MATERIAL INFORMATION AND DESIGN DATA

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The development of materials property design data for aerospace applications has been in process ever since Orville Wright flew the first airplane. Despite this mass of data which has been developed over nearly sixty years, ever-changing technologies require an accelerated effort for generation of materials property information of sufficient quality and quantity for design support purposes on a timely basis.

The Directorate of Materials and Processes, ASD, placed emphasis on filling the more critical gaps in specific materials information areas since it cannot hope to produce all desired data. Three types of gaps seem to stand out insofar as data generation is concerned, namely: (1) Information on promising newly developed materials or material systems is not available, (2) Available information on established materials is of questionable quality or testing conditions, and (3) Available information on existing materials is based on too few tests and too few lots of the material.

Each of the above points warrants a bit of additional discussion. For example, in considering the first gap in view of continuous and rapid development of new materials, we wonder, "How early in the development in a given material should the generation of design data begin?" It is, of course, customary to screen data concurrently with development effort. However, before a design engineer can incorporate a new material into a final design, it is necessary to have comprehensive and reliable materials property data. In the past, the design engineer was satisfied with mechanical property data, but now additional properties such as the thermophysical and electrical properties of materials are necessary to make more efficient design usage.

The second gap concerns the inadequacy or questionable quality of existing and available information on established materials. This deficiency has been most pronounced in the area of thermophysical properties, although it applies in part to mechanical properties as well. Because of the lack of standardization of measurement techniques, problems concerning thermophysical properties, published in great volume in the literature, are still not fully resolved. These include thermoconductivity of metals and nonmetallic materials, of sandwich and composites, and emissivity. In the area of mechanical properties we face such criteria as notch sensitivity; thermal shock; low cycle fatigue; and time, load, and temperature simulation requirements. Although there is concerted effort on the part of industry to resolve this problem, there is still much to be desired. More sophisticated types of materials evaluation require more information on the effects of load-time-temperature environment on various types of materials and their properties. This would include structural plastics, ceramics and intermetallics, composites, refractory metals and their coatings, insulating materials and materials systems.

Air Force objectives strive to:

(1) Provide in-house facilities and techniques to obtain engineering data on promising newly developed materials with a minimum of delay.

(2) Determine from such engineering data whether it is feasible to obtain more comprehensive design data on the new materials, and

(3) Appraise the necessity for more specialized tests, such as effects of load and temperature spectra and the effects of environment, to bring out unique advantages or limitations in the applications of the new material.

The extent to which all of the above shall be conducted must be evaluated since use of the material is also dependent on such factors as producibility, fabricability, and the availability of uniform material in commercial quantities.

To help achieve these objectives and to overcome some of the obstacles prevalent in design because of insufficient data, a number of programs are being conducted by the Air Force which will provide the necessary equipment for accurately obtaining the data needed. Predominant are means for high temperature data generation which involves both development of better heating facilities and property measuring techniques at these high temperatures. One significant example of the type of progress needed in many areas is shown by the successful development in this area of direct strain measurement over a 2-in. gage length of tungsten up to 4750°F. The resultant curve is shown in figure 1. To the best of our knowledge there has been no other such strain recording at this temperature; yet, a much broader capability in this area is needed.

One aspect of this improvement is the development of new methods for presenting design data. As with most novel approaches, the reception of these procedures has been slow, but just as the Ramberg-Osgood parameters, and then the Larsen-Miller parameters were utilized for data interpretation and prediction, so is it expected that the test of time and use will more fully develop other methods which can be universally accepted.

One of the more recently proposed methods, which is particularly connected with prediction of results, is a means of determining the strength of a material after it has been subjected to various temperature and time histories. An example of this shown in figure 2. Another involves creep data prediction by use of a nomograph in which the amount of creep strain in a given material can be determined if the stress and time are known (figure 3). Still a third relates creep and fatigue data and the limitations that creep superimposes on fatigue (figure 4). Another provides a statistical means of determining the extent of tests to be accomplished for obtaining valid data as indicated in figure 5. These methods are still in the early stages of evaluation but are representative of the type of thought being given to presenting data in meaningful ways.

The third type of gap, involving too few tests and too few lots of material on which property information is furnished, ties in directly with the data collection problem. Although tests conducted by one organization may be insufficient adequately to authenticate its data, data from other sources may support or negate the results if test information were only made available through publication in the literature.

This third gap logically brings us to one of the basic difficulties with materials research in particular and scientific research in general, namely, lack of transmission of information and data.

The generation of data is naturally of very little value other than to the originator if the results are not distributed to other scientists or engineers. One of the basic problems, however, is to get these results to the people who could properly use them. Possibly, all have had the experience of the very great problem of attempting to read everything available in a field of interest. In many cases, the very piece of literature needed to solve a specific problem under consideration goes unread, undigested, and unused. This is due in part to the extensive boom in scientific and engineering literature in the past several years. It has been estimated that in every 24 hours, enough technical papers are prepared to fill seven sets of a 24-volume Encyclopedia Britannica. This represents approximately 60 million pages of scientific literature per year. It has also been estimated that research and development comprises 2 1/2 percent of our gross national product. Again, it has been estimated that the present cost to the United States in documentation, storage, and retrieval of information alone, is approximately one billion dollars. Nevertheless, basically, the result of research and development is information which must be transmitted before it is truly effective. It is significant that up to 50 percent of our research and development effort is wasted because of poor information exchange. These facts indicate how extremely difficult it is for a laboratory scientist or engineer to stay abreast of his field. He must be aided, therefore, in receiving information pertinent to his field by having as much as possible of the extraneous matter and information removed.

Information agencies established during the past few years have begun to fill this particular need in the scientific community. (They also play an important role in actual laboratory scientific research.)

Concurrently, materials research, too, has increased at a rapid rate over the last several years. As in many other fields, advanced technical requirements have dictated the development of new materials or the adoption or restudy of old materials with new requirements in mind. There has resulted, therefore, in many articles, reports, and books detailing the role of various materials in these new technologies. It would be difficult to estimate how many. But, as an example, the Directorate of Materials and Processes alone has generated in 20 years over 10,000 reports of various types pertinent to the Aerospace Materials Industry. Add to this similar efforts of other Government agencies and private industries studying aerospace materials and it can be easily estimated that over 1/2 million reports in this category have been developed, representing a wealth of information. Unfortunately, some of these reports receive limited distribution, others obtain scant attention when received because of other pressures on potential readers.

The Directorate of Materials and Processes has attempted to correct this situation. It has circulated over 3/4 million copies of its reports in an effort to keep the Aerospace Materials Industry informed. It has recognized the fact that to establish the most fruitful materials research programs, its own scientists and contractors must have available to them the most recent information on what has been and what is being accomplished in their particular field. Additionally, a comprehensive program has been established concerned with efficient collection, judicial evaluation, and systematic storage of data. Obviously, this program is a tremendous help in relieving the "materials" man from many hours of "digging for data" and frees him to exert his efforts on more rewarding tasks.

While every aspect of information or data processing is important, the first step, naturally, is the collection of data. This is being accomplished in several ways as follows. The Directorate

(1) Obtains copies of all reports prepared by the Directorate of Materials and Processes and its contractors.

(2) Screens all reports issued by the Air Force Systems Command and utilizes those which have reference to materials.

(3) Receives information of current materials research programs being conducted by the Army, Navy, and the Air Force, both under contractual effort and internal research.

(4) Collects all reports through the DOD Departmental Agencies or ASTIA pertinent to materials.

(5) Negotiates agreements with Weapons Systems or Aerospace contractors to obtain materials data from their records which may not have been previously published because of lack of time or money. (In this effort we are receiving data on over 125 materials.)

(6) Obtains data or information as a result of screened abstracts in the materials area.

Evaluating properly and correlating data is of paramount importance to its use. Reliability in this effort can only be ascertained by people who are knowledgeable in the particular materials discipline which is being considered. As part of our collection program, we require that whenever possible we obtain all the information pertinent to the results that have been obtained such as the heat treating process, test techniques used, the specimen geometry, the strain rate, the environmental conditions involved; in short, as much information as can possibly have any effect whatsoever on the overall results. These factors are, of course, carefully considered during data evaluation in determining its overall reliability.

Information or data storage must of necessity be tied in with the method of retrieval since a competent storage and retrieval system is the crux of the advantage of data or information to the scientific user. If it isn't in the system, or if it cannot be located even if it is in the system, it is, of no value to the investigator. Systems for storing materials information are many. The Directorate has adopted a coordinate indexing system, at present on a manual basis, with the expectation that a machine method will be adopted later.

Adequate dissemination of data is, of course, the most important part of the overall program. Several methods are being used and include:

(1) Processing specific requests for information or data.

(2) Preparation and distribution of data sheets and state of the art reports on pertinent materials.

(3) Publication of digests on current materials programs.

(4) Routine distribution of specific available information to known users of such data.

Specific programs in effect in the information processing activity fall presently into three categories, namely, processing of information, data sheets, and handbooks. Coincident with the information processing system, studies are made of the basic requirements in information processing systems and an examination of existing information centers, the type of information handled, the manner in which it is being processed, and the problems involved to identify areas where there is a lack of effort or data, to devise and implement an awareness program among potential users of materials data, and to develop a limited central literature searching activity.

Back of processing materials knowledge is the philosophy that specialized information can best be handled by organizations that have a good deal of background in a particular materials area. The Directorate has concentrated in the past year on three specific areas so far as establishing information programs are concerned. These are: First, activities in which thermophysical properties are the prime product; second, electronic and electrical properties; and third, mechanical properties. Many have heard of and know quite well the Thermophysical Properties Research Center (now about four years old) located at Purdue University. The Directorate partly sponsors this activity and supports programs to obtain data on thermoconductivity of ferrous and nonferrous alloys and 28 gases; emissivity of pure metals, alloys, and coatings; specific heat of pure metals and alloys; and viscosity of 28 gases; plus support of volume II of the Retrieval Guide. Those who have had the opportunity to review the volume I of Retrieval Guide know its immense potentialities and its significant advances in the field of thermophysical properties of materials. The second program, Electronics and Electrical Properties Information, has as its purpose to collect and publish data sheets on properties of materials which could be used for electronic or electrical applications. This effort has just come into being and the first part of the program is concerned primarily with establishing the system to be utilized and with performing the initial work on semi-conductors. The Mechanical Property Information effort has not yet reached the stage of completion which the other two activities have. However, during the past year, much of the work that would normally be accomplished in processing data sheets on mechanical properties has been accomplished through contracts in other areas. Currently, a great deal of fatigue data and creep data have been obtained, and other types of materials properties to a somewhat lesser degree. All of which are being processed and distributed to Aerospace Industries as required.

Establishing other information programs for specific types of properties or materials has been considered but additional guidance is needed from the Aerospace Industry.

Adequate service in these information programs requires working closely with established materials information centers such as the DOD sponsored Defense Metals Information Center (DMIC) at Battelle and the Plastics Technical Evaluation Center at Picatinny Arsenal. This association includes mutual exchange of information and coordination of programs. In the case of DMIC, the Directorate has been assigned contract monitoring responsibility. There are, of course, many other information activities, both government sponsored and private. A report listing those concerned with materials has been prepared so that their services may be used whenever needed.

Handbooks have always been, and probably will continue to be, used to a great extent by the practicing engineer for basic and empirical information. In the design of components, handbooks give, most readily, information which can be transmitted to the drawing board. It is imperative, as it is in such information, that the contents of the handbook be pertinent, accurate, and of the type that will be of the most use or will lead to the most useful information in the specific area. Some of the handbooks of particular concern are:

(1) A design Handbook on Structural Plastic Materials. This handbook will include properties of structural plastic materials, design criteria, stress analysis for specific applications, processing and tooling information, and its effects on properties, testing, and quality control.

(2) A Handbook on Properties of Metals and Alloys. This handbook is a continuing effort which resulted in the Air Weapons Materials Application Handbook, Metals and Alloys. This publication contains a comprehensive listing of a number of metals covering

all aspects of information and properties on a large number of metals. The continuation effort includes 40 metals and alloys not listed in the current handbook and includes titanium, aluminum, low alloy and carbon steels, martensitic and austenitic stainless steels, ultra high strength steels, cobalt and nickel based alloys and refractory metals. As indicated earlier, the various types of properties, whether normally considered design data properties or not, are included.

(3) Electronic Encapsulating Materials Handbook. This includes information on potting and encapsulating materials for insulation, shock protection, and moisture proofing of electronic equipment and components. This handbook is now in the process of being printed and will contain approximately 500 pages of properties and materials covering epoxies, polyesters, urethanes, silicone rubbers and thermoplastics. Information is also given on applicable temperature ranges of these materials.

(4) Handbook on Elastomer Design. This includes information on elastomer properties, design criteria and methods in application information on a wide variety of elastomer materials. It is designed to assist the component designer in elastomer selection.

(5) MIL-Handbook 5, Strength--Metal Elements; MIL-Handbook 17, Plastics for Flight Vehicles; and MIL-Handbook 23, Composite Construction for Flight Vehicles. These handbooks are supporting the design books containing data which have been verified as to their practicability and usefulness for design. (The Navy and FAA assist in their preparation.)

As part of the program, MIL-Handbook 5 is being placed on magnetic tape which will contain all of the data now in the handbook. This is a pilot program to determine the feasibility of putting all similar handbooks on magnetic tape for easy and versatile retrieval.

In summary, then, we would like to emphasize five points which we think are necessary to ensure the proper selection of materials to be used in design. These are:

(1) Continued effort to develop improved criteria for evaluation of materials which more closely relates them to conditions anticipated in service.

(2) Development of commercially available testing equipment for

(a) Simulation of load-temperature-environment based on service conditions, known, and projected.

(b) Determination of thermophysical properties within the present state of the art, i.e., thermal conductivity, and emissivity (total normal, spectral, and total hemispherical).

(3) Freer exchange of conventional data obtained by industrial organizations on like materials to enhance the objectivity of property appraisal and to add to the reliability of resulting property values.

(4) Broader use by industry of similar techniques, equipment, and criteria to obtain the same properties on the same classification of materials.

(5) More detailed description of equipment and techniques used for generation of property data.

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STRESS-STRAIN CURVE FOR TUNGSTEN

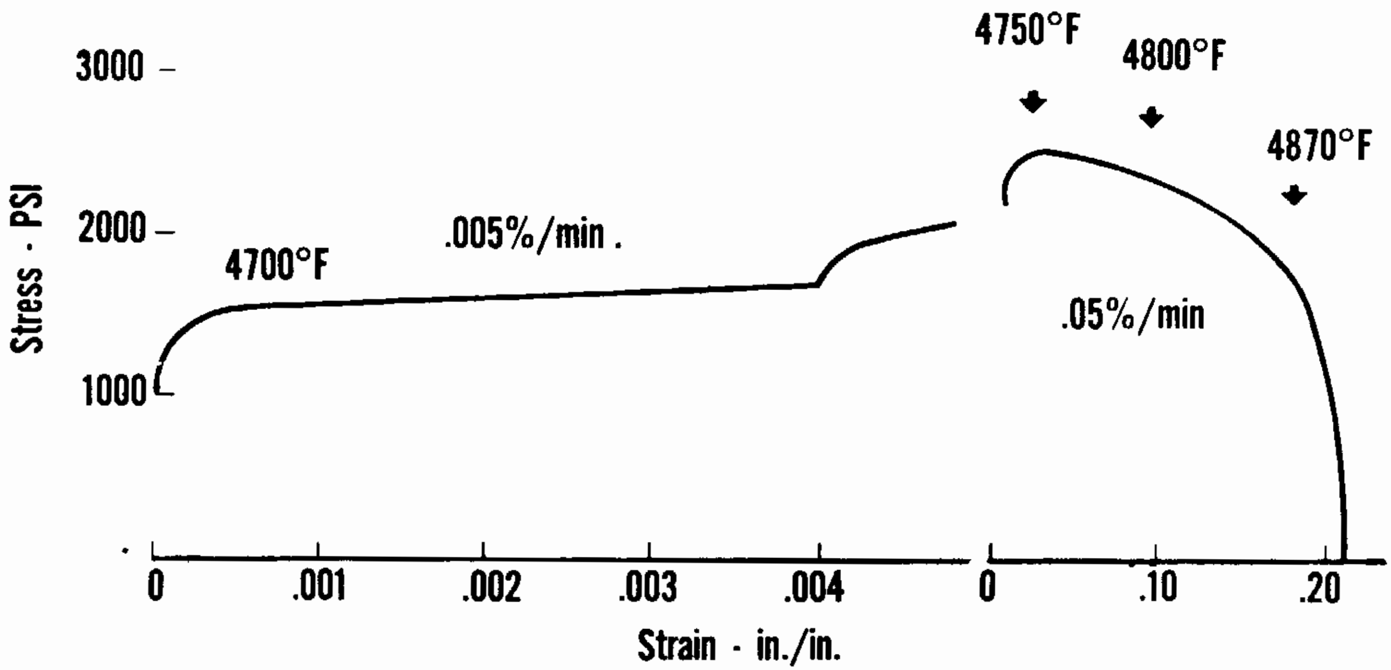

Figure 1. Stress-Strain Curve for Tungsten

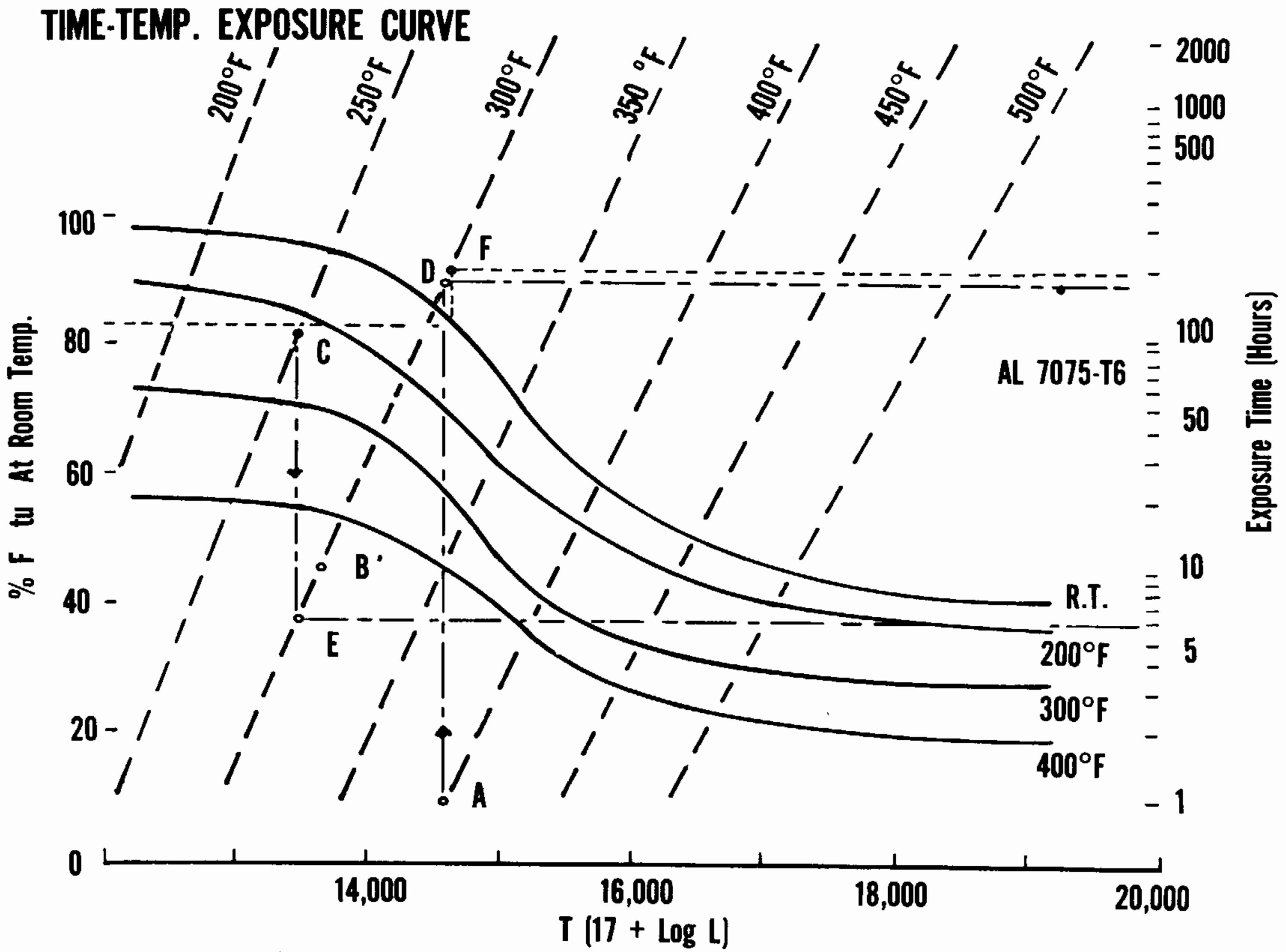

Figure 2. Time-Temperature Relationship

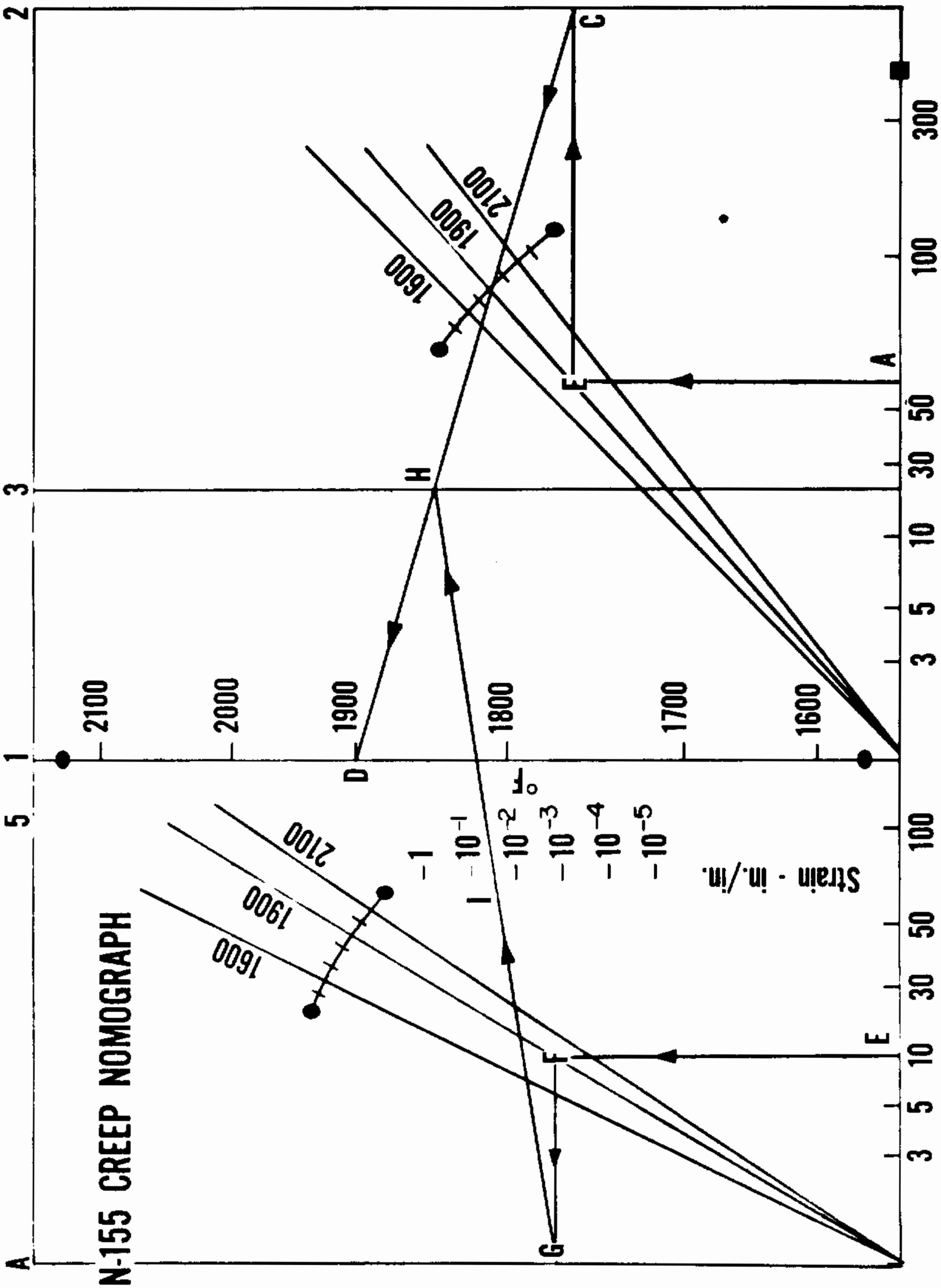

Figure 3. N-155 Creep Nomograph

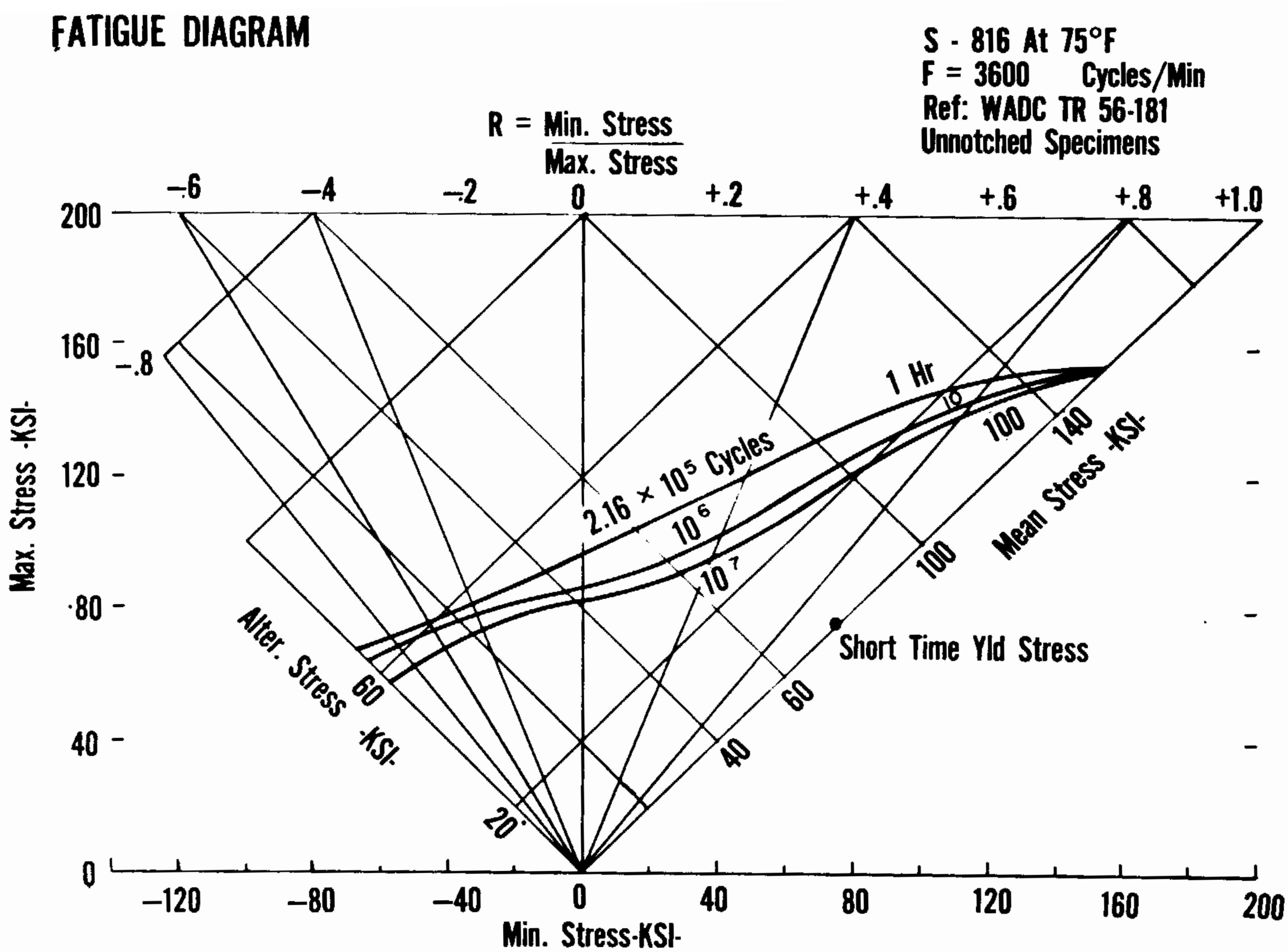

Figure 4. Fatigue and Creep 24S-T4 500°F Data from WADC TR 53-510 I

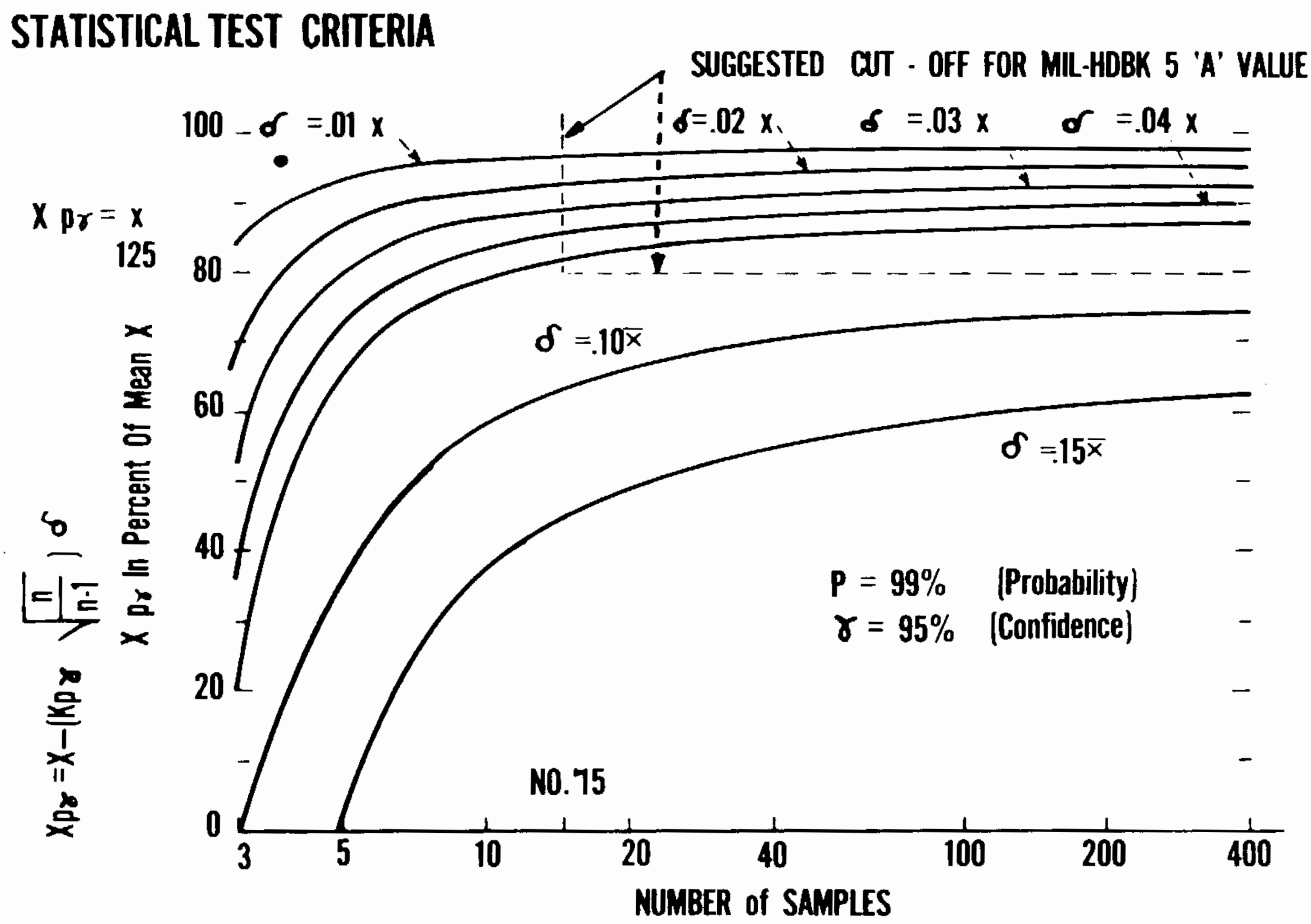

Figure 5. Statistical Test Criteria