THE COLLECTION, GENERATION, AND ANALYSIS OF MIL-HDBK-5 ALLOWABLE DESIGN DATA

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FOREWORD

This report was prepared by Battelle's Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201, under USAF Contract F33615-71-C-1381. This effort has been administered under the direction of the Air Force Materials Laboratory, Air Force Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio, with Mr. D. A. Shinn (LAA) as project engineer.

This annual report covers the period of work from February 15, 1971, to February 15, 1972. This report was submitted by the authors in March, 1972.

This technical report has been reviewed and is approved.

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ABSTRACT

The Department of Defense has designated the Air Force as the preparing activity responsible for MIL-HDBK-5, which is the primary source for design allowable data for metallic materials, fasteners, joints, and other structural elements used in the design of aerospace vehicles. The Air Force Materials Laboratory has contracted with Battelle's Columbus Laboratories (BCL) to provide the planning, coordination, and implementation activities necessary to maintain current design allowable data in the Handbook. The services provided by BCL for the MIL-HDBK-5 program involve the following: an assessment of the design data requirements of the aerospace industry; liaison with appropriate Government agencies, military services, aerospace contractors, and metallic material suppliers; collection of data; statistical analysis of data to determine design allowable properties; preparation of proposals which contain the revisions to MIL-HDBK-5 for the incorporation of new data; presentation of these proposals at the twice-yearly Government-industry coordination meetings for approval; and revision of MIL-HDBK-5 to incorporate these approved changes.

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INTRODUCTION

This annual report describes the activities, accomplishments, and progress of the MIL-HDBK-5 program for the reporting period from February 15, 1971, through February 15, 1972. The Military Standardization Handbook, MIL-HDBK-5, "Metallic Materials and Elements for Aerospace Vehicle Structures", is recognized as the primary source for design allowable data by the Department of Defense (DoD) and other Government agencies responsible for aerospace vehicle design. The Handbook contains design allowable data on metallic materials, fasteners, joints, and other structural elements. The maintenance of this document is achieved through the cooperative efforts of the Air Force, Navy, Army, Federal Aviation Agency (FAA), National Aeronautics and Space Administration (NASA), and industrial users and suppliers of metallic aerospace materials. The DoD has designated the Air Force as the activity responsible for preparing this Handbook. As such, the Air Force Materials Laboratory (AFML) has contracted with Battelle's Columbus Laboratories (BCL) for the past 18 years to provide the planning, coordination, and implementation necessary to develop and maintain current design allowable data and other related information in MIL-HDBK-5.

Following the Summary, this report documents specific activities of BCL personnel assigned to this program. These include (1) liaison with cooperating organizations, (2) assessment of design allowable data requirements, (3) data collection and processing, (4) data analysis and reporting, (5) participation in special task groups, and (6) administrative functions. During the reporting period, the AFML and FAA provided funding to support the MIL-HDBK-5 program.

SUMMARY

The services provided by BCL in the operation of the ongoing MIL-HDBK-5 program were comprehensive in nature and involved a variety of activities. The data collection process was preceded by an assessment of the design data requirements of the aerospace industry. These needs were determined by visits and telephone discussions with the various aerospace contractors and governmental agencies and from contacts at the twice-yearly MIL-HDBK-5 Government-industry coordination meetings. Also, questionnaires were sometimes employed.

After identifying the requirements, the data collection process began with the solicitation of aerospace companies, material producers and fabricators, and Governmental agencies, as well as a search of the Metals and Ceramics Information Center (MCIC) files for applicable data. Unpublished data received (usually in the form of data displays and internal reports from aerospace material suppliers) were logged in a project data diary and given an accession number. Published reports received became a part of the MCIC files. Pertinent data were encoded and keypunched on electronic data processing (EDP) cards.

Mechanical property data were statistically analyzed in accordance with the procedures outlined in Chapter 9 of MIL-HDBK-5B[1], utilizing computer programs developed in previous years on this program. In this manner, minimum design properties for tension ultimate, tension yield, compression yield, shear ultimate, bearing ultimate, and bearing yield strengths were determined. Data for fasteners, joints, and other structural elements were also analyzed in accordance with Chapter 9, on the basis of reports primarily from the fastener companies. In some cases, average or typical values were established. Proposals containing the necessary revisions to MIL-HDBK-5 for the incorporation of new design allowable data were then prepared. These proposals included the supporting data documentation as well as an explanation of the statistical procedures and engineering decisions used in the analyses. Generally, proposals concerned new design allowable data for the common aerospace materials: steel, aluminum, magnesium, titanium, heat-resistant alloys, and beryllium as well as for structural joints (fasteners, etc.). However, considerable effort was involved in determining the type of information to include in the Handbook and in developing analytical procedures for data from new tests, such as fracture toughness and residual strength, crack growth rates, and stress corrosion, which are important in characterizing a material. Proposals were also prepared for ultimate incorporation in Chapter 9 to cover the analysis procedures and data presentation methods to be used for these new properties.

These proposals and those prepared by aerospace companies and material producers are presented at the Government-industry coordination meetings for approval. Proposals that are approved are incorporated into MIL-HDBK-5 by revision of the Handbook. Those proposals not approved at the above meetings are referred to BCL or the originator for further study.

Revisions of the Handbook are normally accomplished by change notices. However, a complete revision is necessary periodically. During this reporting period, considerable effort has been applied to completing Revision B of MIL-HDBK-5 which has been reorganized into two volumes. MIL-HDBK-5B was issued in February, 1972.

Incidental to the primary functions described above were numerous related activities. In order to assess current and future MIL-HDBK-5 requirements and to develop sources for data, liaison was maintained with aerospace contractors, governmental agencies, material suppliers and fabricators, and fastener manufacturers. Special task groups were utilized in the development of analytical procedures and the establishment of methods for data presentation.

To support the MIL-HDBK-5 program, certain administrative activities were also necessary. These duties included coordinating arrangements for the twice-yearly coordination meetings; notifying representatives of Government and industry of meeting arrangements; planning, preparing, and mailing meeting agenda

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(1) Chapter 9 of MIL-HDBK-5B is an updated version of AFML-TR-66-386, "MIL-HDBK-5 Guidelines for the Presentation of Data", dated February, 1967.

(including reproducing proposal attachments to the agenda); and preparing and mailing the official meeting minutes (including reproducing attachments to the minutes). In addition, project files, computer card files, and material specification files were maintained.

LIAISON WITH COOPERATING ORGANIZATIONS

About 2 years ago, many of the aerospace companies agreed to participate in some depth in the MIL-HDBK-5 program. Two features of this cooperation have been particularly pertinent to the program during this reporting period: (1) identification of needs for design allowable information and (2) provision in a timely manner of data obtained on research and development contracts funded by Government agencies and in-house resources. These activities and others required reasonably constant liaison with the aerospace company personnel. This liaison has been carried out by telephone contacts, letters, specific visits, and contacts at the coordination meetings. A list of the aerospace companies with which a significant number of contacts have been made during the year is shown in Appendix I.

During the reporting period, emphasis was placed upon the increased involvement of material suppliers who had not previously participated in the MIL-HDBK-5 program. As a result, Harvey Aluminum, Incorporated, Allegheny Ludlum Steel Corporation, Wyman Gordon Company, Webber Metals and Supply Company, Olin Aluminum, and International Nickel Company, Incorporated, have contributed mechanical property data or provided other support to the MIL-HDBK-5 program. Appendix II is a list of metallic material suppliers with which a significant number of contacts have been made during the year. Liaison with these metal producing companies was maintained to review programs, provide data, or to coordinate the preparation of agenda items. The participation of additional suppliers is highly desirable since it provides a broader data base.

Liaison with the fastener manufacturers also was maintained in a variety of ways. These included telephone calls, letters, discussions at the coordination meetings, and contacts at the various meetings of the DoD-sponsored Fastener Test Development Group. Primarily, these contacts were to assess new fastener developments and also the programs in progress or completed that would lead to agenda items. Those fastener companies with which liaison was maintained are shown in Appendix III.

Activity was maintained with a number of Government agencies: AFML and Aeronautical Systems Division at Wright-Patterson Air Force Base, Naval Air Systems Command, Naval Air Development Center, Army Materials and Mechanics Research Center, FAA-Washington, NASA-Langley Research Center, NASA-Marshall Space Flight Center, and NASA-Manned Space Center. The general features of these contacts were to evaluate the status of design allowable programs and to acquaint personnel in these organizations with the MIL-HDBK-5 project. Expansion of this effort is planned during the next year.

A close working relationship was continued with MCIC, which was a major source of published mechanical property data conveniently located at BCL.

The overall liaison effort has provided a valuable insight into current and future materials data generation programs and potential sources of data. It has been a substantial boon to other aspects of the program as will become evident in subsequent sections of this report. An assessment of the scope of these activities is provided from an estimate of the number of contacts made by project personnel each month. Including only letters, telephone calls, visits to companies, and visits at BCL, about 30 contacts have been made on the average each month during the year.

This active series of contacts has had an especially profound influence on this program. During the coming year, the number of contacted organizations is expected to increase.

ASSESSMENT OF DESIGN ALLOWABLE DATA REQUIREMENTS

Through liaison and discussions with the various aerospace companies as previously described, a continuous effort has been made to assess the current and future requirements of the aerospace industry for MIL-HDBK-5 type of data. This assessment has been considered necessary in order that new data which is needed can be collected, analyzed, approved and incorporated into MIL-HDBK-5 on a timely basis. Visits to the various aerospace contractors and the twice-yearly MIL-HDBK-5 coordination meetings have provided the best opportunity to determine current and future MIL-HDBK-5 needs. However, questionnaires also have been utilized to poll the participating aerospace industry. An example of a questionnaire concerning aluminum castings is shown in Appendix IV. This questionnaire was included in Reference 4 which was mailed to the MIL-HDBK-5 participants. Other questionnaires and mailings have concerned fastener requirements, plane-stress fracture requirements, the reporting and handling of stress-strain curves and tangent modulus curves, and various sections of Chapter 9 which are in the process of revision. The input from the questionnaires has provided relevant direction for certain items on the agenda.

DATA COLLECTION AND PROCESSING

The collection and processing of data can be divided into two categories: (1) the handling and processing of incoming data for future retrieval or input and (2) the retrieval and handling of required data in order to perform statistical analyses of certain properties or output. The following subsections describe these procedures as developed and used by BCL MIL-HDBK-5 project personnel.

Input - General Description

Data collection efforts have been primarily directed toward specific active items on the MIL-HDBK-5 agenda. However, as a result of increased liaison activity with the Government, the aerospace industry, the material suppliers or fabricators, and the fastener manufacturers, a better awareness has been achieved with regard to developing design data needs before they actually appear as formal agenda items. Consequently, a complete system for acquiring, reviewing, selecting, and cataloging data packages for immediate as well as future use has been developed during the past 2 years. Fortunately, the existence and proximity of MCIC have made some aspects of data acquisition much easier. Essentially all of the published (released for general dissemination) data in the MCIC files have been available to the MIL-HDBK-5 project and were readily retrievable by project personnel as the need arose.

Much of the data acquired by the MIL-HDBK-5 project during the past year have not been published but were in the form of internal company reports or memorandum, photocopies of material certification sheets, punched EDP cards or magnetic tape. The acquisition and processing of these packages are shown pictorially as the input phase in Figure 1.

Starting at the point where the package already has been deemed to contain useful engineering data, the first question posed was whether the package was or should be an MCIC document. If MCIC oriented, then a determination was made as to whether the document was of current or future MIL-HDBK-5 interest. If applicable to MIL-HDBK-5, then the MCIC accession number was the only bibliographic record that was required to be stored by MIL-HDBK-5. The document bibliographic control, storage, and retrieval tasks were handled routinely by MCIC. When MCIC data of current or near future interest have been utilized by MIL-HDBK-5, the data were usually incorporated on punched EDP cards along with the MCIC accession number and stored in the MIL-HDBK-5 computer card file, after which the document was returned to MCIC files. The details of data encoding are described in Appendix V.

For those documents containing useful design data but not to be included in MCIC's files (for such reasons as: not pertinent to MCIC scope, data provided only on punched cards or tape, or some restriction imposed by the

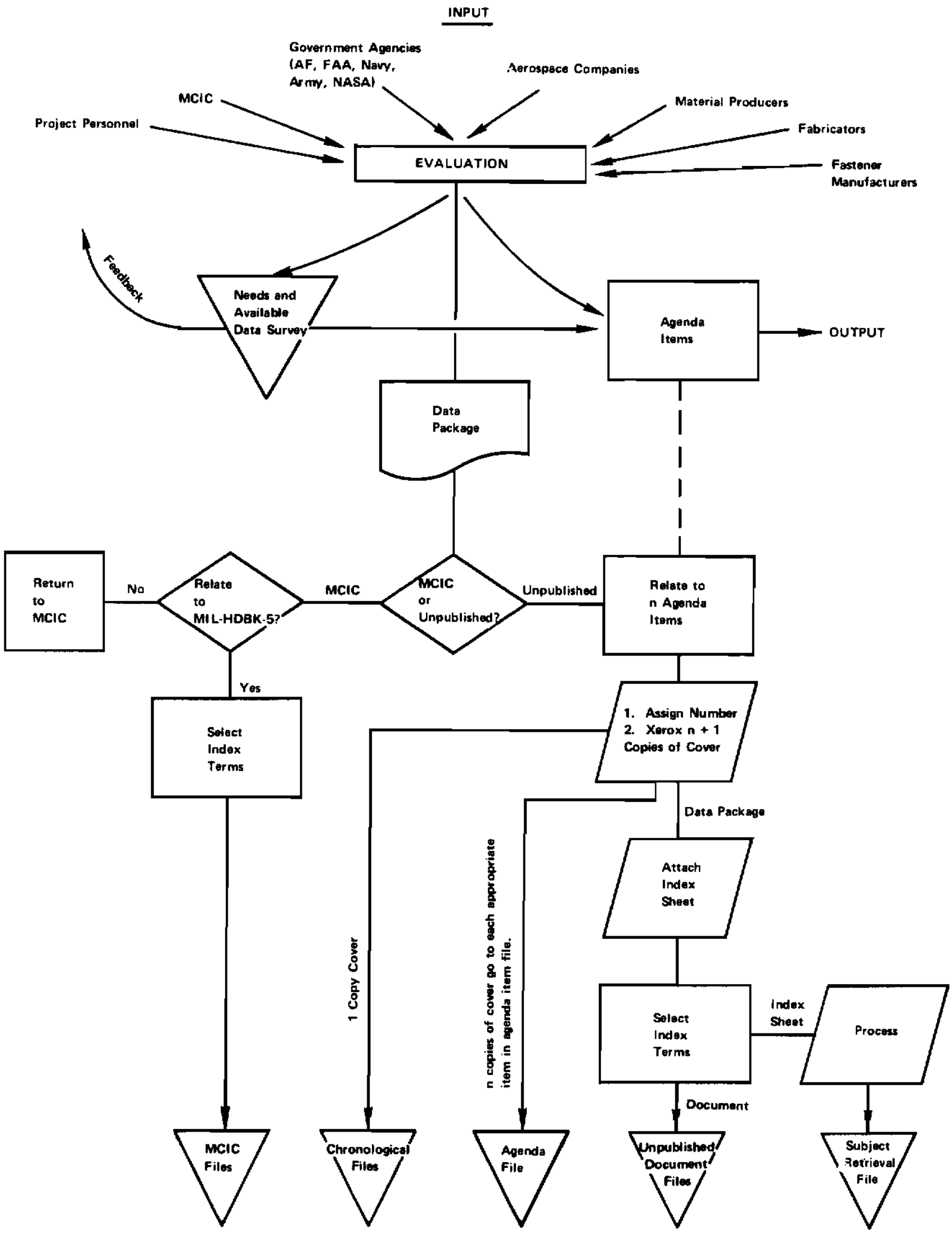

FIGURE 1. MIL-HDBK-5 DATA PROCESSING SYSTEM – INPUT

supplier of the data), a relatively simple processing procedure has been devised. After assigning the data package an accession number (prefaced by M to distinguish between MCIC's number system), a determination was made of MIL-HDBK-5 agenda items for which the data in the package were relevant. This has ranged from none to several items depending upon the nature of the data package. The agenda number(s) were written on the cover along with the accession number. A copy of the cover was filed with the working papers for each agenda item for which the data were relevant. The document then was simply stored chronologically. As each agenda item file was pulled to prepare a proposal or report, a collection of sheets identifying pertinent documents was readily available.

For data documents for which no immediate agenda item was active and for documents which contain data for other alloys, forms, or conditions in addition to active items, an index sheet was prepared which serves as the basis for future retrieval.

Output - General Description

The output phase began with the identification of a specific task or agenda item. A flow chart is depicted in Figure 2. In an initial assessment of the item, the kind of specific data needed to accomplish the analysis was determined. The needed data then were obtained from the MCIC file by project personnel, from the MIL-HDBK-5 representatives, from other known sources, and from the MIL-HDBK-5 file of unpublished data. The documents containing data pertinent to the task at hand were collected and the specific data in each document were selected. Based on the objective of the analysis and correlative information to be presented with the data, an appropriate encoding format was established. During the consideration of a given item, it has frequently been found necessary to contact the source of the data to obtain additional correlative information. A data diary sheet was prepared which describes the data encoded. The diary sheets were filed numerically by accession number and contain the following information:

Accession number	Alloy
Source	Form
General description	Condition
Item number	Special encoding.

A sample data diary sheet is shown in Figure 3. For example, in this particular data analysis it was desired that the effects of test location within a forging and the heat-treat section size be evaluated. The heat-treat section size was encoded in card columns 77-80 in an F4.3 format. (FORTRAN notation for describing a field four characters long and three decimal places to the right of an implied decimal point.)

After encoding, keypunching, and verifying the data, they were analyzed and proposals or reports were prepared for the MIL-HDBK-5 coordination

OUTPUT

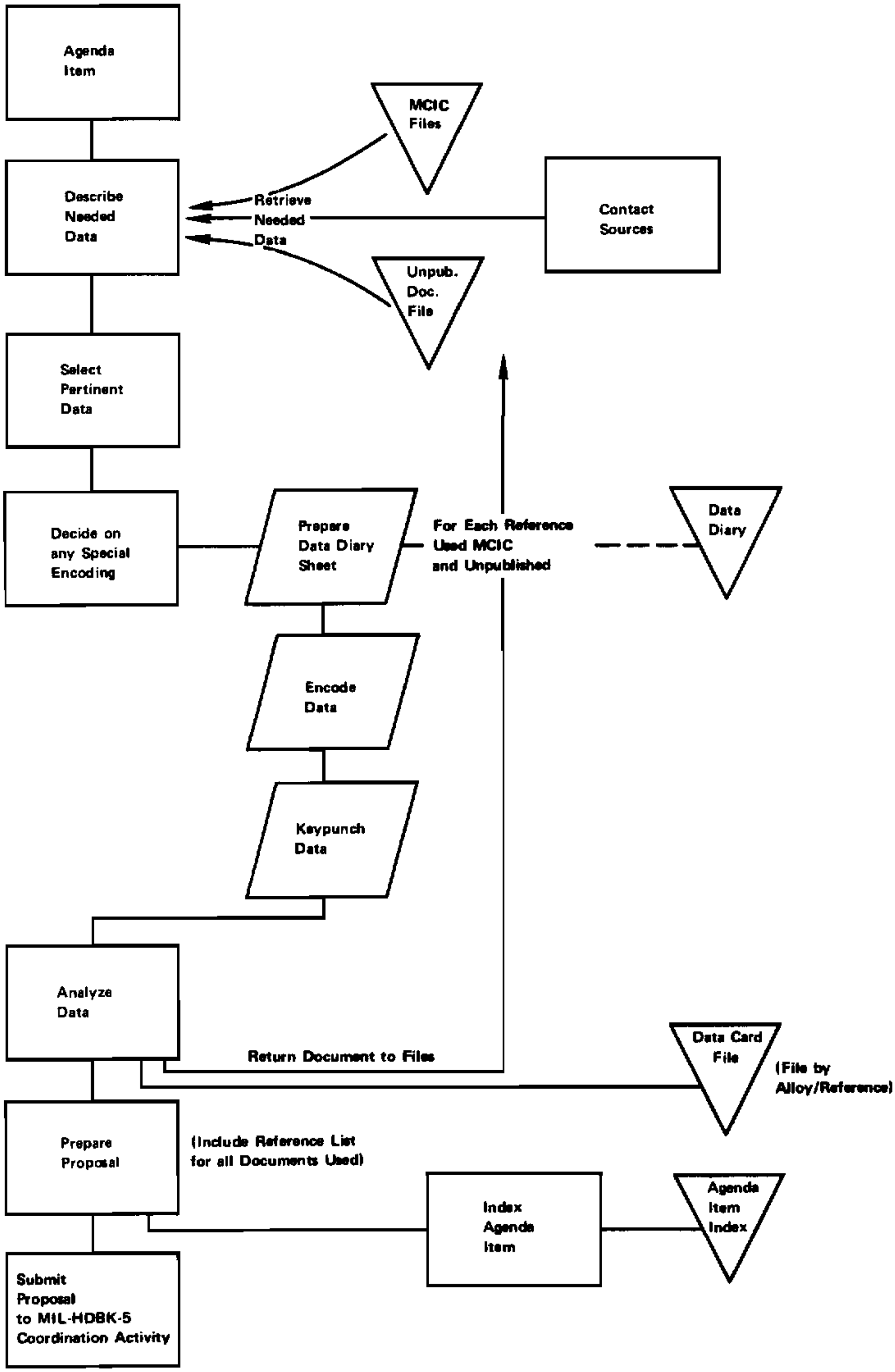

FIGURE 2. MIL-HDBK-5 DATA PROCESSING SYSTEM – OUTPUT

SOURCE:	Letter to Ron Favor from S. J. Erwin of Wyman-Gordon Co., 8/11/71
GENERAL DESCRIPTION:	Tension test results on B-52 gear made from 7049 aluminum
ITEM NO:	71-20
ALLOY:	7047
FORM:	Forgings
CONDITION:	T73

SPECIAL ENCODING:

cc 65-67	Test location	(A3)
68-69	Heat-treat lot	(A2)
70-72	Electrical conductivity	(F3.1)
73-76	Forging section size	(F4.2)
77-80	Heat-treat section size	(F4.3)

FIGURE 3. SAMPLE DATA DIARY PAGE

activity. The documents, punched data cards, and working papers then were returned to their respective files.

Data Acquisition via Computer Tape

A few but growing number of companies, both aerospace and material suppliers, have been accumulating data (primarily certification type data) on EDP cards. In 1971, one company agreed to transmit their file of mechanical property data to the MIL-HDBK-5 program by means of magnetic tape. A tape was mailed to the company and the company read their cards onto the BCL tape and returned the tape with their format described. A computer program was prepared which read selected data off the tape, punched it on EDP cards and arranged it in MIL-HDBK-5 format. Thus, several thousand data points were acquired at a fraction of the usual cost and time by the elimination of encoding and keypunching. It is planned to utilize this method whenever possible in the future.

ANALYSIS AND REPORTING

Analysis

After encoding, keypunching, and verifying the data, statistical analyses were performed in accordance with the procedures outlined in Chapter 9 of MIL-HDBK-5 utilizing various computer programs developed in the past for specific use on this project. A description of these computer routines is given in Appendix V. The general analytical approach used to determine A(2) and B(3) design allowable properties for tensile ultimate strength, tensile yield strength, compressive yield strength, shear ultimate strength, bearing ultimate strength, bearing yield strength, elongation, and reduction of area involved the following procedure.

From the gross sample the population was specified to insure that the resulting computed design allowables were realistic. If the gross sample was composed of subpopulations, such as data from different suppliers, different lots, different heats, different sizes, different grain directions, different processing histories, and different product forms, a decision had to be made as to whether these subpopulations could be combined. To resolve this question, statistical tests of significance (F and t tests as described in Appendix V and Chapter 9 of MIL-HDBK-5) were performed on the subpopulations. If these tests

(2) The A mechanical-property value is the value above which at least 99 percent of the population of values is expected to fall with a confidence of 95 percent.

(3) The B mechanical-property value is the value above which at least 90 percent of the population of values is expected to fall with a confidence of 95 percent.

indicated no significant differences in the data, the subpopulations were combined. When properties were found to vary continuously with some characteristic such as thickness, regression analysis was employed.

Next, the sample size was examined to decide whether the design allowable should be computed directly or indirectly. When the sample was large, direct computational procedures were used. The room temperature design allowables were regularly determined by direct computation only for tensile yield and tensile ultimate strengths, since there were seldom enough data for the use of this procedure to determine remaining properties.

The next step was to determine whether the distribution of the tensile data was normal or nonnormal by employing the "chi-squared" test (described in Chapter 9 of MIL-HDBK-5). If the data were normally distributed and the sample size was 100 or greater, minimum design values for tensile yield and tensile ultimate strengths were computed using the formulas given in Chapter 9 of MIL-HDBK-5). If the data were not normal, at least 300 observations were required so that computation could proceed without knowledge of the distributional form by employing the nonparametric technique described in Chapter 9 of MIL-HDBK-5. This procedure involved the determination of design allowables from ranked values.

Where small samples (as few as ten measurements) were involved, indirect computations were made. Generally, this procedure was employed for compressive yield strength, shear ultimate strength, bearing ultimate strength, and bearing yield strength. These derived properties were those room-temperature mechanical property values that were established through their relationships to directly calculated values for room-temperature tensile ultimate strength or tensile yield strength design allowables. This procedure is described in detail in Appendix V and Chapter 9 of MIL-HDBK-5.

Due to the paucity of data, this same ratio procedure was also utilized to determine the effect of temperature on design properties. (See Appendix V and Chapter 9 of MIL-HDBK-5.)

For some properties such as fatigue, creep, fracture toughness, and stress corrosion, typical properties were established which have no statistical significance. For the properties of joints and structures, a combination of graphical and computational procedures were used to determine design allowables.

One of the most important aspects of the analysis procedure was the engineering interpretation and evaluation of the statistical output. The computed design values were examined for reasonableness and possible trends. In some cases, practical engineering judgment was exercised to override statistical guidelines in the treatment of data. Anomalies were investigated to determine their cause, and resolution was made. This often necessitated coordination with the supplier of the data, material producers, and others. In short, the statistical computer output was always rationalized in terms of engineering practicality before preparation of a proposal.

Reporting

After completing an analysis for a given agenda item, a proposal was prepared which contained the suggested revisions or additions to MIL-HDBK-5 for incorporation of the new design allowable data. The proposal contained the supporting documentation as well as an explanation of the statistical procedures and engineering decisions used in the analysis. An example of a representative MIL-HDBK-5 proposal prepared during the reporting period is shown in Appendix VI.

Proposals generally contained new design allowable data for Chapters 2 through 8 for the common aerospace metallic materials (steel, aluminum, magnesium, titanium, heat resistant alloys, beryllium) and structural joints (fasteners, etc.). However, considerable effort has been involved in determining the optimum type of information to include in the Handbook, developing analytical procedures, and establishing methods of data presentation for some of the newer properties, such as fracture toughness and residual strength, fatigue crack propagation and stress corrosion, which have become increasingly important in the characterization of a material. Consequently, proposals and progress reports also were prepared relative to Chapters 1 and 9 that covered the analysis procedures and data presentation methods to be used for these new properties.

Proposals or progress reports that were prepared by BCL MIL-HDBK-5 personnel were presented verbally to the twice-yearly meetings of the MIL-HDBK-5 coordination activity and were included with either the agenda or the minutes of the meeting. During the past year, BCL MIL-HDBK-5 personnel presented and discussed in detail specific proposals and progress reports at the 41st Coordination Meeting held on April 20 through 22, 1971, at San Francisco, California, and at the 42nd Coordination Meeting held on October 5 through 7, 1971, at Richmond, Virginia. Since other organizations also originated proposed changes and additions to MIL-HDBK-5, these also were discussed and resolved at these coordination meetings. All proposals that were approved by the MIL-HDBK-5 coordination activity were put in final approved form by BCL personnel and issued with the minutes of each meeting. The approved items from the 41st Coordination Meeting were incorporated in Revision B of MIL-HDBK-5; whereas the approved items from the 42nd Coordination Meeting will be incorporated in a change notice to be prepared after the 43rd Coordination Meeting in April, 1972.

Since the technical details and activities involved in these proposals were previously reported in the agenda and minutes for the above meetings (References 1 through 4), this type of information is not included in this report. However, a list of items completed in 1971 including items for which progress reports were made are shown in Appendix VII. A brief description of the activity is given for each item. Appendix VIII is a list of new agenda items introduced in 1971. Shown in Appendix IX is a list of current active items which will constitute the agenda for the 43rd Coordination Meeting.

New Computer Routine Development

During the reporting period efforts were made to improve existing computer routines and develop new programs capable of more sophisticated analyses. As a result of increased liaison activity with the suppliers of input data to the MIL-HDBK-5 program, more definitive correlative information is becoming available for consideration during the data analyses. These factors, coupled with increased data handling capability of new computer programs have contributed to a more useful evaluation of the effect of variables. A better assessment of their individual and interactive significance will begin to appear in future proposals and reports for the MIL-HDBK-5 activity. An example of this kind of analysis was the study of the effect of oxygen content and thickness on the strength of titanium continuous-rolled sheet (Item 69-2) as reported at the 42nd Coordination Meeting.

A new system of computer programs called Statistical Package for Social Sciences (SPSS) has recently become available on the BCL computer and has been adopted for MIL-HDBK-5 utilization. This system has been designed to provide a unified and comprehensive package enabling many different types of data analysis to be performed in a simple and convenient manner. SPSS allows a great deal of flexibility in the format of data. It provides the user with a comprehensive set of procedures for data transformation and file management as well as a large number of statistical routines. The existing MIL-HDBK-5 computer programs require a considerable amount of manual manipulation, such as sorting, merging, and resorting in order to accomplish a sequence of tasks. In the SPSS system, once the raw data have been entered in the system, the computer can be instructed to carry out a variety of sorting, selecting, and computational tasks in any sequence the circumstances dictate. For example, tensile strength data for a forging alloy could be analyzed according to initial thickness ranges, heat-treat thickness ranges, grain directions, and heat-treat tempers without manual intervention, thus saving time. This system can perform multiple regression as well as numerous other commonly used procedures in data analysis.

The language of SPSS is FORTRAN IV, the same as for other MIL-HDBK-5 routines. Some experience has been gained in using this package to analyze 7049 and 7175 aluminum-alloy die-forging data (Items 68-23 and 71-20) in preparation of proposals for the 43rd Coordination Meeting.

Programs SC4060 and REGRES were also developed for MIL-HDBK-5 in 1971. Program SC4060 simply prints a display of the entered data in terms of one measured value versus some other measured value. Visual examination can then assess whether there is any relationship between the two variables and, if so, delineate the mathematical model which best fits the data. The mathematical model so determined and the MIL-HDBK-5 data are then entered into the REGRES program, which computes the regression and prints out the regression coefficients. Program REGRES will also solve the resulting equation at desired values of the independent variable.

Input for Specifications

The MIL-HDBK-5 program has occasionally contributed to another area of activity by providing input for new specifications or specification revisions. Frequently, when specifications for new materials are initiated, there is a paucity of data upon which to establish minimum mechanical properties. Through collective efforts, the MIL-HDBK-5 files may contain the greatest quantity of data available on that particular material. In the past, a statistical analysis of such data has provided an "A" value or a reasonable good estimate of an "A" value. Since "A" values and "S"(4) (specification) values usually are identical, the "A" values for tensile properties have been used for specification values. Additionally, when the analysis of MIL-HDBK-5 data has shown that existing specification values have not agreed closely with the statistically determined "A" value, action has been initiated to obtain a revision of the specification.

Occasionally consideration of an item at a coordination meeting has revealed that existing material specifications were not adequate. For example, at the 42nd Coordination Meeting (held on October 5 through 7, 1971), BCL MIL-HDBK-5 personnel presented a proposal to incorporate updated A and B values for PH13-8Mo bar, H1000 condition. It was pointed out that the existing specification covers the H950 condition and that there is no specification coverage for the H1000 and other "overaged" tempers. The MIL-HDBK-5 coordination activity expressed considerable concern over this lack of proper specification coverage. As a result, BCL MIL-HDBK-5 personnel recommended to the Manager, Technical Division, Society of Automotive Engineers, Inc., that specification AMS5629 be revised to include the overaged tempers. It also was pointed out that the same situation exists for 17-4PH, 15-5PH, and PH14-8Mo corrosion resistant steels. As a result of this action, a draft of the revised PH13-8Mo specification, AMS5629B, was circulated to AMS members and interested suppliers for approval on January 12, 1972.

PARTICIPATION IN SPECIAL TASK GROUPS

During the reporting period, BCL MIL-HDBK-5 personnel participated in each of the various MIL-HDBK-5 special task groups which were active in the solution of specific problems. The active special task groups and their functions are described below.

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(4) The "S" mechanical-property value is the minimum value specified by the governing Federal Specification, Military Specification, or SAE Aerospace Material Specification for the material. For certain products heat treated by the user, the "S" value may reflect a specified quality-control requirement.

The Task Group on Structural Elements was established during the reporting period by the Chairman of MIL-HDBK-5 Coordination Group for the purpose of determining whether methods of structural analysis for certain elements such as beams, columns, frames, trusses, plates, membranes, and similar structural members should be incorporated into MIL-HDBK-5. This Task Group consisted of the following members:

Mr. D. Altman, Chairman
Douglas Aircraft Division
McDonnell Douglas Corporation
Long Beach, California

Mr. C. Davis
Los Angeles Division
North American Rockwell Corporation
Los Angeles, California

Mr. C. Parsons
Commercial Airplane Group
The Boeing Company
Seattle, Washington

Mr. J. Wordsworth
Lockheed California Company
Lockheed Aircraft Corporation
Burbank, California

Mr. W. Poindexter
Vought Aeronautics Company
LTV Aerospace Corporation
Dallas, Texas

Mr. J. Peterson
Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia

After studying this problem, the Task Group recommended that "MIL-HDBK-5 should not have a major expansion in scope to include methods of structural analysis such as analysis of beams, columns, frames, trusses, plates, membranes, and similar structural items." Also, "Expansion of the document to include information on element behavior should emphasize the pertinent aspects of material behavior needed to assist the design function." This recommendation was accepted by the coordination activity and the Task Group was discharged by the Chairman of the MIL-HDBK-5 Coordination Group.

The Task Group on Fail-Safe and Residual Strength is charged with the responsibility of making recommendations regarding the type of fracture toughness data which should be incorporated into the Handbook. This Task Group is composed of the following members:

Mr. C. E. Feddersen, Chairman
Battelle's Columbus Laboratories
Columbus, Ohio

Mr. S. H. Smith
Commercial Airplane Group
The Boeing Company
Seattle, Washington

Mr. J. C. Ekvall
Lockheed California Company
Lockheed Aircraft Corporation
Burbank, California

Mr. F. C. Allen
Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California

Mr. O. N. Thompson
Fort Worth Division
General Dynamics Corporation
Fort Worth, Texas

Mr. J. G. Kaufman
Alcoa Research Laboratories
New Kensington, Pennsylvania

Mr. E. K. Walker
Lockheed California Company
Lockheed Aircraft Corporation
Burbank, California

During the reporting period, this Task Group was concerned with the formulation of guidelines for plane-stress and transitional fracture toughness data evaluation and presentation. These guidelines have been reviewed by the coordination activity and are currently being revised. When finally approved, these procedures will be incorporated into Chapter 9 of the Handbook.

The Fatigue Task Group, which has the responsibility of making recommendations regarding methods of analysis and presentation of fatigue data, consists of the following members:

Mr. G. E. Bockrath, Chairman
Astronautics Company
McDonnell Douglas Corporation
Huntington Beach, California

Mr. C. E. Jaske
Battelle's Columbus Laboratories
Columbus, Ohio

Mr. C. E. Davis
Los Angeles Division
North American Rockwell Corporation

Mr. Glenn Lattin
Sikorsky Aircraft Corporation
Stratford, Connecticut

Mr. Frank Borriello
Naval Air Development Center
Warminster, Pennsylvania

Mr. A. P. Cowles
Naval Air Systems Command
Washington, D. C.

Mr. C. L. Harmsworth
Air Force Materials Laboratory
Wright-Patterson Air Force Base, Ohio.

There were three areas of concern leading to reestablishing this Task Group a few years ago: (1) to provide for statistical analysis of fatigue data, (2) to provide for notch effects, and (3) to include low cycle fatigue data. During the reporting period, BCL MIL-HDBK-5 personnel provided two progress reports on this item relative to the use of an effective strain-lifetime approach that appears to combine unnotched and notched specimen data reasonably well in the low- to high-cycle range. Several effective strain-lifetime relations can be employed and current efforts are examining goodness of fit tests for each.

The Fastener Task Group, which is responsible for the review of proposals for fastener design-allowable data as well as the refinement of the fastener-data-analysis methods, has the following membership:

Mr. W. S. Hyler, Chairman
Battelle's Columbus Laboratories
Columbus, Ohio

Mr. C. E. Parsons
Commercial Airplane Group
The Boeing Company
Seattle, Washington

Mr. R. P. Stewart
Aeronautical Systems Division
Wright-Patterson Air Force
Base, Ohio

Mr. A. P. Cowles
Naval Air Systems Command
Washington, D. C.

Mr. E. J. Bateh
Lockheed Georgia Company
Lockheed Aircraft Corporation
Marietta, Georgia.

During the reporting period, several proposals were reviewed and their adoption was recommended to the MIL-HDBK-5 coordination activity. In other cases, the proposals were referred back to the originating organization for further testing and analysis. In addition, the Task Group began revision of the section of Chapter 9 that describes data requirements and analysis of mechanically fastened joints. The purpose of this revision is to make the section easier to follow and delineate more clearly some of the requirements for test data, analysis and reporting.

Liaison with the DoD-sponsored Fastener Test Development Group (FTDG) was maintained by BCL MIL-HDBK-5 personnel. This Group is concerned with the development of fastener test methods which are embodied in MIL-STD-1312. Some years ago, the Chairman of the MIL-HDBK-5 Coordination Group on request from the aerospace companies suggested that the coordination activity be represented on the FTDG by one of the Battelle program personnel. This was done, and during the past year it has involved attending three meetings of the FTDG, circulating proposed new test standards to those on the coordination activity who wish to comment, collating comments, and presenting the coordinated remarks to the FTDG at each meeting.

ADMINISTRATIVE

BCL MIL-HDBK-5 personnel have attended and entered into discussions of all agenda items at the Government-industry coordination meetings held twice yearly. The two meetings during this reporting period have been previously cited in this report. At both of the meetings, project personnel also were involved in task group meetings which were held to acquaint the task groups of progress during the previous 6-month period and to describe projected activity for subsequent months. The meetings provided an opportunity for the task group members to concur with or redirect efforts.

The duties of the secretary for the MIL-HDBK-5 Coordination Group now are performed by BCL personnel. These tasks during the past year included planning and obtaining agenda inputs for the coordination meetings, notifying representatives of Government and industry of meeting arrangements, preparing and mailing meeting agenda including reproducing proposal attachments to the agenda, and preparing and mailing the official meeting minutes including reproducing attachments to the minutes.

In order to reduce costs by minimizing the labor involved with the attendant routine secretarial details, a series of integrated computer programs utilizing a common data base has been developed for maintaining attendance lists, mailing lists, and telephone lists, as well as for printing mailing labels.

The project file, which contains the pertinent working information for each agenda item, has been rearranged and improved during the past year so that historical reviews of activities in the past relative to a given material or subject can be more easily traced. In addition, filing systems for computer cards containing the statistical data and material specifications have been maintained.

One of the important tasks performed by BCL personnel is the revision of MIL-HDBK-5 to incorporate the design allowable data approved by the Government-industry coordination activity. Most of the revisions are accomplished by change notices to MIL-HDBK-5. However, it becomes necessary periodically to make a complete revision. During the reporting period, intensive effort has been applied to completing the B Revision of MIL-HDBK-5. This process included (1) final consolidation and editing of text material based upon the final suggestions of each chapter review group, which are composed of individuals from the coordination activity, (2) typing text material as a master copy, (3) editing of all tables (including some major revisions in format), (4) correcting master copies of all tables in accordance with edited versions, (5) editing all figures (including redrawing of some master copies), (6) correcting master copies of all figures in accordance with the edited versions, (7) reproducing final copy, (8) securing approval of final copy from appropriate government agencies, (9) preparing final copy with complete typesetting instructions, and (10) proofreading printer's copy. The MIL-HDBK-5B revision was issued in February, 1972.

FUTURE PLANS

During the next year, closer liaison will be maintained with the aerospace industry, particularly engine and space contractors so as to better assess the future MIL-HDBK-5 design data requirements, to review design allowable program plans and activities, to solicit mechanical property data, and to develop potential sources for future data. These tasks will be accomplished by an increased number of visits by BCL MIL-HDBK-5 personnel.

Emphasis will be placed on securing greater supplier involvement so as to broaden the MIL-HDBK-5 data base. Attempts will be made to obtain data from suppliers who have not previously furnished data. With the possible adoption of a new set of minimum data requirements for new materials at the 43rd Coordination Meeting, it is anticipated that a closer coordination in data generation will develop between suppliers and BCL MIL-HDBK-5 personnel.

Data sources will be encouraged to accumulate data on EDP cards so that MIL-HDBK-5 type data can be acquired via magnetic tape. This method will be utilized whenever possible due to significant cost savings.

It is anticipated that more sophisticated statistical analyses will be employed in the coming year through the development of new and improved computer routines. The SPSS computer program will be exploited more fully, especially in evaluation of the effect of multiple variables on strength properties.

Based upon current assessment of future MIL-HDBK-5 requirements, emphasis will be placed on the incorporation of data for the fracture and stress-corrosion-resistant materials, especially the new aluminum alloys such as 7175-T736, 7049-T73, and 2124-T851. Effort will continue to determine the type of information to include in the Handbook, to develop or improve analytical procedures, and to establish new or improved methods for the presentation of data for such properties as fracture-toughness, fatigue and stress-corrosion-resistance.

During the next year, issuance of technical reports, in addition to the annual report, is planned. These technical reports will cover specific materials where significant technical progress of general interest has been achieved.

APPENDIX I

AEROSPACE COMPANIES CONTACTED

Aerojet Nuclear Systems Company
Aerojet General
P.O. Box 13070
Sacremento, California
95813

Energy Controls Division
Bendix Corporation
717 North Bendix Drive
South Bend, Indiana
46620

Aerospace Group
The Boeing Company
P.O. Box 3990
Seattle, Washington
98124

Commercial Airplane Group
The Boeing Company
P.O. Box 3707
Seattle, Washington
98124

Wichita Division
The Boeing Company
3801 S. Oliver
Wichita, Kansas
67210

Buffalo Facility
Curtiss Wright Corporation
P.O. Box 13
Buffalo, New York
14215

Convair Aerospace Division
General Dynamics Corporation
P.O. Box 1128
San Diego, California
92112

Fort Worth Division
General Dynamics Corporation
P.O. Box 748 Grants Lane
Fort Worth, Texas
76101

General Electric Company
Jimson Road
Evendale, Ohio
45215

Grumman Aerospace Corporation
Bethpage, New York
11714

Hamilton Standard
United Aircraft Corporation
Windsor Locks, Connecticut
06096

Lockheed-California Company
Lockheed Aircraft Corporation
P.O. Box 551
Burbank, California
91503

Lockheed Missiles and Space Company
Lockheed Aircraft Corporation
P.O. Box 504
Sunnyvale, California
94088

Lockheed-Georgia Company
Lockheed Aircraft Corporation
86 South Cobb Drive
Marietta, Georgia
30060

Astronautics Company
McDonnell Douglas Corporation
5301 Bolsa Avenue
Huntington Beach, California
92647

McDonnell Aircraft Company
McDonnell Douglas Corporation
Box 516
St. Louis, Missouri
63166

Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California
90801

APPENDIX I (Continued)

Columbus Division
North American Rockwell Corporation
4300 East Fifth Avenue
Columbus, Ohio
43216

Los Angeles Division
North American Rockwell Corporation
International Airport
Los Angeles, California
90009

Space Division
North American Rockwell Corporation
12214 Lakewood Boulevard
Downey, California
90241

Northrop Corporation
3901 East Broadway
Hawthorne, California
90250

Rohr Corporation
P.O. Box 878
Chula Vista, California
92012

Sandia Corporation
Box 5800
Albuquerque, New Mexico
87115

Sikorsky Aircraft
North Main Street
Stratford, Connecticut
06602

Sundstrand Aviation
Sundstrand Corporation
4747 Harrison Avenue
Rockford, Illinois
61101

Vought Aeronautics Company
LTV Aerospace Corporation
P.O. Box 5907
Dallas, Texas
75222

APPENDIX II

METALLIC MATERIALS SUPPLIERS CONTACTED

Allegheny Ludlum Steel Corporation
Allegheny Ludlum Industries, Inc.
Dunkirk, New York
10048

Alcoa Research Laboratories
Aluminum Company of America
Freeport Road
New Kensington, Pennsylvania
15068

Premium Casting Division
Aluminum Company of America
1450 Rincon Street
Corona, California
91720

Advanced Materials Division
Armco Steel Corporation
P.O. Box 1697
Baltimore, Maryland
21203

Armco Research Laboratory
Armco Steel Corporation
Middletown, Ohio

Brush Beryllium Company
17876 St. Clair Avenue
Cleveland, Ohio
44110

Stellite Division
Cabot Corporation
1020 W. Park Avenue
Kokomo, Indiana
46901

Steel Division
Carpenter Technology Corporation
P.O. Box 662
Reading, Pennsylvania
19603

H. M. Harper Company
Morton Grove, Illinois

Harvey Aluminum Inc.
19200 South Western Avenue
Torrance, California
90509

Huntington Alloy Products Division
The International Nickel Co., Inc.
Huntington, West Virginia
25720

The International Nickel Co., Inc.
21535 Hawthorne Boulevard
Suite 224
Torrance, California
90503

Center for Technology
Kaiser Aluminum and Chemical Corporation
P.O. Box 870
Pleasanton, California
94566

Kawecki Berylco Industries
220 E. 42nd Street
New York, New York
10017

Olin Aluminum
Olin Mathieson Chemical Corporation
P.O. Box 164
Hannibal, Ohio
43931

Republic Steel Corporation
Research Center
Independence, Ohio

Reynolds Metals Company
6601 West Broad Street
Richmond, Virginia
23218

RMI Company
Niles, Ohio
44446

APPENDIX II (Continued)

Smithford Products Company
1401 South Baker Avenue
Ontario, California
91761

Titanium Metals Corporation of America
195 Clinton Road
West Caldwell, New Jersey
07006

Applied Research Laboratory
United States Steel Corporation
Mail Station No. 78
Monroeville, Pennsylvania
15146

Universal-Cyclops Steel Corporation
Bridgeville, Pennsylvania

Webber Metals and Supply Company
16646 Illinois Avenue
Paramount, California
90723

Grafton Plant
Wyman-Gordon Company
Worcester Street
N. Grafton, Massachusetts
01536

APPENDIX III

FASTENER SUPPLIERS CONTACTED

California Division
National Screw and Manufacturing Co.
3423 South Garfield Avenue
Los Angeles, California
90022

Cherry Rivet Division
Townsend Company
1224 East Warner Avenue
Santa Ana, California
92707

Hi-Shear Corporation
2600 Skypark Drive
Torance, California
90509

Huck Manufacturing Company
2500 Bellevue Avenue
Detroit, Michigan
48207

Olympic Fastening Systems, Inc.
11445 S. Dolan Street
Downey, California
90241

P.B. Fastener Company
1700 132nd Street
Gardena, California
90249

Standard Pressed Steel Company
Highland Avenue
Jenkintown, Pennsylvania
19046

Aerospace Division, Camcar Division,
Textron Corporation
412 18th Avenue
Rockford, Illinois
61101

Voi-Shan Manufacturing Company
8463 Higurea
Culver City, California
90230

APPENDIX IV
ALUMINUM CASTING QUESTIONNAIRE

Company ____________________________

1. Does your company use aluminum castings?
   Extensively ____ moderately ____ seldom ____ never ____
2. Does this use include critical parts (where failure would cause serious problems)? Yes ____ occasionally ____ never ____
3. Which aluminum casting specifications do you use; check each used.
   MIL-A-21180 ____ QQ-A-601 Type ____ AMS Type ____ , Company or Internal Specification ____, Other (please specify) ____________________________
4. Which aluminum casting alloys do you use? (Check those used.)
   201.0 ____ C355.0 ____ A357.0 ____ Other ____________________
   354.0 ____ A356.0 ____ 359.0 ____ ____________________
5. Are the currently available aluminum casting specifications adequate for your needs (for purpose of this question exclude your company or internal specifications). Yes ____ No ____
6. Are changes or improvements in the industry-wide aluminum casting alloy specifications needed? (If so, please explain.) Yes ____ No ____
7. Normally the design mechanical properties listed in MIL-HDBK-5 are:
   Ftu, Fty, Fcy, Fsu, Fbru, and Fbry.
   Are all of these properties pertinent to castings as used by your company?
   Yes ____ No ____
   Are others needed by your company? Yes ____ No ____
   (Please cross out those not needed and list those needed.)
8. In your opinion, would the development of reliable "A" and "B" statistical values for aluminum premium casting alloys, and including these values in the MIL-HDBK-5, be of value and useful to your organization?
   Yes ____ No ____
   Should statistical data be presented based on one or more of the following bases?
   Separately cast test bars ____ test bars attached (integral) to castings ____ destructive testing of casting ____ proof testing or overload service simulated testing ____

9. Are efforts other than specification or standardizations needed for your company to justify greater utilization of aluminum castings?

   Yes ____ (please explain) No ____

10. To develop "A" and "B" values (a statistical basis for properties of aluminum castings) substantial quantities of data sufficiently defined as to origin with correlative information are required for the various types of aluminum castings. Does your company have mechanical property quality control data (or other) available for the MIL-HDBK-5 Coordination Group for use in determining these statistical values?

    Yes ____ No ____

11. The footnote wording as listed in the status report was developed and submitted by K. J. Oswalt of Northrop Norair with help and suggestions from B. J. Alperin of McDonnell Douglas. Both companies make extensive use of aluminum castings in airframe manufacture. It is proposed that this footnote be added to the tables of MIL-HDBK-5 where mechanical properties of MIL-A-21180 are indicated. They consider these requirements essential to the procurement of reliable aluminum castings in most procurement conditions. In view of the type of castings you purchase and your procurement conditions, do you approve? Yes ____ No ____

    Do you disapprove? Yes ____ No ____

    Do you waive? Yes ____ No ____

    (If you disapprove, please explain using examples, and if possible, suggestions for better solutions to the problem.)

APPENDIX V

MIL-HDBK-5 COMPUTER PROGRAMS

A description of the MIL-HDBK-5 computer routines is listed along with some examples of the outputs.

Programs TENSIL, COMPR, and BEARG

Data for MIL-HDBK-5 are encoded on standard forms. Tension data are encoded on the form shown in Figure V-1, compression and shear data on the form shown in Figure V-2, and bearing data on the form shown in Figure V-3. Associated with each of these encoding formats is a computer program which computes, tabulates, and prints a number of quantities. Figure V-4 shows output from program TENSIL which prints columns for tensile yield strength, TYS, tensile ultimate strength, TUS, elongation, reduction of area, and modulus of elasticity. The number of data, average, and standard deviation are shown as the first three entries for these properties. A logarithmic transformation of the raw data is used for elongation and reduction of area before any calculations are made. A tally by deciles rather than the more customary by equal increments of standard deviation is next presented. In the decile tally each cell should contain approximately one-tenth of the total number of data as opposed to the bell-shaped histogram for equal increments. This method has sometimes proved helpful in illustrating the reason and extent of nonnormality. The "chi squared" calculation is made to compare with a stored tabular value to answer the question of normality. The yes or no result is printed out next. Depending on whether the data checks normal or nonnormal, the program then computes the A and B design allowables by one of two methods. If normal, the allowables are computed by subtracting the product of the appropriate one-sided tolerance factor and the standard deviation from the mean value ($\bar{x}$ - ks). If nonnormal, the A and B values are determined from nonparametric techniques provided there are sufficient data. The compression and bearing programs are similar to the tensile program in their output.

Program TMPKRV

For temperatures other than room temperature and for compression, shear, and bearing properties, it is more usual not to have sufficient data (per Chapter 9 of MIL-HDBK-5) to directly compute allowables by the programs TENSIL, COMPR, and BEARG. In this case, the allowables are derived from the room temperature tensile properties by a ratioing procedure. The lower confidence interval estimate is computed on the average ratio and this "reduced ratio" is then multiplied by the directly calculated allowable at room temperature to give a derived ratio for the other property or temperature. A summary of the ratios that are used is tabulated below:

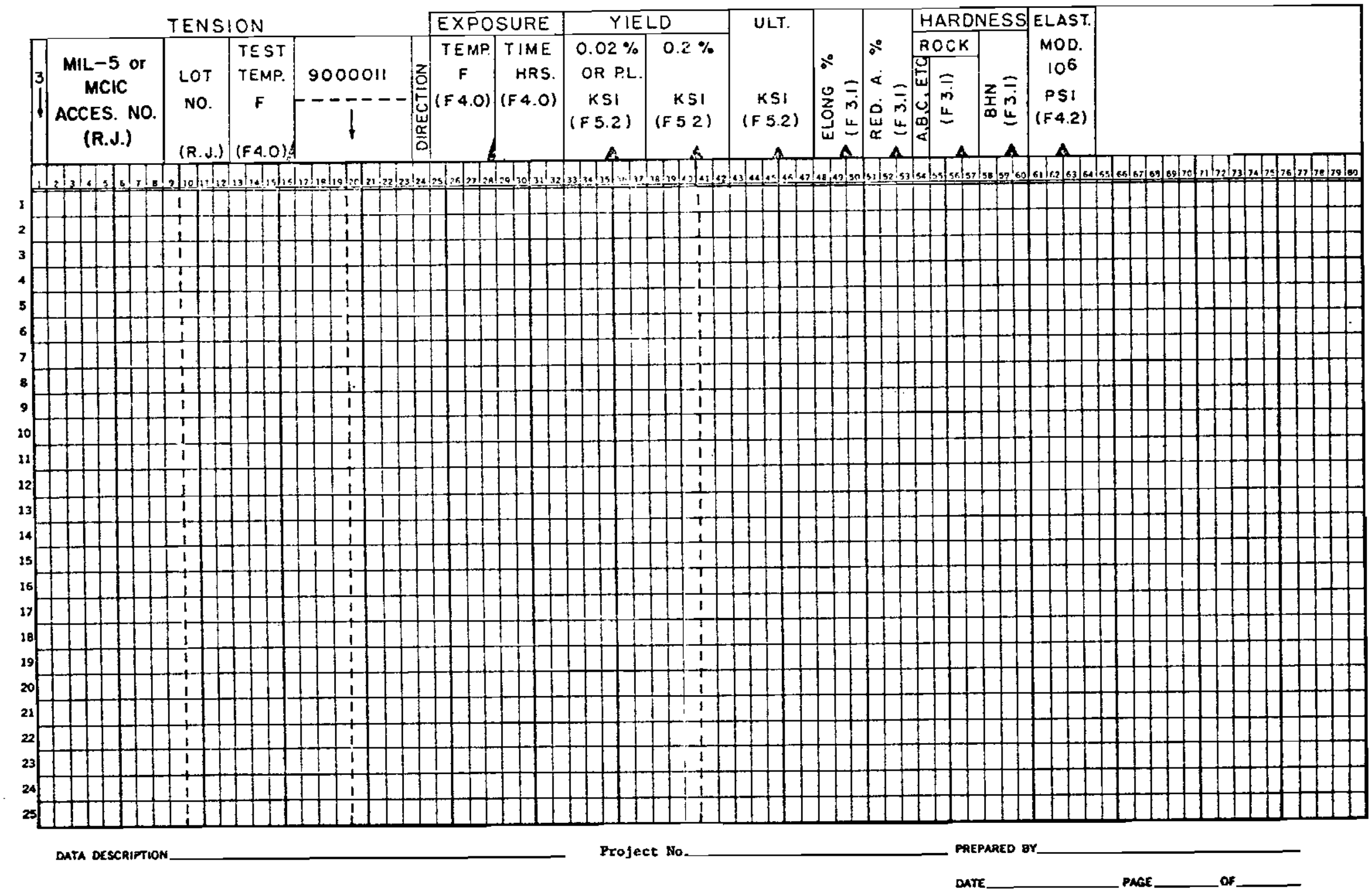

FIGURE V-1. ENCODING SHEET FOR TENSIL PROGRAM

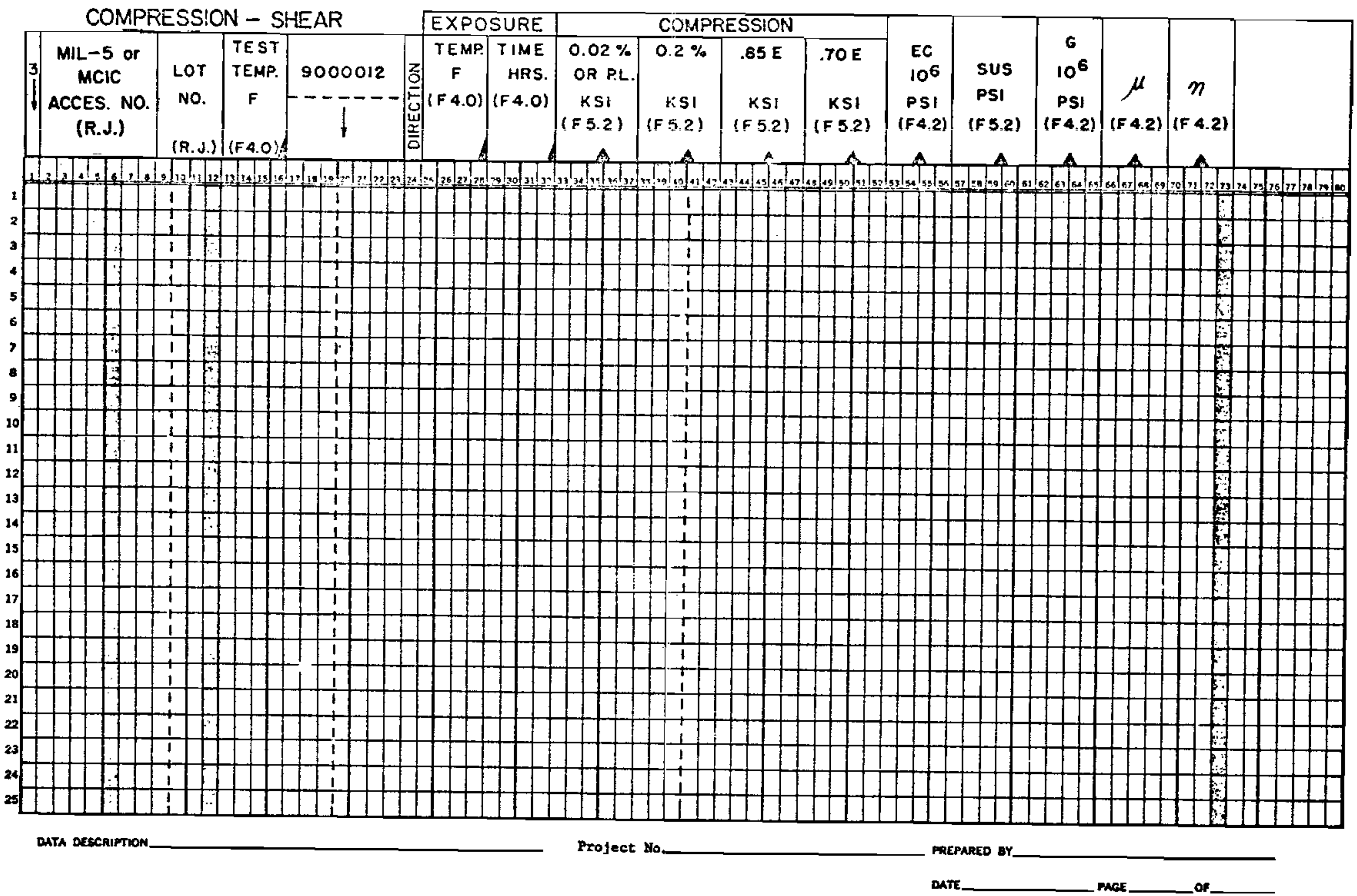

FIGURE V-2. ENCODING SHEET FOR COMPR PROGRAM

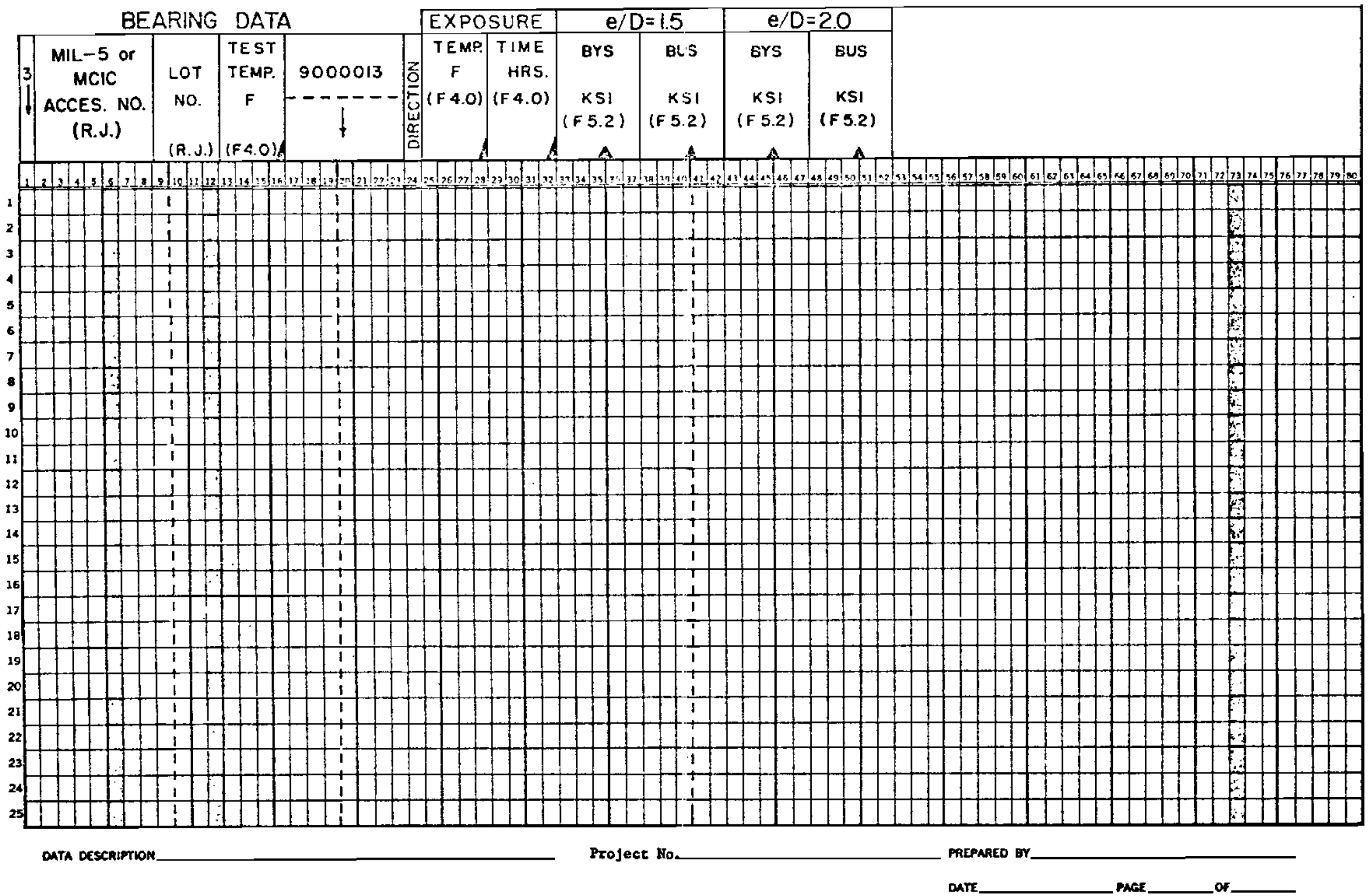

FIGURE V-3. ENCODING SHEET FOR BEARG PROGRAM

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	411	411	411	376	0
AVERAGE	134.92	144.80	1.14*	1.47*	0.00
STD. DEV.	5.127	3.980	0.069*	0.049*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

	33	19	33	26	0
	41	42	40	20	0
	44	76	0	36	0
	68	56	100	46	0
	42	35	1	60	0
	46	37	142	63	0
	42	46	28	41	0
	27	36	0	36	0
	25	19	29	21	0
	43	45	38	27	0
CHI SQUARED	31.26	61.73	463.04	54.96	9999.99
NORMAL	NO	NO	NO	NO	NO

MIL-HDBK-5 A + B VALUES

A BASIS	121.00	133.00	10.00	15.20
B BASIS	128.00	140.50	11.00	25.50

FIGURE V-4. OUTPUT FROM TENSIL PROGRAM

Reduced Ratio of Strength at Temperature/Strength at RT x
Design Strength at RT = Strength at Temperature
Reduced Ratio of Compression Yield/Tensile Yield x Design
Tensile Yield = Design Compression Yield
Reduced Ratio of Shear Ultimate/Tensile Ultimate x Design Tensile
Yield = Design Shear Ultimate
Reduced Ratio of Bearing Yield/Tensile Yield x Design Tensile
Yield = Design Bearing Yield
Reduced Bearing Ultimate/Tensile Ultimate x Design Tensile
Yield = Design Bearing Ultimate

Paired lot averages are entered into program TMPKRV which computes the reduced ratios. Figure V-5 shows a sample output from TMPKRV set up for effect of temperature. The identification of each lot is shown in the first field. The room temperature average for which the derived property is to be ratioed is shown in the second field. There is then a column for each temperature for which there are data. The ratio for each lot is shown in the body of the table. At the bottom of the table is a summary of the statistics for each temperature starting with the number of ratios, the average ratio, some intermediate sums, and ending with the reduced ratio shown in "percent RT". The MIL-HDBK-5 presentation for effect of temperature is as a percent of room temperature value.

Figure V-6 shows the similar output from TMPKRV but set up to compute shear/ultimate ratio rather than a temperature ratio.

Program SEVRAL

In an analysis of property data it is important to identify and characterize the subpopulations or lots of material. Variations in heats of material, thickness, heat treatment, producer, and other variables may have an effect on the properties of that lot. To properly characterize the material, it is well to have sufficient lots of material over the expected range of these variables. It is also desirable from a statistical standpoint to have as large a sample as possible. This is achieved by combining lots when possible. The possibility of combining lots, for example, from two or more adjoining thickness ranges, is explored by testing for the homogeneity of variances and the homogeneity of means of those several lots. Program SEVRAL tests for the homogeneity of variance by Bartlett's procedure (Reference 5) and tests for homogeneity of means by the procedure described by Natrella (Reference 6). When only two lots are being compared, these tests are essentially the F and t tests for variance and mean respectively.

A sample output from SEVRAL is shown in Figure V-7. The input data are listed first with a brief identification of the lots and the number, average, and standard deviations statistics for those lots. These statistics are shown for both tensile yield strength and tensile ultimate strength of PH 13-8Mo bar heat treated to H950 condition. In this case, data from the longitudinal and transverse grain directions are being compared.

TUS VS TEMPERATURE, CROSS-ROLLED BERYLLIUM SHEET, STH-REL (SHEET AVG L+T)

IDENTIFICATION			RT AVG	PERCENT R-T AT INDICATED TEMPERATURE 1200.	-85.	300.	400.	500.	700.	800.	900.	1000.
SHEET 1492	.125	U TR70-143	81.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	49.4	-0.0	43.6
SHEET 1493	.125	U TR70-143	84.2	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	47.1	-0.0	40.3
SHEET 1612	.125	U TR70-143	72.7	-0.0	-0.0	-0.0	80.9	-0.0	-0.0	60.2	-0.0	53.8
SHEET 1835	.060	U TR70-143	79.4	30.6	86.3	83.0	-0.0	67.8	50.5	-0.0	45.4	-0.0
SHEET 1839	.060	U TR70-143	78.3	32.2	-0.0	82.0	-0.0	66.5	54.5	-0.0	45.8	-0.0
SHEET 1852	.056	U TR70-143	79.0	-0.0	-0.0	-0.0	72.5	-0.0	-0.0	48.7	-0.0	44.0
SHEET 1855	.060	U TR70-143	77.1	-0.0	93.6	83.7	-0.0	68.8	49.9	-0.0	49.3	-0.0
SHEET 1856	.060	U TR70-143	80.6	35.5	89.1	81.4	-0.0	65.0	53.0	-0.0	47.9	-0.0
SHEET 1907	.250	U TR70-143	78.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	51.2	-0.0	44.4
SHEET		U TR67-38	77.0	-0.0	-0.0	-0.0	-0.0	69.1	-0.0	-0.0	-0.0	-0.0
SHEET		U TR67-38	83.9	-0.0	90.2	-0.0	-0.0	67.5	-0.0	-0.0	-0.0	-0.0
SHEET		U TR67-38	81.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
SHEET		U TR67-38	80.6	-0.0	78.5	-0.0	-0.0	64.4	-0.0	-0.0	-0.0	-0.0
SHEET		U TR67-38	83.2	-0.0	100.0	-0.0	-0.0	66.1	-0.0	-0.0	-0.0	-0.0
			NUMBER R	3	6	4	2	8	4	5	4	5
			AVG R	32.8	89.6	82.5	0.0	66.9	52.0	51.3	47.1	45.2
			SUM R	98.3	537.7	330.1	153.4	535.2	207.9	256.7	188.4	226.0
			SUMSQ R	3236.0	48446.0	27251.3	11802.5	35820.5	10824.7	13281.7	8884.0	10316.3
			SDEV R	2.0606	6.5535	.9037	0.0000	1.5851	1.8660	4.6110	1.5761	4.5355
			SDEV RBAR	1.4571	2.9308	.5218	0.0000	.5991	1.0774	2.3055	.9100	2.2677
			PERCENT RT	23.6	83.4	81.0	0.0	65.7	48.8	45.9	44.4	39.9

FIGURE V-5. OUTPUT FROM TMPKRV PROGRAM FOR EFFECT OF TEMPERATURE

IDENTIFICATION	TUS	(% TUS SUS
M43 PIECE 1	142.0	66.9
M43 PIECE 1	142.0	65.5
M43 PIECE 1	141.0	66.7
M43 PIECE 1	141.0	63.8
M43 PIECE 1	142.0	64.8
M43 PIECE 1	142.0	62.7
M43 PIECE 3	147.0	63.9
M43 PIECE 3	147.0	66.5
M43 PIECE 3	143.0	63.6
M43 PIECE 3	143.0	62.9
M43 PIECE 3	145.0	63.7
M43 PIECE 3	146.0	62.3
M43 PIECE 1	142.0	62.[illegible]
M43 PIECE 1	142.0	66.2
M43 PIECE 1	141.0	67.4
M43 PIECE 3	145.0	62.1
M43 PIECE 3	146.0	63.9
M43 PIECE 3	146.0	64.4

0

NUMBER R	18
AVG R	64.0
SUM R	1152.5
SUMSQ R	73848.3
SDEV R	1.8473
SDEV RBAR	00.4483
PERCENT RT	63.2

FIGURE V-6. OUTPUT FROM TMPKRV PROGRAM FOR SHEAR/TENSILE ULTIMATE STRENGTH RATIO

IDENTIFICATION	********* NUMBER	TYS, KSI AVERAGE	********* STD.DEV.	********* NUMBER	TUS, KSI AVERAGE	********* STD.DEV.
PH13-8MO BAR H950 LONGITUDINAL	29	209.24	4.6190	29	227.31	4.0800
PH13-8MO BAR H950 TRANSVERSE	260	210.76	5.0620	263	226.77	3.5740
T = NUMBER OF ITEMS IN GROUP		2.			2.	
DF = NUMBER OF DEGREES OF FREEDOM		287.			290.	
N = HARMONIC MEAN OF N		52.18			52.24	
DX = MAXIMUM DIFFERENCE IN AVERAGES		1.52			00.54	
WV = WEIGHTED VARIANCE		25.2054			13.1474	
WSD = WEIGHTED STANDARD DEVIATION		5.0205			3.6259	
X1 = DF X LOG10(WV)		402.2288			324.4637	
X2 = SUM OF (DFI X LOG10(VI))		402.0536			324.0500	
C = BARTLETT #C#		1.0180			1.0180	
CHI SQUARED = 2.3026/C X (X1-X2) =		00.3965			00.9358	
TABULAR VALUE FOR ALPHA =.05 , T-1 = 1		3.84			3.84	
THEREFORE CONCLUDE VARIANCES ARE		equal			equal	
Q(1-ALPHA) = DX/WSD X SQRT(N) =		2.1870			1.0764	
TABULAR VALUE FOR ALPHA = .05, T,DF= 2,287 and 290		2.77			2.77	
THEREFORE CONCLUDE AVERAGES ARE		equal			equal	

FIGURE V-7. OUTPUT FROM SEVRAL PROGRAM

The print-out lists the value of T, the number of lots being compared, DF, the degrees of freedom, some intermediate calculations, and a "chi squared" value. This "chi squared value" is compared to a tabular value for the level of significance desired. Our null hypothesis is that there is no difference in the two variances. If the computed "chi squared" is no bigger than the tabular value, then the hypothesis is accepted, and it is concluded that the variances are equal.

The second computation (for homogeneity of means) uses a pooled standard deviation and is valid conditional to the acceptance of the first hypothesis. The computed Q value is printed and is compared to a tabular value again with the acceptance or rejection of the null hypothesis depending on whether the computed value is less than or greater than the tabular value.

In the example, both the variances and means can be considered to be from the same population and the data can therefore be combined to compute a design allowable which is applicable to both grain directions.

Program SC 4060

Although there may be an effect of some variable, for example, thickness, and it may not be possible to combine the data, there may still be a continuous relationship between the strength and the variable. A visual indication, called a scattergram, is used to determine whether such a relationship exists. A plot of the data can then be assessed to determine the appropriate mathematical model that best describes that relationship. A program was written to utilize the Stromberg Carlson 4060 machine and tailored to the MIL-HDBK-5 data format to plot a property versus any selected encoded variable.

Figure V-8 is an example which shows a plot of tensile yield strength versus oxygen level for a titanium alloy. The program has the flexibility to select the scales, label the axes, and plot up to nine data sets, each with its own symbol, on the same graph. In this particular figure a linear regression of each of the two data sets was later calculated by program REGRES and then superimposed on the scattergram.

Program REGRES

With the aid of the scattergram and engineering considerations, a mathematical model may be selected to describe the effect of an independent variable on strength. Program REGRES has been written to serve as an input-output medium to the standard linear regression program on the CDC 6400 computer. The program accepts the proposed mathematical model and the data in MIL-HDBK-5 format. The program computes the regression and prints out the regression coefficients. It also will solve the resulting equation at desired values of the independent variable.

REGRESSION ANALYSIS OF TYS ON OXYGEN LEVEL FOR
Ti-6Al-4V CONTINUOUS ROLLED SHEET (TRANSVERSE)

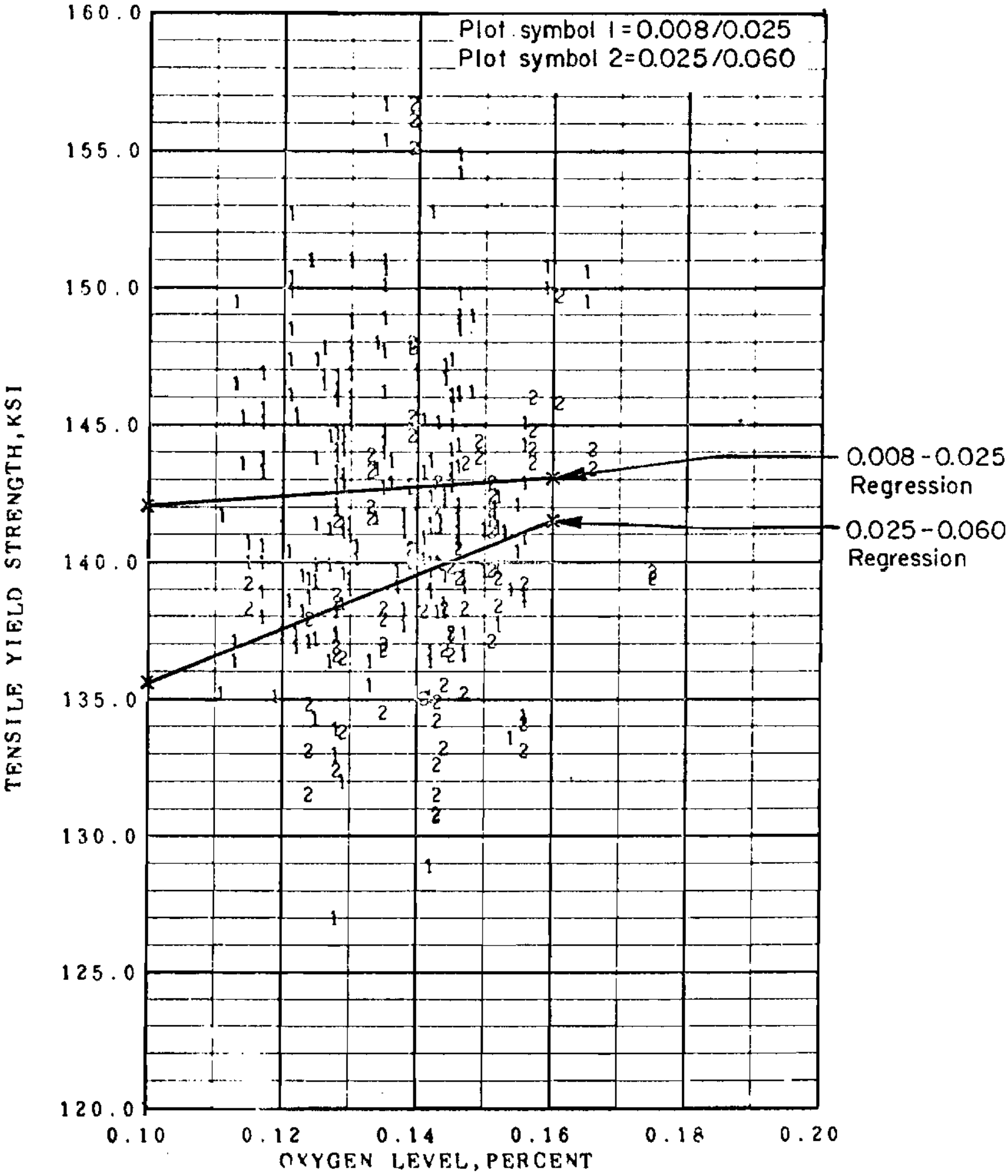

FIGURE V-8. OUTPUT FROM PROGRAM SC 4060 INCLUDING
REGRESSION COMPUTED BY PROGRAM REGRES

APPENDIX VI

REPRESENTATIVE MIL-HDBK-5 PROPOSAL

Item 68-19
42nd Meeting
Agenda

Item 68-19. Ti-6Al-4V Extrusions

A proposed revision of Table VI – 5.4.3.0(e) is presented which includes A and B values for the various annealed mechanical properties in the ≤ 1.00 thickness range. Sufficient data were not available to substantiate the A and B values over the existing thickness range os ≤ 4.0 inches. Consequently, the S values were retained for the 1.01-4.00-inch portion of the range. The A values for longitudinal ultimate strength and long transverse yield and ultimate strengths were slightly higher than S values; therefore, the S values were retained with an appropriate footnote. There were insufficient data (6 paired values) to comply with Guidelines for bearing yield and ultimate strengths for e/D = 1.5; consequently, the A and B values were footnoted as "Estimated".

For the STA condition, there were insufficient data to comply with Guidelines for determination of A and B values. In general, the data show a tendency for most of the A values to be considerably below the S values. Consequently, it is recommended that the S values be retained in proposed Table VI – 5.4.3.0(e) for the STA condition and additional data be collected.

Supporting data and statistical procedures used may be found in the Supporting Data Section.

TABLE VI-5.4.3.0(e) *Design Mechanical and Physical Properties of* Ti-6Al-4V (Extrusions)

Specification	MIL-T-81556							
Form	Extruded Bars, Rods, and Special Shaped Sections							
Condition	Annealed			Solution Treated and Aged				
Thickness or diameter, in.	≤ 1.00		1.01-4.00	≤0.50	0.51-0.75	0.76-1.00	1.01-2.00	2.01-4.00
Basis	A	B	S	S	S	S	S	S
Mechanical properties:								
F_{tu}, ksi								
L	130[a]	138	130	160	155	150	140	130
LT	130[a]	140	130	160	155	150	140	130
F_{ty}, ksi								
L	120	125	120	150	145	140	130	120
LT	120[a]	128	120	150	145	140	130	120
F_{cy}, ksi								
L	129	135						
LT	129	138						
F_{su}, ksi	82	87						
F_{bru}, ksi								
(e/D = 1.5)	219[b]	232[b]						
(e/D = 2.0)	254	270						
F_{bry}, ksi								
(e/D = 1.5)	196[b]	204[b]						
(e/D = 2.0)	229	238						
e, per cent:								
In 2 in.	--	--	--	6	--	--	--	--
In 4 D	10	10	10	--	6	6	6	6
E, 10^3 ksi	16.0							
E_c, 10^3 ksi	16.4							
G, 10^3 ksi	6.2							
μ	0.31							
Physical properties:								
ω, lb/in.^{3}	0.160							
C, Btu/(lb)(F)	See Figure 5.4.3.0							
K, Btu/[(hr)(ft^2)(F)/ft]	See Figure 5.4.3.0							
α, 10^{-6} in./in./F	See Figure 5.4.3.0							

a The A values are higher than the specification values as follows: F_{tu} (L) = 131 ksi, F_{tu} (LT) = 133 ksi and F_{ty} (LT) = 121 ksi.

b Estimated.

SUPPORTING DATA

Annealed Condition

Data for the extruded shapes were received from Harvey Aluminum Company[1] and Lockheed California[2]. The specification, MIL-T-81556, specifies minimum tensile properties for thicknesses ≤ 4.00 inches. The data were identified by extrusion die number, thickness and grain direction. There was a very limited quantity of data above 1-inch thickness and none above 2 inches. Analysis of the data for the ≤ 1.00-inch range indicated no definitive differences or trends with regard to thickness effect upon tensile properties; consequently, data were analyzed according to grain direction only. Due to the small amount of data above 1-inch thickness, these data were not analyzed further. The analyses for the ≤ 1.00-inch range are shown in Tables VI-1 and VI-2. Distribution was non-normal for both grain directions. Standard deviations for long transverse direction were slightly higher than for longitudinal. Tests for homogeneity of variance (F test) and differences in means (T test) indicated a significant difference in the grain directions: consequently, the data could not be combined. In the longitudinal direction, the A values of F_{ty} = 120.5 ksi, F_{tu} = 131.0 ksi and e = 10.0% compare closely with the respective S values of 120 ksi, 130 ksi, and 10%. Long transverse A and B values were slightly higher than longitudinal. Since the A values for F_{tu} (L and LT) and F_{ty} (LT) exceed the specification values, the S values were used as A values in the proposed Table VI-5.4.3.0(e).

It was determined that there was no significant difference in the longitudinal and long transverse compression yield, shear ultimate and bearing yield and ultimate strengths; consequently, the longitudinal and transverse data were analyzed together. Analysis of the paired values for compression yield, shear ultimate, bearing yield, and bearing ultimate strengths is shown in Tables VI-3 through VI-8. Since there were insufficient paired data (6 values) for bearing yield and bearing ultimate strengths for e/D = 1.5, these derived values were indicated as "Estimated" in the proposed revision of Table VI-5.4.3.0(e).

TABLE VI-1. LONGITUDINAL TENSILE PROPERTIES OF ANNEALED
6Al-4V EXTRUDED SHAPES - THICKNESS ≤ 1.00 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
132.30	143.10	17.00	34.00	-0.00
137.43	145.50	16.00	31.00	-0.00
135.10	145.90	16.00	33.00	-0.00
135.10	147.10	16.00	34.00	-0.00
135.90	146.70	14.00	33.00	-0.00
136.70	148.70	14.00	36.00	-0.00
131.00	145.10	12.00	34.50	-0.00
133.00	151.10	12.00	33.70	-0.00
139.00	149.50	14.00	29.40	-0.00
135.90	144.30	15.00	35.00	-0.00
134.30	143.90	16.00	35.00	-0.00
134.70	143.10	14.00	34.00	-0.00
134.70	143.10	13.00	34.00	-0.00
135.90	144.30	14.00	36.00	-0.00
133.50	143.10	14.00	36.00	-0.00
132.30	141.90	17.00	37.00	-0.00
137.50	144.70	16.00	36.00	-0.00
136.70	143.90	16.00	36.00	-0.00
137.90	146.90	17.00	35.00	-0.00
141.50	148.70	15.00	35.00	-0.00
137.90	145.10	17.00	34.00	-0.00
131.50	142.30	14.00	35.00	-0.00
130.30	141.90	15.00	35.00	-0.00
131.50	142.30	14.00	35.00	-0.00
129.90	141.90	15.00	37.00	-0.00
130.30	142.30	14.00	36.00	-0.00
131.70	141.30	14.00	36.00	-0.00
132.50	144.60	15.00	34.00	-0.00
140.20	145.90	14.00	31.70	-0.00
138.00	145.50	14.00	29.40	-0.00
138.50	146.90	15.00	32.20	-0.00
133.50	145.50	15.00	33.10	-0.00
129.20	148.20	12.00	14.30	-0.00
138.20	149.20	14.00	31.00	-0.00
139.10	141.50	20.00	49.00	-0.00
130.70	137.90	16.00	37.00	-0.00
130.30	137.50	17.00	38.10	-0.00
130.30	142.30	16.00	35.00	-0.00
124.50	142.90	15.00	34.00	-0.00
128.50	140.50	15.00	35.00	-0.00

INTERVENING PAGES CONTAINING REMAINDER
OF DATA HAVE BEEN OMITTED

TABLE VI-1 Continued:

PRODUCT DESCRIPTION

	TYS., KSI	TUS., KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	513	513	513	478	0
AVERAGE	131.53	142.89	1.15*	1.52*	0.00
STD. DEV.	4.643	3.736	00.046*	0.056*	0.000
(* = LOG BASE 10)					
TALLY BY DECILES UNDER THE NORMAL CURVE					
	46	42	54	34	0
	45	38	11	37	0
	71	55	49	23	0
	50	77	7	41	0
	68	63	195	50	0
	44	53	6	140	0
	42	45	95	55	0
	62	58	0	40	0
	35	25	66	34	0
	50	57	30	24	0
CHI SQUARED	24.52	36.77	614.27	216.39	9999.99
NORMAL	NO	NO	NO	NO	NO
MIL-HDBK-5 A + B VALUES					
A BASIS	120.50	131.00	10.50	14.00	
B BASIS	125.10	138.00	12.00	28.00	

TABLE VI-2. LONG TRANSVERSE TENSILE PROPERTIES OF ANNEALED 6Al-4V EXTRUDED SHAPES - THICKNESS ≤ 1.00 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
138.40	152.00	20.00	23.00	-0.00
135.30	150.50	20.00	25.00	-0.00
136.90	149.00	18.00	30.00	-0.00
144.50	150.10	16.00	33.00	-0.00
145.20	151.00	14.00	30.00	-0.00
144.10	152.10	16.00	30.00	-0.00
140.90	147.80	11.00	28.10	-0.00
139.50	146.70	12.00	30.50	-0.00
138.90	147.80	20.00	34.30	-0.00
144.20	152.90	20.00	29.00	-0.00
143.50	152.20	20.00	28.10	-0.00
140.90	149.20	20.00	23.60	-0.00
144.20	151.90	20.00	28.00	-0.00
144.90	152.50	20.00	27.00	-0.00
144.70	152.20	22.00	33.00	-0.00
147.20	151.80	16.00	43.00	-0.00
146.80	151.20	16.00	42.00	-0.00
146.50	151.20	20.00	42.00	-0.00
141.80	149.40	18.00	32.20	-0.00
142.10	149.80	18.00	31.30	-0.00
141.90	148.50	20.00	32.80	-0.00
135.00	142.50	14.00	29.40	-0.00
136.50	146.90	14.00	32.20	-0.00
134.00	143.60	13.00	28.90	-0.00
138.50	146.10	11.00	32.00	-0.00
136.20	145.70	11.00	32.00	-0.00
140.80	148.20	11.00	30.00	-0.00
138.50	148.00	10.00	30.00	-0.00
141.40	149.00	11.00	30.00	-0.00
138.50	148.00	12.00	30.00	-0.00
140.90	150.50	12.00	29.00	-0.00
141.90	147.70	11.00	34.00	-0.00
138.20	147.70	12.00	32.00	-0.00
128.30	143.30	13.00	31.20	-0.00
136.50	145.50	13.00	30.00	-0.00
134.50	142.00	14.00	32.00	-0.00
138.50	146.00	13.00	28.00	-0.00
135.00	144.00	14.00	29.00	-0.00
137.00	144.50	14.00	29.00	-0.00
139.50	145.50	14.00	29.00	-0.00

TABLE VI-2 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	411	411	411	376	0
AVERAGE	134.92	144.80	1.14*	1.47*	0.00
STD. DEV.	5.127	3.980	00.069*	00.049*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

33	19	33	26	0
41	42	40	20	0
44	76	0	36	0
68	56	100	46	0
42	35	1	60	0
46	37	142	63	0
42	46	28	41	0
27	36	0	36	0
25	19	29	21	0
43	45	38	27	0

CHI SQUARED	31.26	61.73	463.04	54.96	9999.99
NORMAL	NO	NO	NO	NO	NO

MIL-HDBK-5 A + B VALUES

A BASIS	121.00	133.00	10.00	15.20
B BASIS	128.00	140.50	11.00	25.50

TABLE VI-3. CYS/TYS RATIO FOR 6AL-4V ANN EXTRUSIONS

IDENTIFICATION			TYS	(% CYS/TYS)
M-43	1	L	126.7	109.1
M-43	3	L	129.1	109.5
79009	AA75	L	134.5	105.7
79009	AA77	L	132.8	106.2
79009	AA82	L	138.9	102.5
79009	AA89	L	128.8	105.5
79009	AB67	L	135.7	103.8
79009	AB69	L	129.5	104.6
79009	AC02	L	130.0	114.3
79009	AC18	L	131.8	109.9
79009	AC23	L	128.8	103.9
79009	AC26	L	129.3	104.4
79009	AC3[illegible]	L	132.5	113.7
79009	AC32	L	129.8	111.9
79009	AC32	L	128.2	108.0
79009	AC39	L	132.7	108.1
79009	AC39	L	127.0	114.7
79009	AC40	L	130.2	111.2
79009	AC41	L	131.8	111.1
79009	AC41	L	130.7	107.7
79009	AC41	L	130.2	113.9
79009	AC43	L	133.7	108.8
79009	AC51	L	128.5	108.5
79009	AC57	L	133.0	104.3
79009	AC57	L	133.0	107.7
79009	AC83	L	131.4	103.3
79009	AC89	L	129.6	105.3
79009	AC9[illegible]	L	129.3	104.9
79009	AC91	L	128.8	109.7
79009	AD21	L	132.0	106.1
79009	AD22	L	133.0	108.2
79009	AD49	L	129.0	102.4
79009	AD72	L	128.8	102.0
79009	AD72	L	132.5	105.8
79009	AD73	L	137.0	107.2
79009	AD75	L	130.3	107.1
79009	AD76	L	129.5	112.4
79009	AD79	L	126.3	105.2
79009	AF3[illegible]	L	121.7	107.5
79009	AF38	L	133.0	108.3
79009	AF38	L	120.8	108.8
79009	AF39	L	130.7	110.2
79009	AE39	L	134.0	104.1
79009	AF51	L	131.0	107.9
79009	AF57	L	133.5	110.7
79009	AF59	L	124.2	111.0
79009	A-14	L	134.5	109.5
79009	A-16	L	133.8	110.6
79009	A-18	L	137.3	108.0
79009	A-39	L	130.0	110.8

INTERVENING PAGES CONTAINING REMAINDER
OF DATA HAVE BEEN OMITTED

'TABLE VI-3 Continued:

79009 S-54	139.3	110.4
79009 S-64	136.5	110.5
79009 S-71	144.2	104.6
79009 S-72	135.2	105.3
79009 S-73	138.7	108.7
79009 S-75	135.5	112.8
79009 S-75	134.0	110.6
79009 S-78	138.0	109.9
79009 S-79	143.7	104.7
79009 S-79	143.3	103.6
79009 T-31	134.3	111.7
79009 T-54	132.7	110.4
79009 T-68	144.6	108.1
79009 T-93	138.5	110.0
79009 V-12	133.5	105.4
79009 V-39	133.2	110.1
79009 V-48	135.6	115.6
79009 V-54	136.8	113.4
79009 V-64	144.6	106.6
79009 V-66	146.6	109.8
79009 V-88	133.7	107.5
79009 W-88	139.2	109.0

NUMBER R	184
AVG R	108.3
SUM R	19923.0
SUMSQ R	2159887.2
SDEV R	3.8119
SDEV RBAR	00.2817
PERCENT RT	107.8

TABLE VI-4. SUS/TUS RATIO FOR TI-6AL-4V ANN EXTRUSIONS

IDENTIFICATION	TUS	(% TUS) SUS
M43 PIECE 1	142.0	66.9
M43 PIECE 1	142.0	65.5
M43 PIECE 1	141.0	66.7
M43 PIECE 1	141.0	63.8
M43 PIECE 1	142.0	64.8
M43 PIECE 1	142.0	62.7
M43 PIECE 3	147.0	63.9
M43 PIECE 3	147.0	6[illegible].5
M43 PIECE 3	143.0	63.6
M43 PIECE 3	143.0	62.9
M43 PIECE 3	146.0	63.7
M43 PIECE 3	146.0	62.3
M43 PIECE 1	142.0	62.[illegible]
M43 PIECE 1	142.0	66.2
M43 PIECE 1	141.0	67.4
M43 PIECE 3	145.0	62.1
M43 PIECE 3	146.0	63.9
M43 PIECE 3	146.0	64.4
	NUMBER R	18
	AVG R	64.0
	SUM R	1152.5
	SUMSQ R	73848.[illegible]
	SDEV R	1.8473
	SDEV RBAR	00.448[illegible]
	PERCENT RT	63.2

TABLE VI-5. BUS/TUS RATIO E/D=1.5 FOR TI-6AL-4V ANN EXTRUSIONS

IDENTIFICATION	TUS	(% TUS) BUS
M43 PIECE 1	142.0	174.6
M43 PIECE 1	141.0	173.[illegible]
M43 PIECE 1	142.0	168.3
M43 PIECE 2	147.0	172.1
M43 PIECE	143.0	167.8
M43 PIECE	146.0	169.2
	NUMBER R	6
	AVG R	170.9
	SUM R	1025.1
	SUMSQ R	175186.6
	SDEV R	2.5561
	SDEV RBAR	1.1431
	PERCENT RT	168.4

TABLE VI-6. BYS/TYS RATIO E/D=1.5 FOR TI-6AL-4V ANN EXTRUSIONS

IDENTIFICATION	TYS	(% TYS) BYS
M43 PIECE 1	125.0	168.0
M43 PIECE 1	125.0	165.6
M43 PIECE 1	126.0	164.3
M43 PIECE 3	130.0	166.9
M43 PIECE 3	125.0	164.0
M43 PIECE 3	129.0	162.0
	NUMBER R	6
	AVG R	165.1
	SUM R	990.8
	SUMSQ R	163645.5
	SDEV R	1.9733
	SDEV RBAR	00.8825
	PERCENT RT	163.3

TABLE VI-7. BUS/TUS RATIO E/D=2.0 FOR TI-6AL-4V ANN EXTRUSIONS

IDENTIFICATION	TUS	(% TUS) BUS
M43 PIECE 1	142.0	207.7
M43 PIECE 3	147.0	180.3
M43 PIECE 3	143.0	204.9
M43 PIECE 3	146.0	184.9
M43 PIECE 1	142.0	216.9
M43 PIECE 1	142.0	207.0
M43 PIECE 1	141.0	214.2
M43 PIECE 3	145.0	206.9
M43 PIECE 3	146.0	204.1
M43 PIECE 3	146.0	198.6
	NUMBER R	10
	AVG R	202.6
	SUM R	2025.6
	SUMSQ R	411546.8
	SDEV R	11.1239
	SDEV RBAR	3.7580
	PERCENT RT	195.7

TABLE VI-8. BYS/TYS RATIO E/D=2.0 FOR TI-6AL-4V ANN EXTRUSIONS

IDENTIFICATION	TYS	(% TYS) BYS
M43 PIECE 1	126.0	198.4
M43 PIECE 3	130.0	179.2
M43 PIECE 3	125.0	196.8
M43 PIECE 3	129.0	186.0
M43 PIECE 1	127.0	203.9
M43 PIECE 1	128.0	196.9
M43 PIECE 1	126.0	206.3
M43 PIECE 3	129.0	189.9
M43 PIECE 3	130.0	204.6
M43 PIECE 3	130.0	196.2
	NUMBER R	10
	AVG R	195.8
	SUM R	1958.3
	SUMSQ R	384179.2
	SDEV R	8.1763
	SDEV RBAR	2.7254
	PERCENT RT	190.8

STA Condition

STA data were also received from Harvey Aluminum Company[2] and analyzed according to the thickness ranges specified in MIL-T-81556 as shown in Tables VI−9 through VI−16. Table VI−17 is a summary of the statistics from these analyses. The tension yield and ultimate strengths decreased with increasing thickness except for the 1.01-2.00-inch-long transverse range. The standard deviations appeared fairly consistent except for the ≤ 0.50-inch-long transverse range which was unusually low. Although most of the longitudinal distributions were normal, there was insufficient sample (< 100 values) to meet the Guidelines for determination of A and B values. There were more data in the transverse direction but still insufficient, with one exception, to meet Guideline requirements for A and B values. From inspection of the data, the longitudinal and long transverse directions appear significantly different, except for the 0.51-0.75-inch range, and not capable of being combined. Examination of the data reveals a tendency for most of the A values to be considerably below S values. Consequently, it is recommended that additional data be collected to strengthen the analyses.

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(1) Letter to R. Favor from E. W. Cawthorne, dated October 19, 1970 (unpublished Harvey data). DMIC source 79009.

(2) Section 4 of Lockheed California Report LR 22810, "Metallic Materials Design Mechanical Allowables Data Substantiation" and AFML-TR-67-189, "Development of Engineering Data on Titanium Extrusion for Use in Aerospace Design", Lockheed California Company (July 1967). MIL-HDBK-5 source M-43.

TABLE VI-9. LONGITUDINAL TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS ≤ 0.50 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
160.00	168.10	16.00	22.00	-0.00
165.00	174.60	18.00	28.00	-0.00
157.90	171.10	10.00	26.00	-0.00
170.00	184.00	9.00	27.50	-0.00
155.00	169.00	10.00	18.50	-0.00
155.20	168.50	10.00	17.30	-0.00
152.50	168.00	10.00	17.50	-0.00
160.70	172.70	12.00	27.00	-0.00
163.50	175.50	12.00	31.00	-0.00
160.00	170.00	10.00	12.30	-0.00
161.00	171.50	9.00	13.50	-0.00
158.00	167.00	8.00	11.00	-0.00
159.00	172.50	12.00	22.00	-0.00
158.00	174.00	12.00	30.00	-0.00
158.00	174.00	11.00	24.00	-0.00
159.10	171.10	13.00	37.00	-0.00
153.00	165.00	12.00	21.00	-0.00
149.50	161.50	12.00	26.00	-0.00
152.70	165.90	12.00	25.00	-0.00
165.50	178.70	12.00	31.00	-0.00
168.00	174.00	8.00	19.10	-0.00
159.00	170.00	8.00	20.70	-0.00
162.00	174.00	9.00	19.10	-0.00
164.00	179.00	9.00	16.50	-0.00
158.00	171.50	9.00	19.00	-0.00
161.00	175.00	8.00	19.50	-0.00
162.00	177.00	10.00	20.00	-0.00
164.00	178.50	9.00	18.50	-0.00
163.50	178.50	10.00	19.00	-0.00
155.80	167.90	11.00	16.00	-0.00
155.40	167.50	12.00	19.00	-0.00
155.90	175.10	11.00	17.00	-0.00
166.30	178.30	11.00	24.00	-0.00
166.70	178.70	10.00	24.00	-0.00
155.00	168.30	10.00	16.00	-0.00
160.00	171.00	10.00	-0.00	-0.00
157.00	169.00	8.00	-0.00	-0.00
157.50	171.00	8.00	-0.00	-0.00
155.00	171.00	10.00	10.00	-0.00
172.50	186.00	9.00	16.80	-0.00

INTERVENING PAGES CONTAINING REMAINDER OF DATA HAVE BEEN OMITTED

TABLE VI-9 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	70	70	70	67	0
AVERAGE	159.75	172.71	1.01*	1.34*	0.00
STD. DEV.	5.462	5.596	00.076*	00.127*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

	TYS	TUS	ELONG.	RED.	MOD.
	4	5	11	6	0
	12	6	0	6	0
	7	11	8	6	0
	9	9	0	9	0
	5	6	22	4	0
	10	7	0	4	0
	3	7	11	11	0
	8	6	0	7	0
	6	9	12	8	0
	6	4	6	6	0
CHI SQUARED	10.00	5.71	68.57	6.28	9999.99
NORMAL	YES	YES	NO	YES	NO

MIL-HDBK-5 A + B VALUES

	TYS	TUS	ELONG.	RED.	MOD.
A BASIS	144.65	157.23	0.00	9.61	
B BASIS	151.11	163.86	8.00	13.63	

TABLE VI-10. LONG TRANSVERSE TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS ≤ 0.50 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
158.50	166.20	10.00	22.00	-0.00
155.50	165.00	12.00	27.00	-0.00
155.50	167.00	12.00	27.00	-0.00
157.20	167.00	9.00	24.00	-0.00
156.40	167.60	10.00	27.00	-0.00
156.30	165.90	8.00	24.00	-0.00
157.20	167.00	9.00	24.00	-0.00
156.40	167.60	10.00	27.00	-0.00
156.30	165.90	8.00	24.00	-0.00
159.40	172.80	12.00	21.20	-0.00
162.00	176.20	12.00	21.10	-0.00
160.00	170.50	10.00	26.00	-0.00
155.50	167.50	11.00	23.10	-0.00
157.50	169.50	10.00	22.10	-0.00
155.00	167.00	9.00	22.60	-0.00
155.00	167.00	10.00	23.60	-0.00
158.50	170.50	10.00	24.60	-0.00
154.00	167.50	10.00	23.60	-0.00
155.00	169.00	10.00	22.10	-0.00
155.00	168.50	11.00	24.60	-0.00
159.00	171.00	10.00	24.60	-0.00
158.00	171.50	10.00	23.60	-0.00
156.50	170.00	10.00	20.60	-0.00
158.50	172.00	9.00	19.60	-0.00
157.00	170.50	10.00	24.10	-0.00
159.00	171.00	10.00	25.50	-0.00
156.00	169.50	10.00	24.60	-0.00
153.40	164.40	10.00	23.10	-0.00
153.50	165.50	11.00	25.50	-0.00
156.50	168.50	10.00	24.60	-0.00
160.50	170.50	10.00	23.30	-0.00
158.00	171.50	9.00	18.10	-0.00
162.00	175.50	9.00	23.60	-0.00
156.00	169.50	9.00	20.60	-0.00
158.70	173.10	10.00	24.50	-0.00
157.90	168.60	9.00	26.50	-0.00
156.50	167.50	9.00	23.10	-0.00
159.50	171.50	11.00	27.00	-0.00
157.00	170.50	10.00	20.00	-0.00
160.50	173.00	10.00	22.00	-0.00

INTERVENING PAGES CONTAINING REMAINDER OF DATA HAVE BEEN OMITTED

TABLE VI-10 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	41	41	41	41	0
AVERAGE	157.25	169.29	01.00*	1.37*	0.00
STD. DEV.	2.092	2.724	00.042*	00.041*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

	TYS	TUS	ELONG.	RED.	MOD.
	3	3	2	5	0
	4	3	9	2	0
	5	10	0	4	0
	7	2	0	1	0
	5	2	0	5	0
	1	3	22	8	0
	3	7	0	7	0
	6	5	0	0	0
	2	1	4	4	0
	5	5	4	5	0
CHI SQUARED	7.54	16.32	105.59	13.88	9999.99
NORMAL	YES	NO	NO	YES	NO

MIL-HDBK-5 A + B VALUES

	TYS	TUS	ELONG.	RED.	MOD.
A BASIS	151.10	0.00	0.00	17.84	
B BASIS	153.70	164.40	8.00	20.05	

TABLE VI-11. LONGITUDINAL TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS 0.51-0.75 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
150.00	165.00	8.00	10.30	-0.00
155.50	167.50	13.00	23.00	-0.00
153.50	170.00	13.00	32.10	-0.00
155.50	173.50	8.00	17.00	-0.00
149.00	161.00	11.00	27.00	-0.00
147.50	158.00	11.00	29.40	-0.00
142.00	154.00	11.00	27.00	-0.00
142.00	155.50	11.00	31.70	-0.00
149.00	164.00	10.00	24.60	-0.00
153.50	166.50	11.00	26.50	-0.00
150.00	171.00	11.00	24.60	-0.00
157.00	169.00	10.00	22.10	-0.00
157.50	170.50	10.00	22.10	-0.00
158.50	172.00	11.00	27.00	-0.00
166.50	179.50	10.00	14.50	-0.00
153.50	167.00	11.00	24.60	-0.00
156.00	172.50	13.50	29.40	-0.00
149.00	169.00	11.00	24.40	-0.00
155.00	167.00	10.00	17.10	-0.00
150.00	163.50	10.00	24.60	-0.00
148.50	162.00	10.00	25.50	-0.00
149.50	163.00	10.00	22.60	-0.00
159.00	168.00	11.00	27.00	-0.00
144.50	155.00	11.00	19.60	-0.00
153.00	168.00	11.00	25.50	-0.00
150.50	165.00	11.00	24.60	-0.00

TABLE VI-11 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	26	26	26	26	0
AVERAGE	152.13	166.04	1.03*	1.37*	0.00
STD. DEV.	5.476	6.033	00.051*	00.109*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

3	4	2	2	0
1	0	0	2	0
4	2	8	1	0
5	3	0	0	0
0	2	0	4	0
4	4	0	6	0
1	4	13	3	0
3	3	0	4	0
4	3	0	4	0
1	1	3	0	0

CHI SQUARED	10.15	6.31	68.62	13.23	9999.99
NORMAL	YES	YES	NO	YES	NO

MIL-HDBK-5 A + B VALUES

A BASIS	134.84	146.99	0.00	10.60
B BASIS	142.07	154.95	0.00	14.75

TABLE VI-12. LONG TRANSVERSE TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS 0.51-0.75 INCH

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
	165.00	168.00	10.00	24.00	-0.00
	144.00	155.00	13.00	30.00	-0.00
	153.50	164.00	10.00	21.10	-0.00
	154.00	164.50	10.00	24.10	-0.00
	152.00	164.00	10.00	23.60	-0.00
	163.00	173.50	10.00	23.10	-0.00
	161.00	171.50	10.00	22.60	-0.00
	160.00	170.50	10.00	23.10	-0.00
	158.50	170.50	11.00	22.60	-0.00
	161.00	173.00	10.00	22.10	-0.00
	160.50	172.50	10.00	19.60	-0.00
	152.50	166.00	10.00	19.60	-0.00
	154.00	167.50	10.00	18.60	-0.00
	151.50	165.00	9.00	20.60	-0.00
	156.00	168.00	11.00	20.60	-0.00
	156.50	168.50	10.00	22.10	-0.00
	158.50	170.50	11.00	22.10	-0.00
	153.50	165.50	10.00	21.10	-0.00
	152.50	164.50	12.00	20.60	-0.00
	155.50	167.50	11.00	23.10	-0.00
	156.00	171.00	8.00	14.50	-0.00
	150.00	162.00	11.00	30.50	-0.00
	142.00	148.00	14.00	29.00	-0.00
	144.00	151.50	14.00	27.00	-0.00
	146.00	153.50	13.00	28.00	-0.00
	157.00	169.00	10.00	24.60	-0.00
	156.50	167.00	9.00	20.60	-0.00
	155.00	167.00	11.00	19.60	-0.00
	158.00	168.50	10.00	24.10	-0.00
	157.50	168.00	10.00	22.10	-0.00
	157.00	169.00	9.00	20.60	-0.00
	159.50	171.50	11.00	21.70	-0.00
	160.30	171.00	11.00	20.30	-0.00
	155.10	167.10	12.00	23.70	-0.00
	151.00	163.00	10.00	22.10	-0.00
	153.50	165.50	9.00	24.10	-0.00
	158.00	169.50	9.00	18.50	-0.00
	157.00	169.00	9.00	19.10	-0.00
	158.50	170.50	9.00	19.60	-0.00
	177.00	199.00	9.00	23.60	-0.00

INTERVENING PAGES CONTAINING REMAINDER OF DATA HAVE BEEN OMITTED

TABLE VI-12 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	155	155	155	155	0
AVERAGE	153.82	166.13	1.01*	1.35*	0.00
STD. DEV.	5.714	5.789	00.043*	00.059*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

	TYS	TUS	ELONG.	RED.	MOD.
	18	15	4	15	0
	16	12	22	17	0
	9	13	0	16	0
	9	9	0	8	0
	19	19	87	21	0
	16	21	0	8	0
	17	22	0	20	0
	27	26	29	24	0
	14	13	0	14	0
	10	5	13	12	0
CHI SQUARED	17.45	24.03	430.74	16.29	9999.99
NORMAL	NO	NO	NO	NO	NO

MIL-HDBK-5 A + B VALUES

	TYS	TUS	ELONG.	RED.
A BASIS	0.00	0.00	0.00	0.00
B BASIS	144.00	156.50	9.00	17.90

TABLE VI-13. LONGITUDINAL TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS 0.76-1.00 INCH

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
	145.00	158.50	13.00	24.60	-0.00
	145.00	157.00	13.00	24.60	-0.00
	143.50	157.00	13.00	27.00	-0.00
	146.00	158.00	14.00	22.10	-0.00
	144.50	156.50	13.00	24.60	-0.00
	143.00	155.00	13.00	29.40	-0.00
	142.50	154.50	11.00	24.60	-0.00
	139.50	153.00	11.00	19.60	-0.00
	143.50	155.50	13.00	22.10	-0.00
	142.00	154.00	13.00	19.60	-0.00
	145.00	160.00	11.00	24.00	-0.00
	145.00	160.00	11.00	25.00	-0.00
	143.00	158.00	11.00	20.00	-0.00
	145.50	157.50	10.00	22.00	-0.00
	155.50	167.50	11.00	24.00	-0.00
	147.50	161.00	10.00	19.00	-0.00
	149.00	164.00	10.00	22.00	-0.00
	151.50	163.50	10.00	25.00	-0.00
	148.50	162.00	10.00	23.00	-0.00
	161.00	177.50	11.00	26.00	-0.00
	150.00	163.50	10.00	23.00	-0.00
	155.00	168.50	10.00	19.00	-0.00
	152.50	165.50	10.00	19.00	-0.00
	145.50	159.00	14.00	31.70	-0.00
	143.00	156.50	13.00	27.00	-0.00
	146.00	158.00	14.00	27.00	-0.00
	141.00	156.00	7.00	23.00	-0.00
	141.00	156.00	11.00	22.00	-0.00
	144.00	159.00	14.00	27.00	-0.00
	147.00	159.00	10.00	22.00	-0.00
	144.00	157.50	10.00	17.00	-0.00
	148.00	161.50	10.00	21.00	-0.00
	148.00	163.00	8.00	21.00	-0.00
	148.00	163.00	8.00	20.00	-0.00
	146.00	158.00	9.00	20.00	-0.00
	146.50	160.00	12.00	29.40	-0.00
	145.00	157.00	11.00	24.60	-0.00
	137.00	152.00	11.00	26.00	-0.00
	140.00	155.00	11.00	23.00	-0.00
	141.00	156.00	11.00	26.00	-0.00

INTERVENING PAGES CONTAINING REMAINDER OF DATA HAVE BEEN OMITTED

TABLE VI-13 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	71	71	71	71	0
AVERAGE	146.86	160.04	1.06*	1.38*	0.00
STD. DEV.	5.352	5.507	00.072*	00.076*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

	TYS	TUS	ELONG.	RED.	MOD.
	4	1	5	8	0
	9	10	0	5	0
	11	16	14	4	0
	12	12	0	9	0
	6	8	21	5	0
	9	1	0	17	0
	3	3	6	6	0
	4	8	16	6	0
	5	3	8	6	0
	8	9	1	5	0
CHI SQUARED	12.52	31.68	72.52	18.15	9999.99
NORMAL	YES	NO	NO	NO	NO

MIL-HDBK-5 A + B VALUES

	TYS	TUS	ELONG.	RED.
A BASIS	132.06	0.00	0.00	0.00
B BASIS	138.40	153.00	8.00	17.10

TABLE VI-14. LONG TRANSVERSE TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS 0.76-1.00 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
155.00	167.00	11.00	25.10	-0.00
157.50	169.50	10.00	22.10	-0.00
155.50	167.50	11.00	24.10	-0.00
154.00	162.50	10.00	20.60	-0.00
156.00	169.50	10.00	23.60	-0.00
156.50	170.00	10.00	24.60	-0.00
153.00	165.00	11.00	21.60	-0.00
153.50	166.50	10.00	25.50	-0.00
151.20	164.50	10.00	23.00	-0.00
165.00	174.00	9.00	19.60	-0.00
157.00	169.00	10.00	22.10	-0.00
160.50	171.00	9.00	20.60	-0.00
152.50	169.00	9.00	21.10	-0.00
153.00	169.50	9.00	19.10	-0.00
152.50	169.00	9.00	21.10	-0.00
155.50	166.00	11.00	22.10	-0.00
153.50	165.50	10.00	20.60	-0.00
154.50	165.00	9.00	19.60	-0.00
154.50	166.50	12.00	24.60	-0.00
154.50	166.50	10.00	25.50	-0.00
149.50	161.50	13.00	25.10	-0.00
151.00	161.50	12.00	22.60	-0.00
147.50	158.00	11.00	25.10	-0.00
153.00	165.00	12.00	24.60	-0.00
152.50	164.50	10.00	27.00	-0.00
151.50	165.00	10.00	22.60	-0.00
148.00	161.50	10.00	21.10	-0.00
149.00	162.50	10.00	21.60	-0.00
147.50	161.00	10.00	23.60	-0.00
151.50	163.50	11.00	22.10	-0.00
149.00	162.50	11.00	24.60	-0.00
153.00	165.00	10.00	19.60	-0.00
152.00	164.00	11.00	19.60	-0.00
145.10	157.10	10.00	23.70	-0.00
145.10	157.10	10.00	20.90	-0.00
139.40	151.40	10.00	27.00	-0.00
138.50	152.00	10.00	22.00	-0.00
142.00	144.00	10.00	22.00	-0.00
143.00	156.50	10.00	23.80	-0.00
143.00	155.00	10.00	23.80	-0.00

INTERVENING PAGES CONTAINING REMAINDER OF DATA HAVE BEEN OMITTED

TABLE VI-14 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	283	283	283	283	0
AVERAGE	150.08	162.92	1.01*	1.35*	0.00
STD. DEV.	5.524	5.425	00.061*	00.091*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

24	26	15	30	0
35	30	46	4	0
23	22	1	34	0
25	24	0	22	0
36	25	114	36	0
26	38	0	18	0
33	45	60	80	0
34	22	0	19	0
22	22	19	29	0
25	29	28	11	0

	TYS	TUS	ELONG.	RED.	MOD.
CHI SQUARED	9.61	18.73	426.65	137.46	9999.99
NORMAL	YES	NO	NO	NO	NO

MIL-HDBK-5 A + B VALUES

	TYS	TUS	ELONG.	RED.
A BASIS	136.11	0.00	0.00	0.00
B BASIS	142.22	155.20	9.00	16.80

TABLE VI-15. LONGITUDINAL TENSILE PROPERTIES OF 6Al-4V STA EXTRUDED SHAPES - THICKNESS 1.01-2.00 INCH

PRODUCT DESCRIPTION

TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
148.50	150.50	14.00	27.00	-0.00
143.50	152.50	13.00	24.60	-0.00
151.50	162.00	11.00	22.10	-0.00
144.50	155.00	12.00	22.60	-0.00
138.00	150.00	11.00	22.60	-0.00
152.50	166.00	13.00	24.60	-0.00
142.00	160.00	11.00	29.00	-0.00
147.00	165.00	11.00	29.00	-0.00
147.00	165.00	11.00	31.00	-0.00
139.50	153.00	10.00	26.00	-0.00
142.00	160.00	14.00	29.00	-0.00
140.00	158.00	11.00	32.00	-0.00
144.00	162.00	11.00	32.00	-0.00
145.50	165.00	12.00	31.00	-0.00
147.00	165.00	11.00	29.00	-0.00
147.00	165.00	11.00	29.00	-0.00
139.50	153.00	11.00	24.00	-0.00
142.00	156.00	11.00	25.00	-0.00
141.00	157.50	10.00	20.10	-0.00
161.50	176.50	11.00	27.00	-0.00

TABLE VI-15 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	20	20	20	20	0
AVERAGE	145.17	159.85	1.06*	1.42*	0.00
STD. DEV.	5.523	6.635	00.041*	00.059*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

1	2	2	2	0
3	3	0	2	0
4	2	0	3	0
1	2	12	1	0
2	0	0	1	0
1	2	0	2	0
4	2	2	0	0
1	5	0	5	0
1	1	0	2	0
2	1	4	2	0

CHI SQUARED	7.00	8.00	64.00	8.00	9999.99
NORMAL	YES	YES	NO	YES	NO

MIL-HDBK-5 A + B VALUES

A BASIS	126.98	137.99	0.00	17.05
B BASIS	134.54	147.07	0.00	20.51

TABLE VI-16. LONG TRANSVERSE TENSILE PROPERTIES OF 6A1-4V STA EXTRUDED SHAPES - THICKNESS 1.01-2.00 INCH

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
	150.50	162.50	10.00	20.00	-0.00
	142.00	155.50	10.00	24.00	-0.00
	143.00	156.50	10.00	20.00	-0.00
	154.30	167.50	9.00	21.00	-0.00
	151.50	164.70	9.00	18.00	-0.00
	157.90	169.90	9.00	17.00	-0.00
	155.00	170.00	7.00	15.00	-0.00
	150.00	165.00	9.00	18.00	-0.00
	147.50	162.50	7.00	12.00	-0.00
	148.00	166.00	11.00	18.00	-0.00
	147.50	162.50	11.00	22.00	-0.00
	154.00	169.00	11.00	23.00	-0.00
	150.00	165.00	11.00	17.00	-0.00
	153.00	165.00	10.00	24.00	-0.00
	151.50	162.00	10.00	23.00	-0.00
	151.50	163.50	10.00	22.00	-0.00
	150.50	161.50	12.00	26.00	-0.00
	149.50	161.50	11.00	29.00	-0.00
	151.00	163.00	11.00	25.00	-0.00
	154.00	167.50	10.00	23.00	-0.00
	156.00	168.00	10.00	24.00	-0.00
	154.00	166.00	10.00	24.00	-0.00
	152.00	165.50	10.00	19.00	-0.00
	152.00	166.00	11.00	20.00	-0.00
	148.00	163.00	11.00	20.00	-0.00
	156.00	168.00	10.00	15.00	-0.00
	156.00	169.50	9.00	17.00	-0.00
	155.50	167.50	8.00	15.00	-0.00
	157.00	169.00	9.00	9.00	-0.00
	155.50	167.50	10.00	20.00	-0.00
	156.00	168.00	10.00	19.00	-0.00
	149.50	163.00	10.00	20.00	-0.00
	159.00	171.00	11.00	21.00	-0.00
	157.50	169.50	10.00	22.00	-0.00
	147.00	162.00	10.00	22.00	-0.00
	150.00	163.50	10.00	20.00	-0.00
	152.50	167.50	10.00	19.00	-0.00
	151.00	166.00	11.00	18.00	-0.00
	150.00	165.00	11.00	17.00	-0.00
	143.10	152.70	13.00	26.50	-0.00

INTERVENING PAGES CONTAINING REMAINDER OF DATA HAVE BEEN OMITTED

TABLE VI-16 Continued:

PRODUCT DESCRIPTION

	TYS, KSI	TUS, KSI	ELONG., %	RED., %	MOD., 1000 KSI
NO. OF DATA	52	52	52	52	0
AVERAGE	151.49	164.34	1.01*	1.30*	0.00
STD. DEV.	4.393	4.437	00.052*	00.092*	0.000

(* = LOG BASE 10)

TALLY BY DECILES UNDER THE NORMAL CURVE

6	6	3	5	0
4	2	6	0	0
3	5	0	8	0
6	6	0	5	0
5	3	26	4	0
6	6	0	8	0
2	5	0	7	0
6	11	13	3	0
11	7	0	8	0
3	1	4	4	0

	TYS	TUS	ELONG.	RED.	MOD.
CHI SQUARED	11.08	13.77	122.23	11.85	9999.99
NORMAL	YES	YES	NO	YES	NO

MIL-HDBK-5 A + B VALUES

	TYS	TUS	ELONG.	RED.
A BASIS	138.92	151.64	0.00	10.87
B BASIS	144.26	157.04	7.00	14.05

TABLE VI-17. SUMMARY OF STATISTICS ON Ti-6Al-4V STA EXTRUSIONS

Grain Direction	Characteristic	Thickness Range, in.							
		≤ 0.50		0.51-0.75		0.76-1.00		1.01-2.00	
		TYS Fty	TUS Fty	TYS Fty	TUS Ftu	TYS Fty	TUS Ftu	TYS Fty	TUS Ftu
Longitudinal	$\bar{x}$	159.8	172.7	152.1	166.0	146.9	160.0	145.2	159.9
	s	5.5	5.6	5.5	6.0	5.4	5.5	5.5	6.6
	n	70	70	26	26	71	71	20	20
	Norm?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	A	144	157	135	147	132	---	127	138
	B	151	164	142	155	138	153	134	147
Long Transverse	$\bar{x}$	157.3	169.3	153.8	166.1	150.1	162.9	151.5	164.3
	s	2.1	2.7	5.7	5.8	5.5	5.4	4.4	4.4
	n	41	41	155	155	283	283	52	52
	Norm?	Yes	No	No	No	Yes	No	Yes	Yes
	A	151	---	---	---	136	---	139	151
	B	153	164	144	156	142	155	144	157
Long. & Trans.	Spec.	150	160	145	155	140	150	130	140

APPENDIX VII

MIL-HDBK-5 COMPLETED ITEMS AND MILESTONES - 1971

Chapters 1 and 9 Items

Item 67-15 Residual Strength Properties. This item has not been completed. A significant report "Concepts in Fail-Safe Design of Aircraft Structures" by D. Broek was prepared and issued.

Item 67-42 Revision of MIL-HDBK-5. The preparation of a complete revision of MIL-HDBK-5 was completed in 1971. The MIL-HDBK-5B revision was issued in February 1972.

Item 71-1 Design Methods for Structural Elements in MIL-HDBK-5. The Structural Element Task Group recommendation that methods of structural analysis for certain elements, such as beams, columns, frames, trusses, plates, membranes, and similar structural items, should not be included in MIL-HDBK-5 was accepted.

Item 71-2 Use of Static Strength Curves in Creep Regime. A revision to paragraph 1.4.8.2, was approved. This revision is to alert the designer to the potential problem.

Item 71-3 Data Requirements for New Materials in MIL-HDBK-5. New minimum requirements for data on new materials was accepted. The Coordination Group adopted the policy that all proposals for new materials show substantiating data in accordance with guideline requirements.

Chapter 2

Item 69-11 Pyromet X-15. Item dropped as a result of low anticipated use and termination of specification activity.

Item 71-4 Stress Corrosion on PH Stainless Steels. Although this item was not completed, a comprehensive report was issued describing the problems associated with providing reliable stress corrosion data for the PH stainless steel at the present time.

Chapter 3

Item 68-16 Large Aluminum Forgings. Extensive revisions to the tables for 2014, 7075, and 7079 forgings were approved and will appear in Revision B.

Item 68 25 7075-T76 Sheet, Plant and Extrusions. This item was completed and approved and will appear in Revision B. Specification values were added for T76 temper sheet, plate and extrusions.

Item 70-8 Properties of Stretched Formed Aluminum Extrusions. Since a number of processing variables not controlled by specification influence the properties of stretch formed aluminum extrusions, it was not feasible to incorporate definite data. An existing precautionary note in the Handbook on this effect appears to be adequate. Item was closed.

Item 70-11 X7475 Aluminum Alloy Sheet and Plate. This alloy is proprietary and there are neither government specifications nor current specification activity. Item was closed.

Item 71-7 Revision of Aluminum Modulus Values. Modified values will appear in Revision B in accordance with tasks submitted by ALCOA and approved.

Item 71-21 2024-T3 Sheet. Changes in certain B values were approved and will appear in Revision B.

APPENDIX VIII

MIL-HDBK-5 ITEMS INITIATED IN 1971

71-1	Design Methods for Structural Elements in MIL-HDBK-5
71-2	Use of Static Strength Curves in Creep Regime
71-3	Data Requirements for New Materials in MIL-HDBK-5
71-4	Stress-Corrosion Threshold Data on Precipitation Hardenable Stainless Steels
71-5	Ti-6Al-4V Annealed Plate
71-6	Weld Bonding
71-7	Revision of Aluminum Modulus Values
71-8	X7050 Aluminum
71-9	2219 Aluminum Extrusions and Forgings
71-10	Reduction of Bearing Data (Guidelines)
71-11	Design Allowables for Flush Head and Protruding Head Bi-Metallic Solid Rivets
71-12	Design Allowables for 95 ksi Shear Type Flush Head Huckrimp Fastener
71-13	Design Allowables for 100° Flush Head High-Strength Steel Blind Bolts in Machine-Countersunk Aluminum Alloy
71-14	Joint Allowables for HL87-303 Stainless Steel Collar
71-15	Maraging Steel Castings
71-16	Ti-5Al-2.5Sn Extrusions
71-17	Hastelloy X Sheet
71-18	Rene 41 Sheet
71-19	L605 Sheet
71-20	7049-T73 Forgings
71-21	2024 Sheet and Plate Changes in B Values
71-22	HS188 Sheet
71-23	RV-1000 and RV-1105 Series Blind Fasteners

APPENDIX IX

ACTIVE MIL-HDBK-5 ITEMS FOR 1972

67-12	Methods of Presentation of Fatigue Data
67-15	Residual Strength Properties of Materials Containing Flaws
70-21	Revision of Stress Strain Curves
71-3	Data Requirements for New Materials in MIL-HDBK-5
70-15	A and B Values for 17-4 PH Bar
70-16	Additional Data on PH 13-8Mo Forgings
70-17	Additional Data on PH 14-8Mo Sheet
70-19	Allowables for 9Ni-4Co (0.20 and 0.30C) Steels
71-4	Stress Corrosion Threshold Data on Precipitation Hardenable Stainless Steels
71-15	Maraging Steel Castings
68-23	7175-T66 and -T736 Forgings
69-5	T62 Temper Designation
70-1	201.0 and MIL-A-21180 Aluminum Castings
70-9	2124-T851 Thick Plate
70-10	X224-T7 Aluminum Casting Alloy
70-22	2024-T81 Temperature Effect Inconsistencies
70-23	7075-T6 Temperature Effect Inconsistencies
70-24	Review of Compression, Shear, and Bearing Ratios for 7075 at Elevated Temperatures
71-8	X7050 Aluminum
71-9	2219 Extrusions and Forgings
71-20	7049-T73 Forgings
68-19	Ti-6Al-4V Extrusions
68-21	Ti-6Al-6V-2Sn Extrusions

68-16	Ti-5Al-2.5Sn Extrusions
69-2	Continuous Rolled Ti-6Al-4V Sheet
70-25	Ti-6Al-6V-2Sn Forgings
71-5	Ti-6Al-4V Annealed Plate
70-18	Inconel Alloy 706
71-17	Hastelloy X Sheet
71-18	Rene 41 Sheet
71-19	L605 Sheet
71-22	HS 188 Sheet
67-8	Beryllium Copper
70-13	Brake Grade Beryllium
70-14	Hot Pressed Beryllium Block

Chapter 8.

61-16	Fastener Test Development Group Program
None	Aero Mechanical Fastening Requirements Group
66-3	Bearing Test Procedures
71-10	Reduction of Bearing Data (Guidelines)
71-11	Design Allowables for Flush Head and Protruding Head Bi-Metallic Solid Rivets
71-13	Design Allowables for 100° Flush Head High-Strength Steel Blind Bolts in Machine-Countersunk Aluminum Alloy
71-14	Joint Allowables for HL 87-303 Stainless Steel Collar
71-23	RV-1000 and RV-1105 Series Blind Fasteners

REFERENCES

(1) "Agenda for the Forty-First Coordination Meeting of MIL-HDBK-5 on Metallic Materials and Elements for Aerospace Vehicle Structures", enclosure to letter dated March 12, 1971, from Hyler, Battelle, to (MIL-HDBK-5) Distribution.

(2) "Minutes of the 41st Services-Industry Coordination Meeting MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures", enclosure to letter dated June 4, 1971, from Hyler, Battelle, to (MIL-HDBK-5) Distribution List.

(3) "Agenda for the Forty-Second Coordination Meeting of MIL-HDBK-5 on Metallic Materials and Elements for Aerospace Vehicle Structures", enclosure to letter dated September 3, 1971, from Hyler, Battelle, to Members of MIL-HDBK Coordination Group.

(4) "Minutes of the 42nd Services-Industry Coordination Meeting MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures", enclosure to letter dated November 12, 1971, Hyler, Battelle, to (MIL-HDBK-5) Distribution List.

(5) Hald, A., Statistical Theory With Engineering Applications, Wiley (1952), p 291.

(6) Natrella, M. G., Experimental Statistics, National Bureau of Standards Handbook 91 (August 1, 1963), pp 3-40 through 3-42.

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13. ABSTRACT

The Department of Defense has designated the Air Force as the preparing activity responsible for MIL-HDBK-5, which is the primary source for design allowable data for metallic materials, fasteners, joints, and other structural elements used in the design of aerospace vehicles. The Air Force Materials Laboratory has contracted with Battelle's Columbus Laboratories (BCL) to provide the planning, coordination, and implementation activities necessary to maintain current design allowable data in the Handbook. The services provided by BCL for the MIL-HDBK-5 program involve the following: an assessment of the design data requirements of the aerospace industry; liaison with appropriate Government agencies, military services, aerospace contractors, and metallic material suppliers; collection of data; statistical analysis of data to determine design allowable properties; preparation of proposals which contain the revisions to MIL-HDBK-5 for the incorporation of new data; presentation of these proposals at the twice-yearly Government-industry coordination meetings for approval; and revision of MIL-HDBK-5 to incorporate these approved changes.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Data acquistion						
Data processing						
Design allowable data						
Fasteners						
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Statistical analysis						
Statistical methods						