARY VS COMMERCIAL AIRCRAFT
- MATERIALS DATA BASE -- INTRODUCTION OF NEW MATERIALS AND ALTERNATE SOURCES
- DESIGN DATA BASE -- NEW DESIGN CONCEPTS, DAMAGE TOLERANCE, KEY DESIGN PARAMETERS

II REQUIREMENTS FOR CERTIFICATION PROCESS FOR FULL-SCALE STRUCTURE

- BUILDING BLOCK APPROACH
  - -- ENVIRONMENTAL EFFECTS
  - -- STATISTICAL VARIABILITY
  - -- INCREASED LOADING TESTS
  - -- SCALE-UP OF COMPOSITE STRUCTURES
- ANALYTICAL CERTIFICATION PROCESS FOR FULL-SCALE
- VALIDATION BY FULL-SCALE TEST

COMPOSITES AND STRUCTURES
WORKING GROUP

III. NEED FOR ANALYSIS METHODS AND TEST VALIDATION

- POST-BUCKLING
- IMPACT DAMAGE/DAMAGE TOLERANCE
- BOLTED/BONDED JOINTS
- TRANSVERSE FAILURE MODES
- ACCEPT/REJECT CRITERIA

IV. CONCERNS RELATED TO VARIABILITY IN PROCESSING AND PRODUCT CONSISTENCY

- PROCESSING STANDARDS AND SPECIFICATIONS

- NEW/ALTERNATE FABRICATION METHODS

  -- FILAMENT WINDING

  -- AUTOMATED MANUFACTURING

COMPOSITES AND STRUCTURES
WORKING GROUP

V. NEED FOR STANDARDIZED QUALIFICATION TESTS METHODS AND A STANDARDIZED DATA BASE

- TRANSFERABILITY OF DATA
- PROPRIETARY DATA
- NASA/ACEE PROGRAM ON STANDARDIZED TESTS AND REQUIREMENTS
- MIL-HANDBOOK-17, PLASTECH, AIA, ASTM, ETC.

COMPOSITES AND STRUCTURES
WORKING GROUP

SUMMARY

- A NUMBER OF COMPOSITE COMPONENTS IN SERVICE HAVE BEEN SUCCESSFULLY CERTIFIED.
- PLANNED PROGRAMS FOCUS ON GREATER COMPOSITES USAGE WITH NEW DESIGN CHALLENGES
- DESIRE FOR STANDARD TEST METHODS AND A COMMON DATA BASE TO SUPPORT FUTURE APPLICATIONS.
- POTENTIAL FOR REDUCED COST OF COMPOSITE STRUCTURES WITH ADVANCES IN AUTOMATION.
- GOVERNMENT COULD LEAD IN THE COMPLEMENTATION OF STANDARD DATA BASE DEVELOPMENT.

GENERAL DISCUSSION

General Discussion

Jerry Persh: I'm very glad that Ken Foster and Stan Channon arranged this meeting because something came out to me very clearly. There was a common thread through the working group meetings. I think that the time has come that the U.S. composites industry has to establish an association.

I think that the U.S. composites industry has used SAMPE and the AIAA too long as a crutch. They are not industry associations; they don't represent industry; they are professional societies that have the responsibility for disseminating information. That is fine, but it is not an industry association. I think that the industry has to get itself together to solve the standardization/certification issues.

We've worked with associations over the years and they have been very successful. I'll give you some examples. Ken and I have worked with the Aluminum Association and it has been very successful. They retain proprietary aspects of their work but they come out with a common policy for the entire U.S. industry. We worked with the Plastics industry of America who just saw me the other day. Their major thrust is training of students. I've worked with the American Welding Society, the Welding Research Council. We provided the catalyst for those two groups to get together and establish a U.S. Welding Institute. When they decided they were going to do it, they said "OK, government, go away because we're going to do this thing by ourselves". Another good example of how we've worked with an association is the Specialty Metals Association. These people worked closely with Pratt and Whitney, General Electric, Teledyne, and so on - on a one-to-one basis; when they have a common industry problem, they speak as one voice. I'll give you two examples of their activities. That Association was successful in getting import restrictions on specialty metals pushed through the Congress and the Administration. When they had a problem with the cobalt imports. they were also very successful in getting an assessment made of the cobalt in the stockpile. Those are common industry problems that the Association was successful in working.

I think there are common industry problems here in the standardization and certification so I think that you fellows from the composites industry, working with the system contractors, like Lockheed, Northrop, McDonnell, etc., really ought to think about getting your act together. It works because we in DoD are much more responsive to an Association rather than an individual industry.

Ted Reinhart was talking about the import-export problems and technology-transfer problems. He's talking about policy changes; he's not talking about breaking this rule or that rule; he's talking about basic, fundamental policy changes. The government is not going to respond to Company A, B, C, D or E individually for a policy change. It's got to be an Association that represents the entire industry before Government will even listen to you. and that is important.

To follow up on what Ted said about feed-back from this meeting. I'll go along with the feed-back idea but I'd like to have industry talk to us collectively, as a body, on what they think and not worry about the details; worry about the policy for standardization or certification; what does industry think that we ought to do and what are <u>they</u> going to do? So I agree with the feed-back meeting. Whether the Association pays for it, we pay for it, NMAB pays for it, that's irrelevant; we have mechanisms for doing that; I think its got to be a two-way street. I think the government has got to hear what industry thinks the policy ought to be and then we can come back and say - here's what we think. It has been a very successful relationship that we have had with these various Industry Associations and, furthermore, the Associations have been very successful in dealing with the Congress and the Administration as a collective body. I don't think we're going to solve it in meetings like this. I think we've got to solve it by collective government/ industry action. Stan had the FAA, NASA and DoD here; we in Government can get our act together in the Government, but I'd like to see industry get its act together and talk to us.

Stan Channon: Before he had to leave, George Lubin passed on to me some written comments and asked me if I would present these to you. He has several suggestions along the lines we have been hearing. The first one is to request DoD to fund a committee to evaluate all of the recommendations arrived at during this meeting. Secondly, this committee should consist of 8 to 10 members, including government, industry, ASTM, Mil-Handbook 17 and end users. He is suggesting that overall supervision of the committee might, perhaps, be under the direction of the Academy of Sciences. A committee could set up priorities and recommend actions required. A committee could insure that the goals are accomplished and delays are eliminated or reduced. Unless a small active group initiates such action, we will still be talking about our problems for the next several years.

Now, I'd like to make a couple comments of my own. First of all, I feel that this meeting has been very useful; there is always a question when you organize something like this whether you are going to get the right people, the right topics and the right kind of recommendations. I think we have done fairly well in those respects. I very much appreciate the efforts that you have put out. I see the items that we have to address as covering a very wide spectrum - not just the production items, but we have touched on some of the R&D that is required to support the future production, particularly R&D in the area of test methods and the development of standards, etc. which would eventually become accepted throughout the industry. As you know, I also feel very strongly about the idea and the practical benefits to be derived from an Association of some sort, whether that be purely industry or combination of industry and government. I do think that there are a lot of examples, as Jerry pointed out, from other industries from which we can learn and apply them to this industry.

Juergens: I heartily agree with what Jerry Persh said and I think some of us have been advocates of those Industry Associations for some time. I think the industry deserves exactly what it's got. It's made its bed and it's lying in it. It is not acting collectively; it has no single voice. In particular, the suppliers are vulnerable to the next customer who comes along and lays a whole tier of additional requirements on them and, if they don't like what they get there, they just go to the next supplier. However, I do have some thoughts or feelings on Industry Associations that I'd like to share with you. I think there ought to be Industry Associations; they should be derived from the responsible, mature view of, in this case, the suppliers. The Department of Defense job is to defend the country. Industry's job is to make things and supply them and I'm not even so sure that the users, like ourselves, McDonnell Aircraft Co. should be in the Association. We're not in the Aluminum Industry Association or the American Iron & Steel Institute. I think that may be the way it ought to be. If the industry doesn't organize and present a unified position now, it will sometime down the road as this technology matures. My greatest concern is - how do you start it? The best way would be for it to be voluntary; that would be the most desirable and be consistent with the free enterprise system. I'm not so sure the Material Advisory Board or the DoD or any of the government agencies are really effective in creating it and nurturing it and maybe do some pump priming. Really, the ball is in the industry's court and I'm not so sure that they'll pick it up. I wish they would; I think it would be better for all of us.

Persh: That's very true; when we go to the Aluminum Association, they ask us very specific questions; we go over there, give them our inputs and get tossed out; that's the way it should be. The same thing happened in the refractory metals business. They want our inputs on a specific subject and then they have their own private meeting, which is fine.

Juergens: I think it might be desirable to have someone from the producing industry discuss this because obviously there are some reasons that they are not doing it.

Ken Hutton - (Shell Chemical): Being outside the industry for many years and trying to look at how to become a supplier to the industry in the future and, as a result of my inexperience with the industry, I think the industry needs to think hard about how it can stimulate, if it desires to, new resin suppliers to participate in the business without being pushed into the situation of only being able to look at airplanes or parts that are ten years down the road. How does a resin supplier like Shell move in with new technology with new resin systems to be able to qualify a part on a vehicle that is presently being made out of composites today? Even if I were able to make an identically duplicate material to a resin that's presently being used, can I get that qualified on a part that is already specified? At the present time, that is something that really is almost impossible to do. So, any R&D effort that I need to carry out has to look at a 5 to 10 year time frame and, when you think about that on an economic basis, the driving forces really aren't there for people to begin to spend a significant sum of money. That may be something that could be addressed by a society or an industry activity from the standpoint of qualifications and standards.

Dr. Allen Gray - (ASM): I haven't got a speech to make except to say that ASM is a technical society; we're often talked about as an association. We work closely with the Aluminum Association. At the present time, we are publishing a set of handbooks developed by the Aluminum Association Technical Committee. The Association took this project on and assigned responsibilities to the various company members and technical representatives and they provided us with a copy, which we copy-edit. ASM is expert in producing handbooks, having produced metal handbooks since 1918. The time spent by the authors is, of course, part of the Aluminum Association project. We also have had a project for the last 15 years with the Aluminum Association to collect and publish the World aluminum abstracts. We have a number of other data bases for alloy systems and we're getting very active in collecting metal property data to establish a data base. This is quite a big undertaking when you start putting property data for design into the computerized systems. That is just an example of how we have worked with the Association.

A couple years ago, the government asked ASM if it would conduct a quality assessment of the cobalt in the National Defense stockpile. Some forty million pounds of cobalt was purchased 25 or 30 years ago and is in the stockpile. The President said, through his science advisor, that, in a crisis, industry people are going to have to use this cobalt. They should decide if they could use it in present day applications.

We have looked into potential for developing a handbook on composite materials. ASM is moving, not rapidly, but cautiously, in the direction of becoming the outstanding materials society in the world rather than just a Metals Society. We don't want to launch into those areas and do things that are already being done well. We're very strong in the area of testing, inspection, NDE. We've published handbooks there, we've published the handbook for the Society of Non-Destructive Testing. Basically, we are an educational society; we do not develop standards. We have people in our Society and on our staff that serve on a lot of standards committees, but we do not compete with ASTM, SAE and ASME, etc.

Wayne Stinchcomb - (Virginia Poly.Tech. and Chairman of ASTM Committee D30). If I could, let me put my ASTM hat back on for one moment. When I made the presentation Tuesday, one of the things that I asked for, from this group, was that you make a request to us if you would like us to help you in any way in this business of standardized testing. I want to thank you for the overwhelming response that you have given. I think that each of the working groups has, in some way, indicated that they would like to have some help from ASTM in meeting their goals.

I would like, again, to make two requests from you. One is that, if you have specific statements in mind, whether you were a working group chairman or a participant, please get those statements to me. I think the form of the statement we saw this morning was rather general and, before we can roll up our sleeves and get to work, I would like to see something specific. I think we would like to do that.

The second request to you is that you help us. It has been stated, probably more than it needs to be, that we are a voluntary organization. That means the work gets done by those who want to work on the problem and those who want to see a solution. A number of the folks here, in this auditorium, do work on Committee D30 and many of you represent companies who are represented in Committee D30, so we can get the work done. I can't promise you that it will be short term, although I think there is some correlation between the interest in getting the work done and the shortness of time to get the work done.

I think that some of the working group statements that were made here this morning addressed primarily the organic matrix composites. Would those people in the audience who represent the metal matrix community want to comment, to say whether the statements that were made this morning can be extended to the metal matrix composites or are there some additional comments that need to be made?

J. Dolowy - (DWA Composites): I should thank Wayne also for giving me the opportunity. I took part in two of the working sessions yesterday. I did have an active part in the Fibers group and I agree wholeheartedly with Ted Reinhart's report. Metal matrix composites (and I think the carbon-carbon) people have similar statements to make. We are following along in the footsteps of organic materials and trying to learn what's gone before. In our case, metal matrix systems, we can draw perhaps some closer analogies to what's gone on in the metals industry before us but we don't have a metal; we don't have homogeneous materials, in general, and we can't lose sight of that fact. We're never going to have a simple direct specification type document where you define chemistry and essentially buy to an alloy type specification because a composite is a designable material so it's going to be a little more involved that the simple single document. I do believe that we're making the same kinds of progress and most of the statements were appropriate that were made here today.

My final point is that we do seem to be working in an international technology. I think the sooner that's accepted, the more quickly that we'll all make progress and many of these questions will be answered.

Dan Mulville: There is a major issue of manufacturing technology in the composites area which was not discussed in detail. That is the step between taking the material supplied and transforming it into some useful product. In the components and structures group, we were looking at the analytical methods to assess these products and, from what I've heard of the other groups, they were looking at supplying the products that would go into a manufacturing technology. In retrospect, I think it would have been worthwhile to have had a manufacturing technology working group to assess what the issues are in that area that could be and should be supported to enhance the overall transition of these materials into service. We did a little bit of that and I think some of the other groups touched on it somewhat. When you consider what the export technology issues are, we in DoD have focused on the manufacturing technology and design. So I would pose as a challenge, or just for an open topic for discussion, - are there specific manufacturing technologies that could or should be considered in conjunction with the other things we have looked at?

John Hedgepeth - (Astro Research Corp.): We probably make use of at least 30 pounds a year of composite materials and that makes me enough of an expert that I can try to make a comment. As an engineer, I personally think that the first thing that needs to be done is the standardization, or perhaps I should say the industry-wideness of things, i.e. specifications that are understood and agreed upon on an industry-wide basis and testing procedures that are understood and agreed upon on an industry-wide basis. I think that sort of thing aims at a large part of our problems.

Secondly, I'm not sure that standardization aims at the biggest problem which has to do with the industrialization of this particular technology area which, I guess, is the real purpose of this workshop. If one looks at the industrialization question, it becomes obvious that there needs to be an Industry Association; there needs to be the standard specifications; there needs to be agreed-upon work on test procedures and, indeed, a matrix of tests, - all of those sorts of things. I am concerned that I don't see what the pressure is that's going to cause it to happen in this particular case. I think that it is really incumbent upon the industry, the supplier industry itself, to form its Industry Association but I don't see what advantage its going to be to Fiberite or NARMCO or any of the other prepreggers, for instance, to get together in such an industry, at least from an economic point of view. That doubt primarily arises from the fact that I don't think there's a perception of a significantly increased market as a result of such an action. Normally, the economic benefit for such activities arises from the fact that, if you engage in such activities, the total market will be very greatly broadened to such an extent that you can say our company is going to benefit, even though this is going to help the competition. Why should Ciba Geigy engage in anything that's going to let Shell in the door? Not being part of this thing, I can say that freely. I believe that the people who would benefit from this Industry Association are the users (i.e. the technical benefit), the DoD, the FAA and the commercial manufacturers. They need to help the supplier industry itself find out what is the benefit to the individual companies in the supplier industry of engaging in such activity.

We sell a little overseas; as a matter of fact, if we couldn't, we would have a very hard time making a profit. I'm struck by the fact that the U.S. government makes it difficult for us to sell overseas but, on the other hand, I'm struck by the fact that the U.S. marketplace is a pretty good marketplace from the standpoint of resisting foreign competition and, as long as our customer is primarily government supported aerospace, we're not too worried about the influence of people outside of our country on our markets.

Dave Forest (Fiberite): The few of you that are left figure that eventually one of the remaining material suppliers would get up and address the issue of Industry Associations. Fiberite is a prepreg organization primarily and we consider ourselves a part of the reinforced plastics industry. The generic industry in which we participate has perhaps a two billion dollar a year sales worldwide. If you add up the total sales of all the companies involved in composites , like Hercules and Union Carbide and Beatrice (of which Fiberite is a part) and others, you get a very large number in total sales. If, on the other hand, you add up the total sales of the operations within those companies that make up the continuous composites portion of the reinforced plastic industry, you get around $200,000,000. for last year. That includes all the carbon fiber, all the resin and all the prepreg; it's a small number and this is a very small segment of an industry.

It's a little difficult to understand just how we might support a very active and very aggressive Industry Association on the total sales volume of $200,000,000 and a total profit level that's negative. Although there are one or two of us that show a little positive bottom line, as a whole, the suppliers in this industry lose money. By the way, I personally favor an Industry Association. I would be more than happy to take any active role that anybody wants to give me in forming such an Association. I think it is necessary; I think it would benefit all of us and I speak for Fiberite, too. We don't feel that we'd be giving away more than we'd be gaining by such an Association. On the other hand, I know we're going to have a struggle with a couple of real issues in organizing it. One of them may be the proprietary issue although I think that is losing favor, even among prepreggers, as a real issue. I think a more fundamental issue is the thought that somebody might look at us and say we're colluding on price.

I'd like to make one other comment and that addresses your initial idea, Stan, that we ought to try to come up with a couple of recommendations from this meeting that could actually be implemented and that would be a positive benefit. I'd like to see two things happen. One would be that the DoD, at a policy level, would make it a policy that, on any production program (like a new F15 program or the other new programs that involved composite materials), it would be a requirement that any data on those composite materials that was generated as part of that program be collected and published. This would be a data item within that production program. This is typically handled now in AFML R&D contracts and NADC R&D contracts but it is not done on production programs. Consequently, on the F16 program which generated an enormous amount of data on composite materials under government funding, there was no funding within that program to collect that data and publish it as a report. We're talking about $100,000 on a multi-billion dollar production program to pay somebody to put the data together. It would be helpful to all of us and it would be a way to start the data base that we all think is needed - a centralized data base. I understand why the Boeing Commercial Airplane Co. would not want to share all of the data that they've paid for in generating BMS 8-212 and -168 and other specifications activity. On the other hand, if the government has paid General Dynamics on the F16 program to generate data, I think it's only fair that that data be shared with other contractors. So that's one recommendation and I think that could be a fairly simple policy kind of recommendation for inclusion in production contracts.

The second thing that I would like to see is somebody from the Flight Dynamics Lab, somebody from the Materials Lab, somebody from NADC, and somebody from the FAA come up with a matrix of tests for qualifying a composite material - just the material. I don't want you to tell me how to run the test, what test method to use, necessarily all of the specifics of the environment. I just want a matrix of the required tests so that we can all agree on what tests we are going to run and accept. Are we going to run fracture tests on the material, or are we going to wait and do that on the finished component? What kind of environmental fluids and solvent tests are we going to run? Let's see if we can't get that in a standard test series so that we all have the same matrix. Right now, we're all shooting at a moving target. At Fiberite, when we develop a composite material system, unless we have a specific customer in mind who has told us what tests he wants us to run, we could be running tests forever. It could take us 10 years to run all the tests that people have asked us to do in the past for one particular reason or another. If we could come up with a standard set that would be satisfactory for general aerospace use, then we'd run them ourselves. We have the capability to run all of those tests and we'd prefer to do it that way before we gave the material out to our customers so that we wouldn't be surprised.

Stan Channon: You touched on the cost of testing or the requirements for testing and, also, Michele Abraham from Owens-Corning talked about the high cost of testing S-glass. Does the testing cost represent a large cost to the prepreg supplier in terms of what price you have to put on it for the end user?

D. Forest - (Fiberite): Well, it depends quite a bit. For example, for a prepreg that we sell as a commercial item where we do rather simple physical property testing like resin solids and so on, the testing cost is not particularly significant. We do our testing, of course, on a production batch basis; we run the tests on the production batch. We have had an example of selling a spacecraft prepreg material to a company like Heath Tecna. They needed 5 pounds of material and we didn't have any of that material so we had to run a 5 pound lot. We did $15,000 worth of acceptance on 5 pounds of material that sells at $5.00 a pound. That is not uncommon in the industry now because the average lot size that a prepregger makes in this industry is probably around 200 pounds. The average lot size that we like to make is more like 1,000 pounds or maybe 2,000 pounds, depending on the product but, in actual fact, average lot sizes are around 200 pounds and there are 500 or 600 different variations of materials that we also make so it is very difficult to collect those 200 pound lots into 1,000 or 2,000 pound production runs before it runs out of shelf-life before you can sell it. On a production basis in large lots, one or two thousand pounds, the testing cost typically should run about a dollar a pound. With a very extensive test series that we have occasionally seen, I've seen numbers as high as $10 per pound. We worked with that particular customer and got the number back down to a dollar or two. For a material that costs on the average maybe $40 a pound, the testing is usually about a dollar or maybe two dollars a pound and I don't consider that terribly significant. On the other hand, because of the fact that we're not standardized and our lot sizes are low, the real number can be $5.00 - $10.00 a pound and probably more commonly is $5.00 - $10.00 a pound.

Stan Channon: Thank you. That makes a good argument for trying to reduce the number of available forms of the material to a select few and that might make the whole standardization business a lot easier. You mentioned something like 500 product forms that you have and I presume your competitors probably have a similar range.

Jim Ramsey - (General Dynamics/Convair): I just wanted to comment on something Dave Forest said about requiring dissemination of material property data from these major programs. I'd like to go a little bit further. I would recommend that, on programs of some arbitrary size (I'm not sure what that should be), a comprehensive materials program and the data development program should be an essential part of these contracts. I have found, in my experience in trying to work up proposals, that materials programs are the first things that get cut in trying to be competitive. You end up running trivial materials programs (flex tests, short beam shear which are mainly QC tests) and you end up with very little real data base; we can get longitudinal properties, primarily, but very little transverse property data which are of great concern to structural analysts right now.

Ray Juergens: It is easy to say that we'd like to have data and then get it - but there's always a very significant question on the pedigree of the data and that's a very real headache.

I think it became pretty clear from the discussions today that something ought to be done about Mil-Handbook 17. That came up frequently. The general comments that we have heard are that it is under-funded, it is too slow, it is being done by a group that should be expanded and, according to some critics, it doesn't cover the right materials or the tests are all wrong. Those are all criticisms, but I think what they really reflect is a need for a pedigreed, quality material characterization data base. At the pace at which we are proceeding, even on structural materials, it will be ten years before that can have any impact. So I think something ought to be done about Mil-Handbook 17; I'm not sure what it is, but it apparently is of interest to this community.

PeterDiGiovanni: If there is going to be added thrust to the Mil-Handbook 17 activity, my concern is that, if the thrust continues on its present course by designating materials by a particular brand name or by type of material, e.g., graphite-epoxy, it will never become a Mil-Handbook 17. I question the propriety of the government supporting an activity in which material data are generated for present material designation for which there is no control. The manufacturer can, for very good reasons, modify that material to improve some of its properties and then we have a handbook with obsolete data but it has the same name. I think the pressure should be put on immediately to stop testing material identified by manufacturer's designation. I am sympathetic with the Mil-Handbook 17 group because they have no choice except to do it that way now, but I would hope that one of the action items would be to urge the use of the more generic identifications. The DoD - NASA handbooks that have been issued have experienced the same thing happening there.

I'm not sure that some of those materials which were tested have very much meaning now; they still have the same names, but there is no specification for those materials.

Ray Palmer - (Douglas Aircraft): Just a quick report on the status of our common specification work between Boeing, Douglas and Lockheed. One of the very good side benefits of a meeting of this kind is getting people together. It just happens that the three key authors of that specification are here. We held a little group meeting and set a goal for ourselves as to when something might happen. There is going to be an ACEE Conference in Seattle sometime in early August and we will do our very best to have the next version of that specification, with all companies' comments, ready for reading at that meeting. That is about the time that some of the industry prepreg people might be called in to begin to help us finalize that specification.

Ray Juergens: The AS4/3501-6 material that is going through the round-robin testing program now, and the control on that material, is anticipated to be by specification. There is an AMS specification 3892/9 which covers the AS4 fiber specifically. There is a draft specification going through the system now on 3501-6 resin composition which will define the chemical and rheological characteristics of that material. There are two specifications in the AMS system which define MY720 and DDS and they will be incorporated into the resin specification. There are three other specifications currently in the approval cycle which cover two other minor epoxies and something else. All of those will be combined into an AMS specification which references these sub-specifications to specifically define that material and that will be the specification reference which will be connected to the mechanical property data base in Mil-Handbook 17.

Peter DiGiovanni: Does that mean that, if another manufacturer, (a competitor to Hercules), were to make a material that met all of those specifications you mentioned, a designer could use that Mil-Handbook data for the other material because the other manufacturer stated that it has met those specifications. That material would be called something else, but suppose it's a T300-XXX.

Ray Juergens: It would probably refer to it at some point in time by an AMS number .

P. DiGiovanni: The material would be referred to by an AMS number?

R. Juergens: Yes, that's not uncommon; in aluminum, they refer to them that way.

Allen Gray: I guess some of you know that the titanium producers are getting together to establish an Association, so, if this idea of a Composites Association (or Composites Institute, if you'd rather broaden it and bring in some users as well as producers) is of interest, you might wish to pursue this to see what they have gone through in their thinking in getting together in an Association. I think a lot of this has to do with their interest in standardization of alloys, probably.

Ted Reinhart: The problem of feedback from the government was mentioned. Even within the DoD, FAA and NASA, we have no forum for exchange of information or for presenting our requirements to industry as a body. Each organization pursues its interests and we have half-hearted meetings with NASA every six months to try to coordinate composite programs. Some of the managers attend and some of the engineers don't, and I don't think that's very effective. With the press of business and the shortage of travel funds, the government feedback will never occur unless it is established at some higher level and then mandated down the line.

Stan Channon: I have recognized, in my studies over the years, that it is extremely difficult to put together information which precisely tells you what the DoD requirements are going to be for the next several years. It does appear that there is a need for some focal point where those needs can be assembled and, in some authentic way, transmitted to the industry so that they won't be getting stories from various competing suppliers, fabricators, etc., quite often on programs that are not yet firmed up but are still in the future. My conversations with the suppliers, over the years, has been that they feel very uncomfortable about the numbers that they are receiving. Sometimes they are double or triple counted because of either over-ambitious projections for the programs or time schedules for when they will begin. In an exercise in which I was engaged a couple of years ago to try to assess the DoD needs versus the supply base, I found it extremely difficult to get a good handle on what these needs were. I attacked it from two points of view; from the supplier point of view and from the end-user point of view and sometimes the numbers didn't quite converge on the same point. It would seem to me that that sort of information might be very helpful to the industry to enable it to project its expansion more realistically. I recognize the problem of industry trying to build new facilities based on, perhaps, rather insecure information.

Glenn Kuebeler - (Hercules): To respond to the question about what the material suppliers get in terms of feed-back, I think the amount of feed-back we get is a function of the size of the organization. A large organization can put a lot of people out there making contacts, either with the military organizations, NASA, or with the prime contractors themselves. If you have a lot of interaction with the prime contractors, you're getting feed-back in terms of what they need, what your materials do and what you can do to improve them. The smaller companies don't get as much feed-back as the bigger companies get. Whether or not there needs to be a DoD group or a government group that could pull all these requirements together is debatable. I can see some usefulness in that; maybe that's tough to get that together. We certainly always wonder, when we're getting information, particularly from government organizations, whether we're at the right level. It was mentioned that there can be some ambitious people or some very optimistic people say that this is what it's going to be and, in reality, it never occurs like that. Quantities never turn out to be that big or the time-scale never turns out to be what they said, so you can be misled; you can have forecasts which you get very excited about, go off and do things and then you sit back and wonder why nobody ever bought the material.

The other thing I did want to comment on, as a material supplier, is the idea of the Industry Association. We've thought about that for a number of years. As Dave mentioned, you wonder what that really does for you. You look at the Society for Plastics Institute. The reinforced composites branch of that Society does the same kind of thing, but maybe there is a need for a more selective organization and perhaps one suggestion would be for the material suppliers to take that message back and find out if their own organization would be interested in supporting such a group. The other suggestion would be to use Stan Channon and IDA as, at least, a kick-off point and, since he has a mailing list of the people who were at this meeting, let him work through IDA with a survey just to solicit interest levels. If enough companies are interested in doing this, then it can be explored up at the next level, such as forming a representative task group to try to define some objectives, goals and scope. Certainly, you're going to have to explore the legal question. As Bud Townsend pointed out yesterday, if such an organization were formed, his legal people would probably tell him that he cannot belong. I don't particularly think that's true, since the Aluminum Association would have had the same problem. We would have to go talk to somebody like the Aluminum Association and find out what they had to do to get started. I think the same thing could be done here. There needs to be something to cause it to happen. Therefore, I would suggest going back through Stan with a survey form to at least the companies here and any other companies that we might think about. I would be willing to work with you on that sort of thing, at least to get some sort of feedback to see if there is enough interest.

Stan Channon: For my part, I'd be happy to act as a catalyst to try to bring that sort of thing together. Any other comments along those lines?

Ken Foster: I think it has been a productive three days and I think there is a little way to go. Along the line of industry associations, I think you can help eliminate something that I have heard in the last three days. There is a mysterious aspect about composites which could be eliminated. Not only do you improve the accuracy of information but you also eliminate a lot of misinformation, and I hope we can work toward that.

SPECIAL CONTRIBUTION

AN INDUSTRY ASSOCIATION IS NECESSARY FOR STANDARDIZED COMPOSITE MATERIALS

Raymond J. Juergens

McDonnell Aircraft

"AN INDUSTRY ASSOCIATION IS NECESSARY FOR STANDARDIZED COMPOSITE MATERIALS"

Raymond J. Juergens

Branch Chief Technology

McDonnell Aircraft

Composite materials are becoming a greater factor in the structures of aerospace systems. The structural efficiency of fiber reinforced composites, coupled with fatigue life improvement, corrosion resistance and cost saving potential, has made these modern materials prime candidates for use in new systems where performance improvement is avidly sought. In our product line, we have seen the structural fraction of composites on each succeeding aircraft rise from approximately 1% on the F-15 Eagle to 10% on the F/A-18 Hornet and 27% on the AV-8B Harrier II. Our experience has been shared by others, making high-quality carbon, organic and other fibers with appropriate resin systems a growing market.

Because of the increased production of systems using composites through the 80's, these materials will receive more attention from a supply standpoint. Thirty percent of the structure of an aircraft will provide attention equivalent to that which has been directed to materials such as titanium. Thirty percent is approximately the titanium fraction for an F-15. The titanium that we buy for the F-15 is procured on a competitive basis to a material specification that defines the material. The product is uniform, consistent, interchangeable and essentially indistinguishable from supplier to supplier. It is a standard material; composite materials will mature to a similar position as their use on production programs grows.

The existing metal specifications have all of the elements necessary and relevant to composite materials. They list a description of the material, the form, applicability, composition, processability, mechanical property capability, sampling, testing, handling, marking, safety provisions, etc. They describe well characterized standard production materials that can be reliably procured. As a result, a standard titanium alloy can be specified and used in an aircraft today much easier and with less expense, compared to composite materials.

The present industry practice for composite materials is to require qualification testing of each composite material for each new system application. We require fiber and matrix dominant tests, environmental exposure tests, perhaps some structural element or subcomponent tests, processability tests and tests associated with the uniformity of the product. We require tests on at least five lots of material produced by a supplier so that we can treat the data in a statistical manner. The cost of this qualification effort is repeated by other fabricators as each pursues a composite application with his selected material suppliers. The number and cost of these qualification tests can be significant, considering the numbers of fibers and resins being marketed today. The qualification data base is established and reestablished again and again.

All parties involved, the fabricator, supplier and the eventual customer could benefit from the cost avoidance offered by a standard material.

The technology necessary for a user and a supplier to define a material for multi-source procurement has been gradually evolving. The necessary information appears to be on hand and we are presently incorporating these elements into our production material specifications. There are four major technical areas that need to be defined for composite materials. These are the reinforcing fiber, the matrix resin, the processing characteristics and the cured mechanical property capabilities. While the state of technology varies for these four areas, there is the basis for a standard material specification.

If standard composite materials are desirable, why don't we have them? Why have standard materials not evolved? One of the reasons is the low production material requirements of previous composite applications.

Standard materials arise from substantial production usage. Production usage creates the standard. If, by using what everyone else uses, one can avoid costs, and get better delivery and price, then the use of a standard product becomes desirable. Several vehicle systems are currently using or qualifying the 3501-6 and the 5208/3502 resins. These two resin types appear to be establishing themselves as standard materials through their application on several production systems. They could become standard materials solely because of their use on production programs.

Another factor inhibiting the establishment of a standard material is the proprietary aspects of resin formulation. Almost all resin formulations are considered to be proprietary because of the lack of patent protection for resin formulations. The development of multiple sources of supply for the same material (i.e. a standard product) usually follows in the production phases of a system development.

Progress or lack of progress toward standardization results from supplier market strategies and not necessarily from a user's need. Trading, royalties, front end fees, etc. are the business prerogatives of the suppliers. However, the user's investment and risk in establishing the material thru a production commitment can be as great as a supplier's proprietary claim. The supplier's advantage in keeping a material proprietary is counterproductive to the multisource desires of the user.

The time has come for standard composite materials. Production usage will create standards eventually. One action that could accelerate standardization is mutual production agreements between suppliers. To accommodate the business aspects of such agreements it is recommended that suppliers take action as an industry group to hasten standardization so that all parties can benefit.

FINAL PROGRAM

COLLOQUIUM/WORKSHOP

COMPOSITE MATERIALS AND STRUCTURES

STANDARDIZATION,
QUALIFICATION,
CERTIFICATION

NATIONAL ACADEMY OF SCIENCES BUILDING
2100 BLOCK OF C STREET, N.W.
WASHINGTON, D.C.

May 8 - 10, 1984

Sponsored by
Department of Defense,
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Organized by
Institute for Defense Analyses

Tuesday, May 8, 1984

OVERVIEWS

8:00	Registration	
9:00	Welcome	Kenneth R. Foster, OUSDRE (Acquisition Management)
	Keynote Address	John A. Mittino, Asst. Dep. Under Secretary of Defense (Production Support)
9:15	Review of IDA Study	Stanley L. Channon, Consultant to IDA
9:30	DoD Qualification Practices	
	9:30 Army	Edward Lenoe, Army Materials & Mechanics Research Center
	9:45 Navy	Michael Dubberly, Naval Air Systems Command
	10:00 Air Force	John W. Lincoln, Aeronautical Systems Division
10:15	NASA Practices	Louis F. Vosteen, NASA, Langley Research Center
10:30	FAA Practices	Joseph R. Soderquist, Federal Aviation Administration
10:45	COFFEE BREAK	
11:00	Commercial Aerospace Practices	
	11:00 Boeing	M. Katsumoto, Boeing Aerospace Company
	11:15 Lockheed	Arthur James, Lockheed California Co.
	11:30 McDonnell Douglas	Raymond J. Palmer Douglas Aircraft Co.
11:45	Industrial Products	Gerald L. Sauer, Narmco Materials, Inc.
12:00	Standards Activities	
	12:00 ASTM	Wayne W. Stinchcomb, V.P.I. Chairman, ASTM Comm D-30
	12:15 SAE/AMS	L. Johnson, Honeywell, Secretary, NonMetallics Committee
	12:30 MIL Handbook 17	Paul Doyle, Army Materials & Mechanics Research Center
	12:45 International	Stanley L. Channon, Consultant to IDA
1:00	LUNCH	

2:00	Reinforcement Materials	
	2:00 Carbon & Precursors	Herbert N. Townsend, Union Carbide Corp.
	2:15 Carbon & Precursors	James Burns, Hercules, Inc.
	2:30 Aramid	Paul R. Langston, DuPont
	2:45 High Strength Glass	Michele Abraham, Owens-Corning
3:00	Organic Matrix Materials	Gail D. DiSalvo, Ciba-Geigy Corp.
3:15	Multi-dimensional Weaves and Carbon-carbon	Jay Baetz, Atlantic Research
3:30	COFFEE BREAK	
4:00	Intermediate Products	
	4:00 Organic Prepregs	Juan Chorne, Hexcel Corp.
	4:15 Metal "Prepregs"	Stan Paprocki, Materials Concepts, Inc.
4:30	*Metal Matrix Composites*	
	4:30 Fiber and Particulate Composites	J. F. Dolowy, Jr., DWA Composite Specialties, Inc
	4:45 Whisker/Metal Composites	Jack L. Cook, ARCO Metals, Inc.
5:00	Instructions for Working Groups	Stanley L. Channon, Consultant to IDA

Wednesday, May 9, 1984

WORKING GROUPS

9:00 Working Groups Convene

Working Group 1	Fibers and Reinforcements	
Chairman		Theodore J. Reinhart, Air Force Materials Laboratory
Co-Chairman		Paul E. McMahon, Celanese Corporation
Working Group 2	Matrix Materials	
Chairman		Bernard M. Halpin, Army Materials and Research Center
Co-Chairman		Gary L. Patz, Hysol/Dexter Corporation
Working Group 3	Intermediate Products (PREPREGS)	
Chairman		Raymond J. Juergens, McDonnell Douglas Corporation, St. Louis
Co-Chairman		David Forest, Fiberite
Working Group 4	Components and Structures	
Chairman		Dan Mulville, Naval Air Systems Command
Co-Chairman		J. G. Williams, NASA, Langley
Co-Chairman		Jay Baetz, Atlantic Research

Adjourn at discretion of Chairman

Thursday, May 10, 1984

COMBINED SESSION

9:00 Working Group Reports

9:00	Working Group 1
9:30	Working Group 2
10:00	Working Group 3
10:30	Working Group 4
11:00	COFFEE BREAK
11:30	General Discussion
1:00	LUNCH
2:00	General Discussion (Continued)
4:00	*Recommendations*

MESSAGE PHONE

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COMPOSITE MATERIALS AND STRUCTURES

STANDARDIZATION, QUALIFICATION, CERTIFICATION

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ABRAHAM, Michele D.	Owens Corning Fiberglas Fiberglas Tower T-7 Toledo, OH. 43659	419-248-8147
ANDERSON, Dr.Robert E.	Grumman Aerospace Corp. Bethpage LI., N.Y. 11714	516-454-8390
BAETZ, Jay G.	Atlantic Research Corp. 5390 Cherokee Ave. Alexandria, Va. 22312	703-642-4394
BAXTER, Donald F.Jr.	American Society for Metals Metals Park, OH. 44073	216-338-5151
BERKHOUSE, Linda H.	Kaman Tempo (MMCIAC) 2560 Huntington Ave. Suite 500 Alexandria, VA. 22303	703-960-4774
BONSALL, Robert A.	Grumman Aerospace Corp. Mail Stop A04-12 Bethpage, N.Y. 11768	516-575-7671
BRADY, Dr.Don G.	Phillips Petroleum Bartlesville, Okla. 74004	918-661-0453
BRAYDEN, Thomas H.	Vought Corp. 9314 Jefferson St. Dallas, Texas 75265	214-266-5943
BRINK, Norman O.	Rohr Industries, Inc. P.O. Box 878 Chula Vista, Ca. 92012	619-691-2077
BURDEN, Owen T.	Clark-Schwebel Fiber Glass Corp. P.O. Box 2627 Anderson, SC 29622	803-224-3506

BUTTS, Ha. y V.	Sikorsky Aircraft No. Main St. Stratford, CT. 06602	203-386-4221
CHANNON, Dr. Stanley L.	Consultant 2361 Daventry Rd. Riverside, CA. 92506	714-683-7357
CHESS, Henry L.	ProForm Inc. 7901 Xerxes Ave. So. Minneapolis, MN. 55431	612-887-1820
CHIAO, T.T.	Lawrence Livermore National Lab. Box 808 L-338 Livermore, CA. 94550	415-422-9271
CHORNE, Juan	Hexcel Corp. P.O. Box 2312 11711 Dublin Blvd. Dublin, CA. 94566	415-828-4200
CLARK, James M.	Great Lakes Research Corp. P.O. Box 1031 Elizabethton, TN. 37643	615-543-3111
CLEVINGER, Dr. Gary S.	Babcock & Wilcox Co. Lynchburg Research Center Lynchburg, VA., 24505	804-522-5626
COOK, Jack L.	ARCO Metals Co. P.O. Box 3010 Arlington, Ill. 60006	803-977-0123
DEAKYNE, C	E.I.DuPont deNemours & Co. 1007 Market St. Wilmington, DE. 19898	302-999-3518
DEMUTS, Edvins	Structures & Dynamics Div. AFWAL/FIBAC Wright-Patterson AFB, Ohio 45433	513-255-6639
DHINGRA, Dr. Ashok K.	E.I.DuPont DeNemours & Co. D6005 DuPont Building Wilmington, Del. 19898	302-772-3663
DIGIOVANNI, Dr. Peter R.	Raytheon Co. Missile Systems Div. Mail Stop MAP 5-1 Bedford, MA. 01730	617-274-7100
DISALVO, Dr. Gail D.	Ciba-Geigy Corp. 3 Skyline Drive Hawthorne, N.Y. 10532	914-347-4700

DIXON, Jack R.	NSWC - Navy White Oak Oab. Silver Spring, MD. 20902	202-394-1535
DOLOWY, J.F.,Jr.	DWA Comp. Spec.Inc. 21119 Superior St. Chatsworth, CA. 91311	818-998-1504
DOYLE, Paul	AMMRC, DRXMR-STM Arsenal St. Watertown, MA. 02172	617-923-5554
DUBBERLY, M.	Naval Air Systems Command Air-5302 Washington, D.C. 20361	202-692-3591
EDINGER, John M.	DuPont Company 1007 Market St. Room D-6001 Wilmington, DE. 19898	302-774-3038
EPP, John	Avtex Fibers Inc. P.O. Box 880 Valley Forge, PA. 19482	215-251-7722
FOREST, James David	Fiberite 645 N. Cypress St. Orange, CA. 92666	714-639-2050
FOSTER, Kenneth R.	Staff Director, Material Policy Room 3C 257 The Pentagon Washington, D.C. 20301	202-697-0957
GARDNER, Hugh C.	Union Carbide Corp. P.O. Box 670 Bound Brook, NJ. 08805	201-356-8000 Ext.2727
GARDNER, J. Donald	Aluminum Association 818 Connecticut Ave. NW Washington, D.C. 20006	202-862-5100
GIBSON, D. W.	HITCO/FCD 1600 W. 135th St. Gardena, CA. 90249	213-537-8210
GOLDSWORTHY, W.Brandt	Goldsworthy Engineering, Inc. 23930 Madison St. Torrance, CA. 90505	213-373-6875
GOLICK, Robert A.	Hysol P.O. Box 312 Pittsburg, CA. 94565	415-697-4201

GRAY, Dr. Allen G.	American Society for Metals 4301 Esteswood Dr. Nashville, TN. 37215	615-269-0421
GRECZEK, W.	Office of Industrial Base Assessment Two Skyline Place, Suite 1406 5203 Leesburg Pike Falls Church, VA. 22041	703-756-2310
HALPIN, Bernard M,Jr.	Army Materials & Mechanics Research Center Arsenal St. Watertown, MA. 02172	617-923-5100
HARRIS, Frank L.	U.S. Army Belvoir R&D Center STRBE-VL Fort Belvoir, VA. 22060	703-664-5471
HAVENS, LaMar D.	Heath Tecna Aerospace Co. 19819 84th Ave. South Kent, Washington 98032	206-872-7500
HEATON, Michael J.	Fothergill Composites, Inc. #6 Shields Dr. P.O. Box 618 Bennington, VT. 05201	802-442-9964
HEDGEPETH, John	Astro Research Corp. 6390 Cindy Lane Carpenteria, CA. 93013	805-684-6641 Ext. 315
HETTICH, B. V.	AVTEX Fibers Inc. P.O. Box 42 Front Royal, VA. 22630	703-635-2141
HORNER, Howard E.	U.S.Army Belvoir R&D Center STRBE-VL Fort Belvoir, VA. 22060	703-664-5126
HURWITZ, Frances	NASA Lewis Research Center 21000 Brookpark Rd. Cleveland, OH. 44135	216-433-4000 Ext. 6826
HUTTON, K.M.	Shell Chemical Co. P.O. Box 2463 Houston, TX. 77001	713-241-0407
JACKSON, Donald G.	General Dynamics/ Fort Worth Div. MZ2860 P.O. Box 748 Fort Worth, TX. 76101	817-777-2139

JOHNSON, Clark W.	Martin Marietta Aerospace P.O. Box 179 Denver, CO. 80201	303-977-5271
JOHNSON, L. I.	Honeywell - DSD MN11-2480 600 Second St. N.E. Hopkins, Minnesota, 55343	612-931-6097
JOHNSON, Robert A.	Northrop Corp. 8900 E. Washington Blvd. Pico Rivera, CA.	213-942-5529
JUERGENS, Raymond J.	McDonnell Aircraft Co. P.O. Box 516 St. Louis, MO. 63166	314-233-8648
KILBOURN, W.R.	Martin Marietta 103 Chesapeake Park Plaza Baltimore, Maryland 21220	301-338-5471
KATSUMOTO, M. T.	Boeing Commercial Airplane Co. P.O. Box 3707 Seattle, Wash. 98124	206-237-9725
KOLLMANSBERGER, Ron	Fairchild Republic Mail Stop 19M18 Conklin St. Farmingdale, NY. 11735	516-531-2172
KOUBEK, Francis J.	Naval Surface Weapons Corp. Silver Spring, MD. 20910	202-394-2262
KUEBELER, Glenn C.	Hercules Inc. Hercules Plaza Wilmington, DE. 19894	302-594-6090
KUNIHIRO, R.A.	Defense Materials Standards & Specifications Organ. 1403 Two Skyline Plaza Falls Church, VA. 22041	703-756-2342
LADIKA, Michael	FMC Corporation 1105 Coleman Ave. San Jose, CA. 95108	408-289-4488
LANGSTON, Paul R.	E.I. DuPont deNemours & Co. Textile Fibers Dept. Centre Road Bldg. Room G217 Wilmington, DE.. 19898	302-999-2735

LENOE, Edward M.	Army Materials & Mechanics Research Center DRXMR-SM Arsenal St. Watertown, MA. 02172	617-923-5426
LINCOLN, John W.	ASD/ENFS Wright-Patterson-AFB Ohio 45433	513-255-6879
LUBIN, George	Hysol-Grafil 5373D Lakefront Blvd. Delray Beach, FL. 33445	305-495-0133
LUSTIGER, Arnold	Battelle - Columbus 505 King Ave. Columbus, OH. 43201	614-424-7782
MALLORY, Harvey	E.I.DuPont deNemours & Co. Centre Rd. Bldg. 12E6 Wilmington, DE. 19898	302-999-2680
MARTIN, W. R.	Hercules Inc. 1800 K St., N.W. Washington, D.C. 20006	202-223-8590
MERSCHEL, Richard P.	Martin Marietta Aerospace P.O. Box 179 Denver, CO. 80201	303-977-8707
McCARTY, John E.	Boeing Military Airplane Co. P.O. Box 3707 Mail Stop 41-37 Seattle, WA. 98124	206-655-3479
McDANIEL, Paul L.	Garrett Turbine Engine Co. P.O. Box 5217 Dept. 93-392-302 Phoenix, AZ. 85010	602-231-2758
McKAGUE, Lee M.	General Dynamics Mail Zone 2860 P.O. Box 748 Fort Worth, TX. 76101	817-777-2126
McMAHON, Paul E.	Celanese Corp. 26 Main St. Chatham, N.J. 07928	201-635-4107
MITTINO, John A.	DoD/OUSDRE Room 3E144 Pentagon, Washington, D.C.	202-695-6322

MITTNICK, Melvin	AVCO, Specialty Materials Div 2 Industrial Ave. Lowell, MA. 01851	617-454-5746
MULVILLE, Dan	Naval Air Systems AIR--310B Washington, D.C. 20361	202-692-7447
NEWMAN, John E.	Office of Technology Assessment U.S. Congress Washington, D.C. 20510	202-226-2208
OLIVER, Dr.Robert C.	Institute of Defense Analyses 1801 N. Beauregard St. Alexandria, VA. 22311	703-845-2256
OLTROGGE, Victor	Stanley Aviation Corp. 2501 Dallas St. Aurora, CO. 80010	303-364-6411
PALMER, J. M., Jr.	Douglas Aircraft Co. 3855 Lakewood Blvd. Long Beach, CA. 90846	213-593-6512
PALMER, Raymond J,	Douglas Aircraft Co. 3855 Lakewood Blvd. Long Beach, CA. 90846	213-593-7305
PAPROCKI, Stan	Material Concepts Inc. 666 N. Hague Ave. Columbus, OH. 43204	614-272-5785
PATZ, Gary	Hysol Grafil P.O. Box 312 Pittsburg, CA. 94565	415-938-5533
PEDERSON, Donald J.	Hercules Inc. P.O. Box 98 Magna, Utah 84044	801-250-5911
PERSH, Jerome	Room 3D 1089 The Pentagon Washington, D.C. 20301	202-695-0005
POESCH, Jon G.	Hercules, Inc. P.O. Box 98 Magna, Utah 84044	801-250-5911
RAMSEY, James E.	General Dynamics/Convair P.O. Box 85357 Mail Zone 23-6810 San Diego, CA. 92138	619-573-9398

RAO, Dr. R.N.S.	Prairie View A&M University P.O. Box 2345 Prairie View, TX. 77446	409-857-3923
REINHART, Theodore J.	AFWAL / MLSE Wright-Patterson AFB Ohio, 45433	513-255-3691
RIECHMAN, Jon S .	AFWAL / MLBC (AFSC) Wright-Patterson AFB Ohio 45433	513-255-2201
RUTH, J. E.	Martin Marietta Aerospace 103 Chesapeake Park Plaza Baltimore, Maryland 21220	301-338-5471
SAUER, Gerald L.	Narmco Materials, Inc. 1440 N. Kraemer Blvd. Anaheim, CA. 92806	714-630-9400
SCHNEIDER, Cecil W.	Lockheed - Georgia Co. D-72-77 Zn.399 86 S. Cobb Dr. Marietta, GA. 30063	404-425-4355
SENICH, George A.	National Bureau of Standards Polymers Div. A209 Washington, D.C. 20234	301-921-3318
SHYPRYKEVICH, Peter	Grumman Aerospace Corp. Mail Stop B10-25 Bethpage, N.Y. 11714	516-575-6295
SIEGMUND, Dr.Robert F.	Ciba-Geigy Corp., CMD 10910 Talbert Ave. Fountain Valley, CA. 92708	714-964-2731
SIGUR, Wanda	Martin Marietta Aerospace Mail Stop 3573 P.O. Box 2930X New Orleans, L.A.	504-255-3617
SODERQUIST, J. R.	Federal Aviation Admin. AWS-103 800 Independence Ave.,S.W. Washington, D.C. 20591	202-426-8198
SOTIR, Socrates P.	Army Materials & Mechanics Research Center Watertown, MA. 02172	617-923-5566

ST.CYR, Marjorie C.	Northrop Aircraft Corp. One Northrop Avenue Hawthorne, CA. 90250	213-416-2347
STINCHCOMB, Wayne W.	Virginia Poly. Inst. Eng. Science & Mech. Dept. Blacksburg, VA. 24061	703-961-5316
STONE, Robert H.	Lockheed, California Co. P.O. Box 551 Burbank, CA. 91520	818-847-4272
SUSMAN, Gene	American Cyanamid Old Post Road Havre de Grace, MD. 21078	301-939-1910
SUTULA, Dr. R. A.	Naval Surface Weapons Center Bldg. 24-2, Code R-32 New Hampshire Ave. Silver Spring, MD. 20910	202-394-2724
TAYLOR, Robert L.	Celanese Specialty Operations 26 Main Street Chatham, N.J. 07928	201-635-4135
THOMPSON, R. J.	Mobay Chemical Penn Lincoln Pkwy. Pittsburgh, PA. 15205	412-777-2916
TOWNSEND, Herbert N.	Union Carbide Corp. Old Ridgebury Road Section M-1 Danbury, CT. 06817	203-794-3750
TRACESKI, Frank T.	Army Materials & Mechanics Research Center Arsenal St. Attn: DRXMR-SMS Watertown, MA. 02172	617-923-5567
TRULSON, O. C.	Union Carbide Old Ridgebury Road Danbury, CT., 06817	203-794-3730
VOSTEEN, Louis F.	NASA Langley Research Center Mail Stop 188M Hampton, VA. 23665	804-865-2361
WELLER, Richard D.	Naval Surface Weapons Center Silver Spring, MD. 20910	202-394-1317
WHITE, J. L.	The Aerospace Corp. P.O. Box 92957 Los Angeles, CA. 90009	213-648-6276
WILLIAMS, Dr. J. G.	NASA Langley Research Center Hampton, VA. 23665	804-865-4052

DISTRIBUTION OF THIS DOCUMENT

Initial distribution of this document included all listed on the preceding attendee list, and in addition included the following:

N.R. Adsit
H.R. Textron, Inc.
2485 McCabe Way
Irvine, CA 92714

Donald J. Baker
MS 1888
NASA, Langley Research Center
Hampton, VA 23665

Gordon Bourland
LTV Aerospace & Defense Co.
Vought Aero Products Div.
P.O. Box 225907
Dallas, TX 75265

Martin Burg
Composite Market Reports
7670 Opportunity Road, #250
San Diego, CA 92708

J. William Davis
3M Co.
Structural Products Dept.
3M Center, Bldg, 230-1F-02
St. Paul, NM 55144

Albert C. Fehrle
Dept. 72-771/ Zone 399
Lockheed Georgia Co.
Marietta, GA 30063

Samuel P. Garbo
United Technologies
Sikorsky Aircraft
North Main St.
Stratford, Conn. 06601

Commander
U.S. Army Aviation Systems Command
DRSAV -EAS (Attention: Phil Haselbauer)
4300 Goodfellow Blvd.
St Louis, MO 63120

Henry G. Heck
Dow Chemical U.S.A.
412 Commonwealth Rd.
P.O. Box 400
Wayland, MA 01778

Ted Hicks
Code 3242
Naval Weapons Center
China Lake, CA 93555

John Hinman
AMOCO Chemicals Co.
200 E. Randolph Drive
Chicago, IL 60601

Ray E. Horton
Boeing Commercial Airplane Co.
P.O. Box 3707 M.S. 6C-11
Seattle, WA 98124

W.W. Houghton
Army Materials & Mechanics Research Center
Watertown, MA 02172

N.H. Kordsmeier, Jr.
Lockheed Missiles & Space Company
1111 Lockheed Way
Sunnyvale, CA 94086

Ted Kruhman
U.S. Polymeric
700 East Dyer Rd.
Santa, Ana, CA 92707

A. Hans Magiso
Boeing Vertol Co.
P.O. Box 16858
Philadelphia, PA 19142

Leonard Marchinski
Boeing Vertol Co.
M.S. F32-38
P.O. Box 16858
Philadelphia, PA 19142

Joseph S. McDermott
Society of the Plastics Industry, Inc.
355 Lexington Avenue
New York, NY 10017

Frederick M. Norton
Hercules, Inc.
Bacchus Works NZEG-17
P.O. Box 98
Magna, UT 84044

Bryan M. Noton
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201

Harry E. Pebly, Jr.
Plastics Technical Evaluation Center
U.S. Army Armament Research & Development Command
Dover, NJ 07801

R. Byron Pipes
Center for Composite Materials
201 Spencer Laboratory
University of Delaware
Newark, Delaware 19716

John J. Ricca
Army Materials and Mechanics Research Center
Watertown, MA 02172

Richard C. Rice
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201

D.G. Richardson
Lockheed California Co.
Burbank, CA 91520

John Schibler
Hughes Helicopters M/S. 6-C-352
Centinela and Teale Sts.
Culver City, CA 90230

Larry Sparks
National Bureau of Standards: 773.30
325 Broadway
Boulder, CO 80303

Walter L. Torrey (2)
ASD/ENFSS
Wright Patterson AFB, OH 45433

Terry L. Vandiver DRSMI - RLC
U.S. Army Missile Command
Redstone Arsenal, AL 35898

Brian A. Wilson
Aerojet Strategic Propulsion
Box 15699C DP 5855 B 1900
Sacramento, CA 95813

Director
DoD-IDA Management Office
1801 N. Beauregard Street
Alexandria, VA 22311

Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209
Attn: Dr. F.W. Patten
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Defense Technical Information Center (12)
Cameron Station
Alexandria, VA 22314

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