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A STUDY OF NACA AND NASA PUBLISHED INFORMATION OF PERTINENCE IN THE DESIGN OF LIGHT AIRCRAFT

Volume I - Structures

by Frederick O. Smetana

Prepared by
NORTH CAROLINA STATE UNIVERSITY
Raleigh, N. C.
for Langley Research Center

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Prepared under Contract No. 1-7265 by
DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING
NORTH CAROLINA STATE UNIVERSITY
Raleigh, N.C.

for Langley Research Center

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Acknowledgements

Examination will show that the preparation of this report involved a great many lengthy editorial tasks. Many figures were prepared, reports had to be secured, account kept of those reviewed, typescript proofread, etc. Mr. Delbert C. Summey was principally responsible for these functions. His contribution is herewith gratefully acknowledged.

Mr. Joseph W. Stickle of the Langley Research Center, who acted as technical monitor, made many valuable suggestions relative to the conduct of the work. His contribution is also acknowledged.

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GENERAL INTRODUCTION

Individuals in the National Aeronautics and Space Administration have long felt that much of the agency's research, although originally performed in support of military and commercial transport programs, has not been applied as completely as it might have been to general aviation activity, particularly as the flight speed of these aircraft reached regions in which military and commercial transport aircraft have operated during the past twenty-nine years. NASA has also recognized that general aviation manufacturing concerns are quite small compared to the usual aerospace manufacturer; they do not have the large engineering staffs to adapt new technology rapidly, but operate more nearly like the majority of American manufacturing concerns where evolutionary changes rather than revolutionary changes are the order of the day. As a result, technical information contained in NASA files must be specially processed to make it really useful to such firms. As originally conceived, the vehicle for this transfer would be a modern, step-by-step design manual.

Another difficulty faced by the general aviation industry is the lack of young engineering talent with an appreciation of and interest in the industry's problems. This is a result of the almost exclusive attention to the problems of supersonic and space flight which has been characteristic of American aeronautical education for the past 15 years. Younger faculty, for the most part, are not familiar with the problems of light aircraft design and so fail to motivate students to consider this field.

As a way of aiding the general aviation industry in this area as well as with technical information, NASA contracted with North Carolina State University to have a group of younger faculty and students conduct a survey of all NACA and NASA-generated work since 1940 to identify technical information of potential use in a light aircraft design manual. Five faculty members of the Department of Mechanical and Aerospace Engineering participated in the program. Each was assisted by two Aerospace Engineering seniors who also were given special sections of the regular senior work in Aerospace Engineering of direct pertinence to light aircraft.

Dr. James C. Williams was responsible for reviewing the work in aerodynamics and was assisted by Mr. Edwin Seiglar and Mr. Delbert Summey.

Dr. John N. Perkins was responsible for reviewing the work in air loads and was assisted by Mr. Donald Knepper and Mr. William Rickard.

Dr. Clifford J. Moore reviewed the work on propulsion systems analysis and was assisted by Mr. Donald Gray and Mr. Johnny Logan.

Mr. Dennis M. Phillips reviewed the work in performance, stability and control, and flight safety and was assisted by Mr. Robert Pitts and Mr. Paul Ho.

Dr. Frederick O. Smetana was responsible for reviewing the work in construction analysis, materials, and techniques and was assisted by Mr. Hudson Guthrie and Mr. Frank Davis. Dr. Smetana also acted as Principal Investigator on the project.

The majority of the work began 1 June 1968. The students devoted approximately 30 hours a week each for the 13 weeks of the summer and 8 hours per week during the fall semester to the project. Faculty commitment was approximately 1/4 time during the summer and 2/5 time during the fall semester.

The students performed the majority of the actual document reviews after being instructed as to the type of information desired. The faculty also provided guidance when pertinence of a particular report was questioned or the treatment was too advanced. Beginning in late fall, the faculty members carried out an analysis of the reviews in their areas of cognizance to (1) identify those of most probably interest in the development of a design manual, (2) define the state of the art in each area, and (3) identify those areas particularly well-treated or requiring additional research. The body of this report contains the results of the analysis relating to structural design. The individual reviews are reproduced in the appendix. Volume II treats aerodynamics and aerodynamic loads while Volume III is concerned with propulsion systems, propellers, performance calculation, stability and control, and flight safety.

It will be recognized that the assignment of a "not applicable" label to a particular report is a judgment decision; the standards for making such assignments inevitably vary somewhat from day to day and from individual to individual. There is also the tendency on the part of any reviewer to become more critical of the value of a report to a particular project as his experience and the number of reports he has reviewed increases. Since the present review began with the earliest documents, this discrimination is applied more noticeably in the later documents. Additionally, it seems to be inevitable that in the process of assigning reports to the various groups and individuals for review some are reviewed twice and others not at all. Although an effort was made to correct such deficiencies, some undoubtedly remain. For these and others, the reader's indulgence is requested.

No attempt has been made to have the analyses prepared by the faculty conform to a single style. This would have been difficult because all were prepared simultaneously; but more importantly, the various topics were found to have been given different emphasis with time and to vary widely in depth. Consequently, each faculty member was asked to adopt that style which seemed most appropriate to the material being covered.

The number of documents to be examined was on the order of 10,000. A simple calculation will show that on the average less than 30 minutes could be allotted to each report. Even if one discounts the 30%-40% which were considered not applicable, the time available for review was still not large. It is a fact, also, that the rate of generation has increased markedly during the last nine years. However, since an in-depth index of all current NASA-generated documents has been available for computer searching since 1962 and since current reports are more likely to be familiar to the working engineer, major emphasis was placed on those reports produced prior to 1962.

GENERAL CONCLUSIONS

Five faculty members, assisted by ten undergraduate students, of the Department of Mechanical and Aerospace Engineering at North Carolina State University have reviewed the NACA/NASA-generated literature published since 1940 for information of possible pertinence to the design of light aircraft. On the basis of these reviews, it is concluded that:

1. There is a wealth of structural design information available which, if incorporated intelligently in light aircraft construction, could result in improved structural efficiency.

2. To apply this information in the most effective fashion possible, computer programs which have modest time requirements and which specify the material gauges, the stiffener configuration and the stiffener spacing when supplied with the body shape desired and the loading expected must be developed.

3. The information available on propulsion subsystems is adequate for design purposes but requires careful and complete assembly and must be accompanied by detailed instructions for it to be used effectively.

4. There are adequate, although, complex, theoretical methods available for calculating aerodynamic wing loads.

5. More sophisticated theoretical methods making use of high-speed computers need to be developed for the calculation of aerodynamic loads on tail surfaces.

6. There is insufficient accurate information available on hinge moments to construct reliable design charts.

7. Information on gust load experiences and spectral distribution is in need of updating to permit structural designs suited to the varied utilization of light aircraft.

8. Information on landing gear loads appears to be adequate.

9. Flutter information, while limited, appears to be suitable for development of adequate design criteria.

10. There is a lack of data on body aerodynamics and wing-body and tail-body interference effects; otherwise, there appears to be sufficient information in the NACA/NASA literature to compile and prepare a design manual suitable for use in the aerodynamic design of personal-type aircraft.

11. Refined performance calculation procedures which permit the attainment of instantaneously optimum flight paths and which are suitable for

use with light aircraft are available. Their utilization could be increased through machine evaluation.

12. Generally-accepted, yet detailed criteria for the stability and and control characteristics of light aircraft do not now exist, although there is a wealth of data from which such criteria can probably be constructed.

13. Recent high horsepower propellors have been designed using copious data obtained during the late 1940's. This permits performance improvements over the pre-1943 data used to design current light aircraft propellers.

14. Insufficient attention has been given to fixing quantitatively the combination of aerodynamic, propulsion, and structural parameters which are required for a really safe-to-fly light airplane, although much of the basic data from which such determinations can be made already exists.

A STUDY OF NACA AND NASA PUBLISHED INFORMATION OF PERTINENCE IN THE DESIGN AND CONSTRUCTION OF LIGHT AIRCRAFT STRUCTURES

The basic structural elements used in light aircraft construction have changed but little in the last 30 years. To be sure, the intervening years have seen many improvements in fabrication techniques, materials, and structural efficiencies, but the rings, frames, plates, shells, beams, columns, stringers, torsion boxes, shear panels, etc. remain. As a result, the models used for analytical representation of actual structures remain much the same as those used 30 years ago. This relative constancy of approach and the continuing need for more accurate prediction of structural performance to permit the selection and achievement of the most efficient structures has resulted in a steadily-rising production of in-house, NASA-supported, and foreign-translation publications providing new test data or refined analytical treatments. In only the two month period October and November 1968, NASA/SCAN listed 94 articles under the heading "Stress Analysis" and 128 under "Shells." Over a year's time, this projects to something on the order of 700 pertinent documents, allowing for overlap. This does not include much of the considerable volume of work being done on structural vibrations, fatigue, and creep. It is thus reasonable to expect that most of the raw material from which improved techniques in light aircraft design and construction can be mined will be of very recent origin.

The translation of most of this wealth of raw material into practical design and construction procedures, however, is not a simple task, since the reports are for the most part solutions to specially-posed boundary value problems which are related - but not necessarily identical - to realistic structures. Considerable judgment must therefore be exercised in adapting these methods to calculating the strength of proposed designs to insure that an adequate safety margin is maintained and that the region of applicability is not exceeded. Also, while many of the methods are readily adaptable to computer calculation, others are closed-form solutions of more approximate formulations better suited to manual manipulation. It seems inevitable, however, that aircraft structural design must proceed in the direction of

(1) computer solution of more exact methods and

(2) the use of materials and techniques which permit higher strength-to-weight ratios and require fewer man hours to fabricate.

Unfortunately, little in the way of detailed numerical methods or actual computer programs seems to have emerged from the literature as yet. Since these require considerable efforts to produce, it is likely that general aviation manufacturing firms will be slow to adopt such methods. In the latter area (newer materials and fabrication techniques) an even slower rate of acceptance is to be expected since such steps usually mean working with unfamiliar materials, large capital investment, and retraining the labor force.

At present, wing structures are usually treated basically as beams. They must resist tension, compression, and torsion as well as bending. Torsional stiffness is usually achieved by utilizing the wing skin as an element in a multicellular torsion box. The thin skin required for this purpose in subsonic aircraft is also effective in resisting tension but not the compression which occurs during wing bending. To stiffen the skin, spanwise stringers are used. To hold the skin surface to the airfoil shape and to transfer the air loads to the cellular beam structure, ribs are used.

This structural arrangement, while efficient, is highly indeterminate so that various simplifying assumptions must be made to obtain a tractable problem for hand calculation. Shear lag is neglected and linear stress-strain relations are assumed. Skin and stringers are often assumed to carry only tension loads. In practice, stringers are usually more lightly loaded than the skin and more heavily than the spar caps for safety reasons.

Refinements in member sizes and hence structural efficiency are often made when computing equipment is available to solve the many simultaneous relations which must be written for highly redundant structures.

Fuselages are often treated as either fairly simple beams or trusses subject to most of the same types of stress as the wing. The curved plates which constitute the skin, however, often contribute considerably to buckling stiffness.

Detailed design of ribs and frames usually considers them as stiffened plates with cutouts subject to shear and normal loads.

In recent years, the requirements for missile and spacecraft structures have led to considerable interest in monocoque and semi-monocoque or stiffened cylindrical shells. Note the large quantity of recent literature dealing with this topic. This structural form also has application to aircraft fuselages but is not so employed extensively at present. This is probably because the form, while offering some improvement in structural efficiency over more conventional (ring-frame or truss) construction, is relatively new to this application and theoretical methods for predicting strength are neither highly accurate nor easy to use. Also conventional construction provides bulkheads upon which equipment items may be attached and payload supported. Rather radical procedures would be necessary to support concentrated loads in quasi-monocoques. Bulk loads such as liquid propellants, of course, are more readily carried.

For the review which follows, extracts from that portion of the NACA/NASA-generated literature which initial examination had indicated were probably applicable to the structural design of light aircraft were first segregated according to topic and then studied in detail. It became evident that it would not be possible in general to select a few reports under each topic and say these contained either forgotten gems of wisdom or were <u>the</u> definitive work in the area; the areas are simply too diverse for this and the utility of so much of the test data and analytical procedures depends upon the service to which the user wishes to put it. For this reason, the review mentions most of the reports cited in the appendix but groups them according to problem areas within each topic. The bibliographic information and comment for those considered to be of greater significance to someone devising modern design procedures is more complete than for those of historical interest primarily. Reference to the appendix, however, will provide virtually complete details.

It is intended that this review work serve as the initial phase of a program to prepare a systemitized light aircraft design manual or set of procedures. One is led to the conclusion, however, that to take full advantage of significant recent developments in structural analysis theory, no design manual in the conventional sense is feasible. The methods that should be employed are quite complex, sufficiently so as to be beyond the comprehension of the young designer. The time required to check several alternate approaches becomes prohibitive, even for experienced analysts. One cannot reasonably expect the general aviation industry to invest the capital required to translate adequately much of this material into usable computer programs; the payoff is just too long. Yet this is precisely what is needed; digital computer programs to specify the material gauges, stiffener spacing, stiffener type, and stiffener attachment method for each type of construction (e.g., ring-supported, stiffened cylinder; semi-monocoque; etc.) when the loading is given. Minimum cost and minimum weight options can be provided. Plastic flow of secondary structure should be permitted and accounted for when the loading reaches 100% of design values and failure of the primary structure should occur at the usual 1.2 to 1.5 times limit design load. To keep the programs and computing time manageable, each major component of the aircraft-wing, aerodynamic control surfaces, fuselage, engine attachments, empenage, landing gear, and passenger cabin should have individual design programs with alternates for different construction techniques.

Programs of this complexity can only be written by large, sophisticated engineering organizations such as those possessed by the major aerospace companies and perhaps a few firms which specialize in computer software. Rudimentary forms of such programs are, however, already in use by a few of the large manufacturers for preliminary design activity. The cost of running the programs, while economically advantageous for the large concerns because of the large amount of engineering that goes into new commercial transport or military aircraft, is not yet at a sufficiently low level to attract the general aviation manufacturer. It is to be expected, however, that some organization will recognize the commercial importance of this approach and prepare suitable programs which can be sold to and used advantageously by general aviation manufacturers.

One would anticipate that the use of such programs would lead to lower cost aircraft with improved performance within a relatively short period of time. There should also be maintained a continuing program to refine and expand the programs, since the initial efforts of necessity will model some aspects of the structure more crudely than one would desire.

It is suggested that initially only one of the major structural components, such as the wing, be treated and that when completed, this program be field-tested to provide feedback for use in the design of other programs. The wing program should have as inputs the external wing geometry and air loading in detail, the type and location of attachment to the fuselage, the type of structure desired (e.g., ribs and spars of stressed-skin box beam with relatively few internal supports), and the attachment points, directions and magnitudes of major loads (landing gear, engines, control surfaces, and fuel tanks). The output would then be the skin thickness and the number, location, and configuration of internal supports. Initially, the design should be for a single material and for minimum weight with a limit on minimum material gauge. Later, the program could include options for other materials, could include estimates of manufacturing costs, and provide a minimum cost option which can be compared to the minimum weight option.

The effort described above is regarded as that most likely to lead to significant improvements in structural efficiency and attendent reductions in fabrication cost in a short period of time; nevertheless, gains, although more modest, can still be expected from a careful codification and application of existing analytical and experimental results to produce a design procedure manual in the same style as long-time standard college texts on aircraft structural design and analysis, but at a more advanced level and with more detail.

Typically, new models in the general aviation industry are changed but little from preceding models. Experience and a rudimentary knowledge of strength of materials indicates generally what alterations need be made for structural integrity; static test of the new structure then validates the design. Most of the existing dies and jigs are utilized. Engineering, tooling, and training costs are thus kept reasonable and predictable. Inefficient designs are retained simply because it costs a lot of money to change them and the competition also has inefficient designs which the average buyer is usally too unsophisticated to recognize.

In the American economy, product price usually has a strong influence on sales volume. With the relatively low-volume production runs given most models, it is just not practical to invest large sums in engineering; the sharply increased sales price necessary to recover the investment will disillusion buyers unless there is a corresponding, marked improvement in performance. Structural design, being still a somewhat inexact science, is difficult to quantize. One cannot often say that a completely new airframe with a given,superior, structural efficiency, satisfying all expected failure modes can be designed for X dollars, X being a sufficiently small number that corporate management can be guaranteed that the aircraft will have significantly higher performance per dollar.

Realistically, in the absence of the quantum performance jump which would accompany the availability of really low cost computer design programs, one would anticipate that a series of competently-constructed design charts and nomograms to lead a small group of less-sophisticated engineers rapidly and step-by-step through the design of an improved major structural component -

would be welcomed by the industry; adoption of these charts for the design of first one component and then another, as the various models evolve and as the benefits of the approach are demonstrated, is to be expected.

As indicated above, another facet of aircraft manufacturing upon which substantial effort must be lavished in order to increase the level of aircraft ownership is that of reducing the assembly cost. It should be obvious that hand riveting of all the components is, or soon will be, prohibitively expensive. Machine fabrication by either riveting or spot welding of substantially the same type of structural elements can be cheaper only if the tooling cost per item can be reduced below the labor cost - usually possible only for long or high-volume production runs. What is needed is something akin to blow molding of plastics during which an entire structural component such as a wing or fuselage is created in one or two pieces. The development of the requisite materials, fabrication techniques, and analysis procedures should therefore be an item of high priority in a meaningful structural research program.

It will be noted from the review that the continuing and very active program in the prediction of the static load-carrying ability of various configurations of plates, and more recently of shells, still has not been able to provide soundly-based methods which yield slightly conservative predictions; the best methods available give allowable loads more than 10% above experimentally-determined failure points. One problem in correcting this situation is that more efficient stiffener and support configurations are constantly being developed. Thus new analytical approaches are constantly required and time is not available to refine the predictions on a single configuration. Since the static load-carrying capacity of a structural member is the most important performance parameter to be calculated, it is entirely appropriate that the major portion of the research effort should be in this area and that the analysis methods which have been developed are more refined here than in some other areas. This situation can be expected to continue in the future.

Although treatments of structural vibrations and flutter have important applications in high speed, high-usage aircraft and particularly in launch vehicles, they have not yet reached this stage of significance in light aircraft. Somewhat similar comments may be made with regard to fatigue design. The portion of the total research program devoted to these areas is thus regarded as adequate.

Contributions to beam theory while not plentiful, particularly in recent years, are considered as being issued at an acceptable rate. This reviewer also regards NASA contributions to the theory of elasticity to be at an adequate level as far as light aircraft design is concerned.

One area where the need for a somewhat higher level of effort appears to be indicated is in plasticity analysis, particularly if reasonably ductile metals continue to be the favorite materials of construction.

Langley Research Center is justly famed for its research on materials for an almost infinite variety of aircraft and spacecraft applications. A large quantity of reports bears testimony to this fact. From the standpoint of the light aircraft structural designer, however, strictly metallurgical information, test results obtained under unusual conditions, and design information on exotic or unfamiliar materials are of little interest. For these reasons, many reports dealing with tests on structural shapes have been marked as "not applicable" or have not been discussed in the body of the review. In general, the properties of suitable metallic materials for light aircraft construction appears to have been covered adequately. As suggested earlier, however, one facet which could profitably be added to the research program is the development of moldable materials with strength-to-weight ratios comparable to that of aluminum and the techniques required to produce large, complex, dimensionally-accurate, load-bearing shapes in single units from such materials.

The reader is encouraged to examine these conclusions as he scans the following review.

It will be noted that the reports in the Appendix are divided into two groups: those considered at least generally applicable to the design and/or analysis of light aircraft structures; and those considered to relate to structural design and analysis or to material properties and tests in a general fashion but not to be particularly applicable to light aircraft. In each group, the reports are listed chronologically by series. The table below gives the initial and final number of the reports in each group by series.

	Applicable	Not Applicable
First NACA Technical Note	746	744
Last NACA Technical Note	4403	4372
First NASA Memorandum (Memo)	5-3-59L	10-5-58E
Last NASA Memorandum (Memo)	5-3-59L	6-14-59L
First NASA Technical Note	98	1
Last NASA Technical Note	2578	2649
First NACA Technical Report	696	707
Last NACA Technical Report	1343	1392
First NASA Technical Report	R-13	R-5
Last NASA Technical Report	R-103	R-112
First NACA Wartime Report	L 2 W 31	None W 70
Last NACA Wartime Report	L 691 W 102	None W 103
First NACA Research Memorandum	L 8130b	A 51 L 17a E 7 G 18a L 7 H 28

	Applicable	Not Applicable
Last NACA Research Memorandum	L 8130b	A 58 B 26 E 57 K 22a L 57 L 13
First NACA Technical Memorandum	933	964
Last NACA Technical Memorandum	1297	1290
First NASA Technical Translation	F-27	F-34
Last NASA Technical Translation	F-27	F-64

As noted in the Introduction, the student reviews began with reports from the year 1940 and proceeded forward to those issued about 1964. It became evident, however, that there was much information of direct pertinence to the review in the current literature. Accordingly, the writer secured most of the D-series technical notes, technical translations, and generally-circulated contractor reports dealing with structural analysis for the years 1966, 1967, and 1968. Some earlier documents were also included. These he reviewed; those regarded of pertinence are discussed below. The bibliographic information given is not complete, except for those reports regarded to be the more significant; but in all cases sufficient detail is given so that the interested reader may secure the report for himself. This method was adopted to aid the flow of the narrative. Since these reports were not reviewed by the students, the Appendix mostly lists bibliographic information for the D-series technical notes after 1964. Contractor reports are not mentioned.

The bibliographic information given in the review below for the older work is generally very short, usually just the report number. Complete citations for these older documents are given in the Appendix.

Contributions to the Theory of Elasticity

1. Essential to the development of new improvement structural analysis procedures are the more powerful or more detailed theoretical methods upon which they are built. Thus despite the apparent inapplicability of many of the more recent contributions to the theory of elasticity, it is imperative that such studies be continued. Typical of some of this activity are CR-549 (The Eigenvalue Problem for Beams and Rectangular Plates with Linearly Varying In-Plane and Axial Load), CR-621 (An

Extension of Plane Strain Analysis) and CR-779 (An Integral Equation Method in Plane Elasticity).

2. Older work in this area is represented by TNs 871 and 1823 and TR 1342.

3. Another recent contribution of interest which generalizes earlier and simpler theory is "A Theory of Anisotropic Viscoelastic Sandwich Shells" by John L. Baylor, CR-396, March 1966, 69 pp.

4. Analytical solutions for the stress state in an edge-stiffened rectangular plate with boundary loads, boundary displacements, and temperature gradients are presented in CR-864,(August 1967),226 pp. by Lin and Libove. Numerical evaluation by computer was found to require substantial time. Earlier work by the same group is given in TN D 2505, 1964.

Advanced Analytical Methods - Plasticity Analysis

1. "Discrete-Element Methods for the Plastic Analysis of Structures" by G. Isakson, H. Armen, Jr., and A. Pifko, NASA CR-803, October 1967, 206 pp. This is a study of improved methods of structural analysis and the accompanying digital computer programs which could be used in the construction of large, supersonic aircraft. The position taken is that improved failure prediction techniques must include consideration of plastic behavior. Two areas are considered: inelastic stress analysis in the presence of load cycling and plastic buckling of the bifurcation type. Applications treated include the swept multicell box beam, the notched bar, and the stiffened panel. Associated computer programs are presented in CR-66364. 80 references.

2. Earlier contributions to plastic buckling and plastic behavior include TN 1530 (TR 946), TN 1556 (TR 898), TN 1681, TN 1705, TN 1817, TN 1871, TN 1971, TN 1985, TN 1990, TN 2029, TN 2217, TN 2287, TN 2301, TN 2737, and TR 1029.

Structural Vibrations and Flutter

1. Representative of the analytical and experimental efforts to specify panel flutter, whole wing flutter and vibrational modes, and beam vibrations are TN 746, TN 1594, TN 1747, TN 2132, TN 2300, TN 2540, TN 2608, TN 2682 (TR 1129), TR 914, and TR 1302.

2. Of interest when wing structures are subject to impact loads is TR 828, "Bending and Shear Stresses by the Instantaneous Arrests of the Root of a Moving Cantilever Beam," by Elbridge Z. Stowell, Edward B. Schwartz and John C. Joubolt.

3. Other studies dealing with beam vibrations are presented in TN 1522, TN 1583, TN 1909, TN 1996, TN 2185, TN 2594, TN 2874, TN 2875, and TN 2884.

Determination of Inertial Parameters

1. Techniques for measurement of full-scale aircraft moments of inertia along with data on a number of older aircraft type are presented in TNs 780, 1187, 1629, and 2201.

2. Of interest in determining the required torsional stiffness of an aircraft wing are the charts and equations presented in TR 799 by Henry A. Pearson and William S. Aiken, Jr.

Fatigue Design

1. "Some Considerations in the Fatigue Design of Launch and Spacecraft Structures," R. H. Christensen and R. J. Bellinfante, NASA CR 242, June 1965, 109 pp. A handbook, virtually, on recommended design practice where fatigue failures may be involved. Many charts and tables. 41 references.

2. Fatigue tests of a full scale transport aircraft wing structure are reported in TN 2920 by M. James McGuigan, Jr.

3. Results on axial fatigue tests of 10 airplane wing-beam specimens are presented in TN 959.

Materials

1. In general, the physical properties of aluminum alloys are well known in the airframe manufacturing industry. The material suppliers make it their business to provide such information to the users of their products. The suppliers are also alert to provide the user with the latest in fabrication techniques for their products. Information on spot welding of aluminum falls in this category. One can mention TNs 869, 1322, 1411, 1415, 1464, 2157, and 2538, however, as providing additional information.

2. An important area where supplier information is likely to be less satisfactory is the fatigue life of construction materials and built-up shapes. This is covered in some detail for aluminum in TNs 792, 852, 857, 865, 900, 917, 955, 971, 983, 992, 1030, 1469, 1485, 1489, 1514, 1889, 2012, 2231, 2276, 2324, 2389, 2390, 2394, and 2812.

3. Bearing strengths of aluminum alloy sheets is treated in TNs 901, 920, 974, 981, 1502, and 1503. Rivet properties are covered in TNs 804, 916, 930, 942, 948, 1036, 1125, 1205, and 1523.

4. Information on general stress-strain properties of aluminum alloys is given in TNs 819, 924, 927, 1010, 1072, 1162, 1385, 1512, 1513, 1536, 1552, 2085, and 2094.

5. The effects of circular holes or other stress raisers is covered in TNs 1611, 1830, and 1974.

6. Torsional strength of aluminum shapes is reported in TNs 879, 885, 904, and 1097.

7. Shear strength of aluminum sheet is treated in TNs 833 and 1756.

8. Properties of honeycomb structures are treated in TNs 1529, 2084, 2106, 2208, 2243, 2289, and 2564.

Plates and Shells

1. SHELL ANALYSIS MANUAL, Baker, E. H.; Cappelli, A. P.; Kovalevsky, L.; Rish, F. L.; and Verette, R. M., North American Aviation, Inc., Downey, California, NASA CR-912, 804 pp., April 1968.

   Volume is divided into five topics:

   1. Introudction to Shell Theory
   2. Procedures for Static Analysis of Shell Structures
   3. Procedures for Stability Analysis of Shell Structures
   4. Minimum Weight Shell Design
   5. Optimum Use of Computer Programs

   This volume reviews shell analysis methods in use in 1965. 197 references to the literature are presented. Generally, the techniques presented are adaptations of the classical solutions in the literature rather than systematic design procedures to arrive at minimum weight structures for particular applications. The emphasis is on the first three topics. Treats mainly thin shells with both linear and non-linear deflections.

2. GENERAL THEORY OF SHELLS AND ITS APPLICATIONS IN ENGINEERING, V. Z. Vlasov, NASA TTF-99, April 1964, 913 pp. Presents the results of perhaps twenty years work by the author (up to 1947) dealing with advanced topics in the theory of shells.

3. THEORY OF SHELLS AND PLATES, S. M. Durgar'yan editor. NASA TTF-341, 1966, 948 pp. Proceedings of 4th All-Union Conference on Shells and Plates held at Erevan 24-31 October 1962, 122 papers dealing with theoretical developments and applications to a variety of engineering problems. Interest in thermal stresses, dynamics of shells, and stability is evident. Little work reported on computer solutions (perhaps 4 or 5 papers).

4. DYNAMICS AND STRENGTH OF SHELLS, P. M. Ogibalov, NASA TTF-284, 1966, 319 pp. Translation of a 1963 Russian textbook on shell dynamics and shell stability. Special topics considered are elastic and inelastic stability, effect of plastic hardening of shells, inhomogeneity of shell materials, and penetrating radiation.

5. RIB-REINFORCED PLATES AND SHELLS, G. M. Savin and N. P. Fleishman, NASA TTF-427, 1967, 334 pp. 1964 Russian book which is the result of 12 years work by the authors and their students in the following subject areas:

   (1) analysis of stress concentrations in plates and shells reinforced by stiffening ribs

   (2) efficient design of the reinforcing elements, aiming at an optimum structure of thin plates and shells with ribs.

   Contains a bibliography of 213 items.

6. As part of a continuing in-house study of the buckling of stiffened cylinders, NASA has published at least 22 TNs (or equivalent) during the period 1959-1967. Two of these, TN D 2960 by Block, Card, and Mikulas and TN D 3351 by David L. Block, present a small deflection theory for buckling of stiffened orthotropic cylinders which includes eccentricity. Loadings considered include pure bending (TN D 3351) and combined axial and circumferential loading (TN D 2960). Test data has been acquired for honeycomb sandwich cylinders subject to bending (TN D 2926), truss core sandwich cylinder loaded in bending (TN D 3157), buckling of ring-stiffened circular cylinders loaded by uniform external pressure (TN D 3111), bending of ring-stiffened corrugated cylinders (TN D 3336), ring-stiffened thin wall cylinders subject to axial compression (TN D 506), buckling of stringer-stiffened cylinders (TN D 3639), compression of stringer-stiffened cylinders (Memo 2-12-59L), buckling of ring-stiffened cylinders (TN D 3647), and bending of corrugated, ring-stiffened cylinders (TN D 3702). The test data indicate that failure occurs at about 70% of predicted value (using the theory of TN D 3351 or TN D 2960). As a result, additional theoretical work is underway to improve these predictions as evidenced by TN D 3769 (plastic buckling of axially compressed, eccentrically stiffened cylinders), TN D 3826 (eccentrically stiffened shallow shells of double curvature), and TN D 4073 (structural efficiency of ring-stiffened corrugated cylinders in axial compression). Others in this series include TN D 3089 (general instability of ring-stiffened corrugated cylinders under axial compression), TN D 1510 (a collection of papers on shell stability), TN D 2482 (influence of ring stiffeners on instability of orthotropic cylinders in axial compression), TN D 1251 (structural behavior and compressive strength of circular cylinders with longitudinal stiffening), TN D 526 (correlation of the buckling strength of pressurized cylinders in compression or bending with structural parameters), TN D 98 (optimum proportions of truss core and web-core sandwich plates loaded in compression), TN D 2783 (effect of face sheet stiffness on buckling of curved plates and cylindrical shells of sandwich construction in axial compression) and for an unstiffened cylinder TN D 2814 (collapse tests of pressurized membrane-like circular cylinders for combined compression and bending).

7. In addition to its in-house program NASA is supporting substantial university and industry programs in cylindrical shell analysis as well

as translations of Russian works. Representative examples are CR 540 (buckling of cylindrical shell end closures by internal pressure), CR 161 (influence of edge conditions on the stability of axially compressed cylindrical shells), TN D 2537 (the effect of end slope on the buckling stress of cylindrical shells) and TTF 412 (local stability of sandwich shells of revolution).

8. Work on spherical shells in addition to that in the monographs cited above is represented by CR 567 (Analysis of a Spherical Shell with a Non-Axisymmetric Boundary), CR 550 (An Experimental Study of the Buckling of Complete Spherical Shells), and TN D 3002 (Membrane Analysis of Pressurized Thin Spheroid Shells Composed of Flat Gores and Its Application to Echo II).

9. Since most fuselages must contain access ports of various sizes, there has always been considerable interest in the effect of such cutouts on the strength of the fuselage and in means of redistributing the stress concentrations. Typical of NASA's recent publishing activity in this area are TTF 408 (Stress Concentration About Curvilinear Holes in Physically Nonlinear Elastic Plates), TTF 282 (Stress Concentration in a Cylindrical Shell with a Round Aperture in Its Side), TN D 2672 (Investigation of the Elastic-Plastic Stress State Around a Reinforced Opening in a Spherical Shell), and TTF 424 (The Stressed State Near Curvilinear Reinforced Orifices in Shells).

10. Other reports which have application to fuselage design but are not as readily categorized include TN D 2799 (Analysis of Pressurized and Axially Loaded Orthotropic Multicell Tanks), TTF 402 (Propagation of an Arbitrarily Oriented Rectilinear Crack During Extension of a Plate), CR 705 (On the Duality Between the Problems of Stretching and of Bending of Plates), and CR 707 (The Influence of Prebuckling Deformation on the Buckling Load of Truncated Conical Shells Under Axial Compression).

11. Of general interest in the design of plates and shells is the stress intensity at the edge of "cracks." Typical of the activity in this area are TN D 2603 (Stress-Intensity Factors for Single-Edge-Notch Specimens in Bending or Combined Bending and Tension by Boundary Collocation of a Stress Function), CR 655 (Development and Application of a Photoelasto-Plastic Method to Study Stress Distributions in the Vicinity of a Simulated Crack), and TR R 265 (Stresses at the Tip of a Longitudinal Crack in a Plate Strip).

12. Norris F. Dow, William A. Hickman and others compiled a series of reports presenting test data and voluminous design charts for the compressive strength of panels of various materials with stiffeners being attached by rivets:

    TN 1274 - Compressive Strength Comparisons of Panels Having Aluminum Alloy Sheet and Stiffeners with Panels Having Magnesium Alloy Sheet and Aluminum Alloy Stiffeners.

TN 1389 - Design Charts for Flat Compression Panels Having Longitudinal Extruded Y-Section Stiffeners and Comparison with Panels Having Formed Z-Section Stiffeners.

TN 1421 - Effect of Variation in Diameter and Pitch of Rivets on Compressive Strength of Panels with Z-Section Stiffeners. Panels of Various Lengths with Close Stiffener Spacing.

TN 1439 - Compressive Strength of 24ST Aluminum Alloy Flat Plates with Longitudinal Formed Hat-Section Stiffeners Having a Ratio of Stiffener Thickness to Skin Thickness Equal to One.

TN 1467 - Effect of Variation in Diameter and Pitch of Rivets on Compressive Strength of Panels with Z-Section Stiffeners. Panels of Various Stiffener Spacings That Fail by Local Buckling.

TN 1640 - Direct Reading Design Charts for 75ST Aluminum Alloy Flat Compression Panels Having Longitudinal Straight Web Y-Section Stiffeners.

TN 1737 - Effect of Variation in Diameter and Pitch of Rivets on Compressive Strength of Panels with Z-Section Stiffeners. Panels That Fail by Local Buckling and Have Various Values of Width-to-Thickness Ratio for the Webs of the Stiffeners.

TN 1777 - Direct Reading Design Charts For 24ST Aluminum-Alloy Flat Compression Panels Having Longitudinal Straight-Web Y-Section Stiffeners.

TN 1778 - Direct Reading Design Charts For 24ST Aluminum-Alloy Flat Compression Panels Having Longitudinal Formed Z-Section Stiffeners.

TN 1787 - Comparison of the Structural Efficiency of Panels Having Straight Web and Curved Web Y-Section Stiffeners.

TN 1978 - Data on the Compressive Strength of 75S-T6 Aluminum Alloy Flat Panels Having Small Thin, Widely Spaced, Longitudinal Extruded Z-Section Stiffeners.

TN 2139 - Effect of Variation in Rivet Diameter and Pitch on the Average Stress at Maximum Load for 24S-T3 and 75S-T6 Aluminum Alloy, Flat Z-Stiffened Panels That Fail by Local Instability.

TN 2435 - Direct Reading Design Charts for 75S-T6 Aluminum Alloy Flat Compression Panels Having Longitudinal Extruded Z-Section Stiffeners.

TN 2792 - Direct Reading Design Charts for 24S-T3 Aluminum Alloy Flat Compression Panels Having Longitudinal Formed Hot-Section

Stiffeners and Comparisons with Panels Having Z-Section Stiffeners.

TN 2963 - Effect of Variation in Rivet Strength on the Average Stress at Maximum Load for Aluminum Alloy, Flat Z-Stiffened Compression Panels That Fail by Local Buckling.

These 15 reports, representing the most advanced methods generally available for this type of construction, form a rather complete set of design specification aids, allowing one to select the sheet size, stiffener spacing, rivet size and spacing when the loading is specified. TR 827, "Charts for the Minimum Weight Design of 24S-T Aluminum-Alloy Flat Compression Panels with Longitudinal Z-Section Stiffeners," by Evan H. Schuette and TR 1195 (RM L53 L13a) "Formulas for Elastic Constants of Plates with Integral Waffle-Like Stiffening" by Norris F. Dow, Charles Libove, and Ralph E. Hubka are also useful in this connection.

13. Information on the behavior of stiffened and unstiffened plates under combined axial load and normal pressure is contained in TNs 786, 848, 849, 943, 949, 1041, and 1047. See also TR 740. Both analysis and experimental data are presented. Stainless steel is the tested material in TN 786. These data have application in boat hulls, pontoons, pressurized fuselages, and integral wing fuel tanks.

14. Some of the initial theoretical and experimental studies of sandwich plates are represented by the series TN 1251, TN 1526 (TR 889), TN 1822 (TR 967), TN 1832 (TR 975), TN 1886, TN 1910, TN 2017, TN 2214, TN 2225, TN 2581, TN 2601, TN 2620, TN 2637, TN 2679.

15. Representative of the almost continuous study - theoretical and experimental - of stiffened and unstiffened plates carried out by the Langley Research Center since 1940 are the TNs 752, 811, 856, 882, 883, 884, 885, 921, 944, 1009, 1119, 1124, 1157, 1172, 1222, 1223, 1346, 1347, 1348, 1425, 1462, 1480, 1482, 1553, 1557, 1559, 1565, 1589, 1625, 1661, 1710, 1728, 1750, 1825, 1829, 1851, 1879, 1891, 1928, 1972, 2392, 2536, 2556, 2671, and 3023. These 41 reports present a wealth of test data and analytical efforts on a variety of plate configurations which have application in aircraft structures. Considerable codification, correlation, and condensation is required, however, to make these results usable in design manuals or formalized procedures. Additional data and analysis in this area are presented in TRs 733, 734, 735, 739, 809, 847, and 1255 and in TN 2873, TN 2782 and RM L8 I30b.

16. About 1944, N. J. Hoff and others began three extended analytical and experimental studies of monocoque cylinders for use as fuselages in aircraft. "The Inward Bulge Type Buckling of Monocoque Cylinders" in five parts (TNs 938, 939, 968, 1499, 1505) provides methods for calculating critical loads which come within about 23% of experimental results. "Numerical Procedures for the Calculation of the Stresses in Monocoques" in four parts (TNs 934, 950, 998, and 999) are developments of Southwell's relaxation methods to the solution of these problems. More recent,

faster numerical methods for solving the equations are, however, now available. "Stresses in and General Instability of Monocoque Cylinders with Cutouts" in eight parts (TNs 1013, 1014, 1263, 1264, 1435, 1962, 1963) presents a numerical method for making such determinations analytically and compares the results with experimental results. In every case, the analytical procedure was somewhat optimistic - from 13% to 39%. The book, Stresses in Aircraft and Shell Structures by Paul Kuhn (McGraw-Hill, 1956) of the Langley Research Center presents an exposition of the most desirable stress analysis methods available through the mid 1950's. Other work on stress analysis of cutouts in circular semimonocoque cylinders may be found in TR 1251 (TN 3199) by Harvey G. McComb, Jr.

17. Other older but excellent theoretical and experimental work on cylinders for fuselages is given in the series "Some Investigations of the General Instability of Stiffened Metal Cylinders" by members of the Gugenheim Aeronautical Laboratory at the California Institute of Technology -- TNs 905, 906, 907, 908, 909, 910, 911, 1197, and 1198, July 1943 to May 1947.

18. A detailed discussion of the state of knowledge dealing with the stability of cylinders as of 1943 is found in TN 918 by L. H. Donnell.

19. Typical of the work on cylinders still in widespread use as evidenced by its treatment in CR 912 (see above) is the series by S. B. Batdorf and others, TN 1334, TN 1341 (TR 874), TN 1342 (TR 874), TN 1343, TN 1344, TN 1345, TN 1981, and TN 2021. See also TR 887.

20. Some test data from smaller scale test programs on cylinders is found in TNs 800, 851, 2188, and 2821.

21. Other older work, both theoretical and experimental on cutouts in sheets or cylinders is contained in TNs 1176, 1241, 1852, and 2073.

22. Studies of the stresses on the rings supporting cylindrical shells are given in TNs 929, 993, 1098, 1219, 1310, 1692, and 1786 (Report 934). Kuhn's book covers this information.

23. When cylinders or stiffener sections become very long and are loaded axially they are treated as columns. Representative of the work done in this area are TNs 824, 1004, 1027, 1335, 1519, 1751, 2163, 2267 (Report 1072), 2272, 2362, 2640, and 2872.

24. An interesting study of "The Shearing Rigidity of Curved Panels under Compression" by N. J. Hoff and Bruno A. Boley (TN 1090) finds that the shearing rigidity decreases with increasing compression.

25. Two works dealing with bending, stretching and torsion of sandwich shells are TR 975 and TR 1316 (TN 3749).

26. Indicative of the type of analysis which must, for reasons of cost and performance, soon come into general use is CR 1217, "Structural Synthesis of a Stiffened Cylinder" by William M. Morrow II and Lucien A. Schmit, Jr., December 1968, 163 pp., 39 references. For a given cylinder dimension and loading, the synthesis scheme determines the skin thickness, the dimensions of the stiffeners, and the spacing of the stiffeners. Eleven different failure modes are considered. Material yield failure in skin and stiffeners are considered as well as instability modes. The problem is treated as a nonlinear mathematical programming problem. The constrained minimization problem is converted to a sequence of unconstrained minimization problems and then solved. The solutions generated are a sequence of noncritical designs with decreasing weight. Detailed mathematical analysis of the stiffened cylinder along with the computer program for obtaining numerical results are presented.

27. Another of the recent approaches to the analysis of stiffened cylindrical shells which rely on the use of computers is CR 1280, "The General Instability of Eccentrically Stiffened Cylindrical Shells under Axial Compression and Lateral Pressure" by John N. Dickson and Richard H. Brolliar, January 1969, 108 pp., 22 references. The governing equations for the general instability of an orthogonally stiffened cylindrical shell are derived, using small deflection theory, and the computer program for solving the system is presented along with instructions for its use.

28. An outstanding compilation of the theoretical and experimental knowledge concerning the stability of plates and shells as of 1957 is contained in the series of technical notes by George Gerard and Herbert Becker given the general title, <u>Handbook of Structural Stability</u>:

    TN 3781 - Buckling of Flat Plates, 102 pp., 64 refs.
    TN 3782 - Buckling of Composite Elements, 72 pp., 30 refs.
    TN 3783 - Buckling of Curved Plates and Shells, 154 pp., 84 refs.
    TN 3784 - Failure of Plates and Composite Elements, 93 pp., 31 refs.
    TN 3785 - Compressive Strength of Flat Stiffened Panels, 89 pp., 44 refs.
    TN 3786 - Strength of Stiffened Curved Plates and Shells, 82 pp., 56 refs.

Beams

1. Work on various design materials and loading aspects of box beams is represented by the series TN 784, TN 791, TN 806, TN 872, TN 873, TN 893, TN 953, TN 1066, TN 1297, TN 1323, TN 1466, TN 1525, TN 1749, TN 2054, TN 2153, TN 2414, TN 2452, TN 2529, TN 2760, and TN 3082.

2. Truss stability studies are presented in TN 937 and TN 2886.

3. Buckling of beam structures is covered in TNs 770, 962, 1063, 1433, 2020, and 2840.

4. Studies of wing (beam) deflection are contained in TN 1361 (Deformation Analysis of Wing Structures, by Paul Kuhn), TN 1827 (Matrix Methods for Calculating Cantilever-Beam Deflections, by S. V. Benscoter and M. L. Gossard), TN 2600 (Stresses and Deformations in a Wing Subjected to Torsion, by B. F. Ruffner), and TN 2621 or TR 1131 (Deflection and Stress Analysis of a Thin Solid Wing of Arbitrary Plan Form with Particular Reference to Delta Wings, by Manuel Stein, J. E. Anderson, and J. M. Hedgepeth).

5. Strength analysis and test of stiffened beam webs is covered by TN 1058, TN 1364 (superseded by TN 1756), TN 1544, TN 1635, TN 1820, TN 2548, and TN 2930.

6. Specific consideration of diagonal tension is contained in the work of Paul Kuhn and others: TN 1481 (Diagonal Tension in Curved Webs), TN 2661, TN 2662 (A Summary of Diagonal Tension. Part I Methods of Analysis, Part II Experimental Evidence), TR 697 (Investigations on the Incompletely Developed Plane Diagonal Tension Field), and TR 739 (Shear Lag in Box Beam. Methods of Analysis and Experimental Investigation). This material is covered at length in Kuhn's book, Stresses in Aircraft and Shell Structures, McGraw-Hill, 1956.

APPENDIX

NACA Technical Notes Dealing with Structural Analysis or Design Judged Applicable to Light Aircraft

TN 746 THE FREQUENCIES OF CANTILEVER WINGS IN BEAM AND TORSIONAL VIBRATIONS, C. P. Burgess, January 1940

A simple method to determine the period and frequency of vibration of a wing in which the weight and moment of inertia vary along the span. The approximation is that the curvature of the wing in vibration is assumed to be constant. The results have an error of less than 1%. The period is given by

$$T^2 = \frac{4\pi^2 \int wy^2 dx}{g \int EI(d^2y/dx^2)^2 dx}$$

w = weight per unit length
y = deflection
g = acceleration of gravity

$$\frac{d^2y}{dx^2} = \text{constant}$$

An approximation is also available for the torsional period. It is assumed that the angle of twist varies linearly along the semispan. The period is given by

$$T^2 = \frac{4\pi^2 \int P^2 dx}{gG \int (\frac{1}{k}) (\frac{d\theta}{dt})^2 dx}$$

The quantity $\frac{d\theta}{dt}$ is assumed equal to one.

P = polar moment of inertia of weight per unit length
G = shear modulus
k = kinetic energy

TN 751 DAMPING FORMULAS AND EXPERIMENTAL VALUES OF DAMPING IN FLUTTER MODELS, Robert C. Coleman, NACA, 1940

Structural damping, theory and experiments. See Scanlan and Rosenbaum, Aircraft Vibration and Flutter, 1951.

TN 752 AN INVESTIGATION OF SHEET STIFFENER PANELS SUBJECTED TO COMPRESSION LOADS WITH PARTICULAR REFERENCE TO TORSIONALLY WEAK STIFFENERS, Louis G. Dunn, California Institute of Technology, February 1940

This report is a reference for TN 918 which is a condensation of several theory processes.

A total of 183 panels of 24ST aluminum alloy with thicknesses of 0.020, 0.025, and 0.040 inch with extruded bulb-angle sections of 12 shapes spaced 4 and 5 inches as stiffeners were tested to examine buckling stress.

Primary purpose was to investigate the behavior of stiffened panels such as are used in aircraft construction.

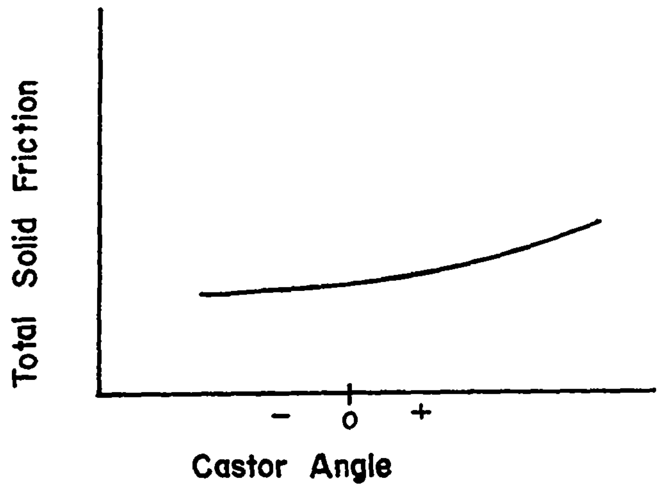
"The scope of the tests is insufficient for general design criteria."

In 1943 TN 918 uses the data of TN 752 to compare with a theoretical analysis of this type and similar problems.

The data agrees generally with the theory of TN 918.

TN 760 A FULL SCALE INVESTIGATION OF THE EFFECT OF SEVERAL FACTORS ON THE SHIMMY OF CASTERING WHEELS, Walter B. Howard, Jr., April 1940

A detailed study was made to determine the effect of several factors on the shimmy of castering wheels. The factors considered were the geometric arrangement, the tire types, the variation of loads, the spindle moment of inertia, and the tire inflation. By varying the above factors the minimum solid friction required to damp the shimmy was compared to these changes in the above factors. Experiments were carried out on a cart pulled by an automobile and a Hammond Y-1 Airplane with a tricycle landing gear. The tendency for the wheel to shimmy can be seen by the value of solid friction needed to stop shimmy. These values ranged from 50 in-lb to 150 in-lb. The general variation of solid friction required to stop shimmy vs caster angle is shown below.



This indicates that the tendency to shimmy does not vary much with the caster angle. The tendency to shimmy was less at zero or small negative caster angles than at the larger positive angles.

The results from tests on the test cart were as follows:

1. The inflation (high or low) or type of tire does not greatly affect the tendency to shimmy.

2. When the spindle moment of inertia was increased there was a slight increase in the tendency to shimmy.

3. Increases in the load on the cart causes significant increases in tendency to shimmy.

4. As the fork offset was increased the tendency to shimmy was also increased.

5. The solid friction needed to prevent shimmy was found to be proportional to the load on the cart.

The values obtained with the tow cart when applied to the Hammond Y-1 Airplane were sufficient to prevent shimmy.

The determination of the tire constants were determined as follows. For the streamline tire the solid friction required is given by

$T_{max} = 0.02\ ruW$ lb-ft
r = tire radius
u = coefficient of friction
W = load

The vicious damping for the streamlined tire is given by

$$K_{max} = 32r^2 \sqrt{Iw} \qquad \frac{\text{lb-ft}}{\text{radians per sec}}$$

These expressions are intended only to indicate the range and order of damping. But the solid friction can be considered exact. The theory from which these equations are derived is from the following publications:

Arthur Kantrowitz, Stability of Castering Wheels for Aircraft Landing Gears, T.R. No. 686, NACA, 1940

TN 770 THE LATERAL STABILITY OF EQUAL-FLANGED ALUMINUM ALLOY I-BEAMS SUBJECTED TO PURE BENDING, C. Dumont and H. N. Hill, NACA, August 1940

Beams extruded from 27ST aluminum alloy were subjected to pure bending loads which caused failure. Mechanical properties:

	Flange	Web
Tensile strength	62,735	61,350
Tensile yield strength	54,100	52,700
Compressive yield strength	56,150	

Ends were not completely fixed, but degree of fixity was ascertained. Thus, experimental results were used to verify an equation for critical stress.

$$S_{cr} = \frac{1.98 \times 10^7}{(KL)^2 Z} \sqrt{I_\ell [J(KL)^2 + 6.58\ I_\ell h^2]}$$

S_{cr} = critical stress in pounds per square inch
K = degree at end fixity
L = laterally unsupported length of beam
Z = section modulus of beam about principle axis normal to web
I_ℓ = moment of inertia of beam about principle axis in web
J = torsion factor
h = depth of beam

See Timoshenko: Theory of Elastic Stability, McGraw Hill Book Co., Inc., 1936.

Tests extended through plastic range of material. Material chosen because tensile and compressive properties are approximately equal and wide elastic range.

Results indicated use of reduced modulus allows use of previous equation into plastic region.

$$E_r = \frac{4E\ E_t}{(\sqrt{E} + \sqrt{E_t})^2}$$

E = elastic modulus
E_t = tangent elastic modulus based on average compressive stress

Modified equation

$$S_{cr} = \frac{E_r}{E} \frac{1.98 \times 10^7}{(KL)^2 Z} \sqrt{I_\ell [J(KL)^2 + 6.58\, I_\ell h^2]}$$

K = 0.5 for complete lateral restraint. For longest beams (L = 88"), error in K was 4%. For shortest beam, (L = 18"), error in K was 19%.

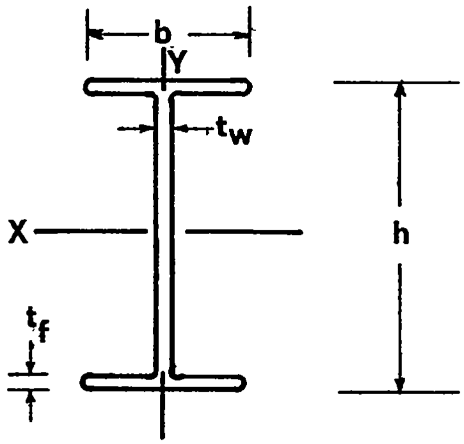
Approximate values of S_{cr} computed by equivalent slenderness ratio method were 20% lower than experimental values, where buckling occurred near the yield strength. Values of S_{cr} determined by Southwell method from load-deflection data agreed with experimental values. Thus Southwell is applicable to lateral buckling of I-beam.

$I_\ell = I_{yy} = 0.04295$ in^4 (flanges)

$I = I_{xx} = 1.3916$ in^4

$Z = 0.6962$ in^3

$J = 0.0015382$ in^4



$t_f = 5/32$

$t_w = 5/64$

$b = 1\text{-}3/8$

$h = 4$

Test No.	L_{tot}	P_{cr}	M_{cr}	S_{cr}	L	P_{cr} [1]
1	114	1,800	5,400	7,800	88	1,800
2	104	2,185	6,555	9,420	78	2,180
3	94	2,735	8,199	11,780	68	2,800
4	84	3,455	10,365	11,890	58	3,580
5	74	4,585	13,755	19,760	48	4,750
6	64	7,000	21,000	30,170	38	7,750
7	59	8,590	25,770	37,020	33	8,800
8	54	10,280	30,840	44,300	28	11,800
9	49	11,900	35,700	51,300	23	11,600
10	44	12,840	38,520	55,300	18	12,600

[1] From Southwell plot.

TN 773 CHART FOR CRITICAL COMPRESSIVE STRESSES OF FLAT RECTANGULAR PLATES, H. N. Hill, NACA, 1940

More complete coverage of subject in Marks' Engineering Handbook.

TN 780 MOMENTS OF INERTIA OF 32 AIRPLANES, William Gracey, NACA, 1940

Moments of inertia of planes were determined by pendulum method. See NACA Rep. No. 467, 1933, for description.

Moments of inertia about X and Y axes (through c.g.) found by swinging plane as compound pendulum, moment of inertia about Z axis found by oscillating plane as a bifilar-torsional pendulum. Corrections made for (1) bouyancy of structure, (2) air entrapped within structure and (3) additional mass effect (to account for payload, minor changes).

A, B, C - true moments of inertia in X, Y, Z directions.

K_X, K_Y, K_Z - radii of gyration in X, Y, Z directions.

$$K_X = \sqrt{\frac{A}{w/g}} \qquad K_Y = \sqrt{\frac{B}{w/g}} \qquad K_Z = \sqrt{\frac{C}{w/g}}$$

C_X, C_Y, C_Z - span coefficients of moment of inertia.

$$C_X = K_X/b \qquad C_Y = K_Y/b \qquad C_Z = K_Z/b$$

Accuracy of method with corrections:

A $\pm$ 2.5%
B $\pm$ 1.3%
C $\pm$ 0.8%

Accuracy of weight schedule method: $\pm$ 10%

TN 784 STRESS DISTRIBUTION IN AND EQUIVALENT WIDTH OF FLANGES OF WIDE, THIN WALL STEEL BEAMS, George Winter, Cornell University, November 1940

The primary purpose of the investigation was to analyze the stress distribution in the flanges of wide, thin wall beams of I, T, U, and box shape and to obtain information applicable to design. It is shown that the magnitude of the bending stresses of the flanges of such beams varies across the width of the section and that the amount of this variation depends upon the dimensions of the beam and upon the type of loading.

Therefore, in the determination of the magnitude of the maximum bending stress in design work, the equivalent width of such flanges should be used instead of the actual width.

For the purpose of facilitating the experimental verification of the analytical results, further curves were computed that give the ratios of the maximum to the minimum bending stress in the flanges. These ratios have been checked experimentally by means of strain measurements on 11 I-beams. The experimental data confirm very satisfactorily the analytical results.

It is further shown that the cross sections of wide beams made of extremely thin sheets are subject to distortion that gives rise to additional stress concentrations. The equations listed furnish simple conditions for determining the limiting dimensions of beams for which the effect of this distortion may be neglected in practical applications.

It may be easily verified numerically that practically all beams with structurally possible dimensions will satisfy these conditions:

FOR I-BEAMS	FOR BOX BEAMS
$\frac{b^2}{dh} \leq \frac{0.0817\ E}{\sqrt{1-\nu^2}\ \sigma_w}$	$\frac{b^2}{dh} = \frac{0.0633\ E}{\sqrt{1-\nu^2}\ \sigma_w}$

b = half the flange width
d = the flange thickness of the beam
h = the depth
σ_w = the working stress
ν = Poisson's ratio
E = modulus of elasticity

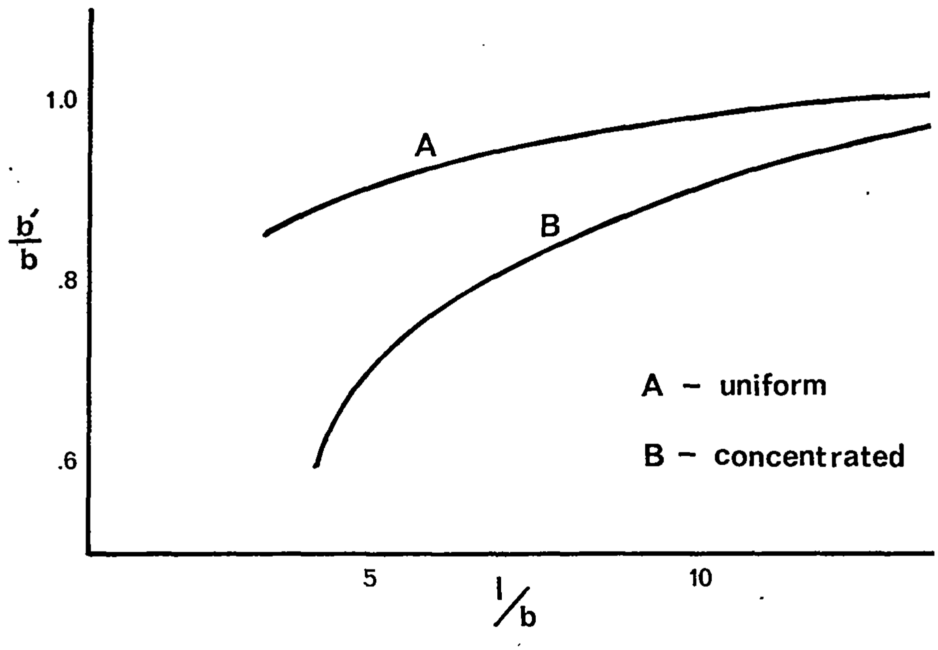
Thus, data for the equivalent width given in the table and figure below may be applied to any beam satisfying the conditions expressed in the above equations.

Ratios of Equivalent to Actual Width, 2b'/2b

Beams	I- and T-		Box and U-	
ℓ/b	$P^{(a)}$	$P^{(b)}$	$P^{(a)}$	$P^{(b)}$
π	0.857	0.575	0.880	0.557
2π	0.958	0.791	0.957	0.778
3π	0.981	0.881	0.983	0.881
4π	0.990	0.927	0.989	0.926
5π	0.993	0.949	0.994	0.950

$P^{(a)}$ is uniformly distributed load.

$P^{(b)}$ is concentrated load at center of span or two equal concentrated loads at quarter points.



TN 786 STRUCTURAL TESTS OF A STAINLESS STEEL WING PANEL BY HYDROSTATIC LOADING, Ralph H. Upson, NACA, Washington, 1940

Object: To develop a metal wing which compares favorably with wood and fabric wing in weight and cost, in this case a lightly loaded wing with large unsupported panels.

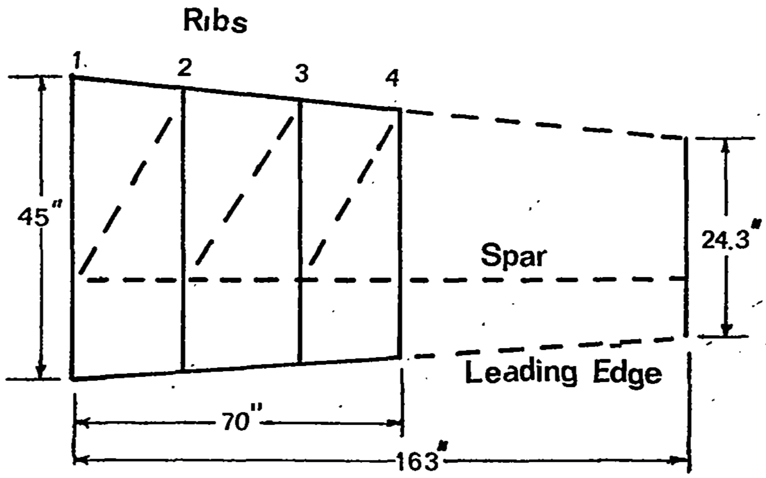
Basis of Problem: Metal skin is superios to fabric in strength and stiffness, but structure required to prevent buckling of skin and transmit loads negates weight and cost savings.

Solution: Eliminate excess structure and fabrication costs by applying sufficient initial tension to skin to keep it from buckling under flight conditions.

Wing Characteristics

1. Proportions - Testing method favored by wing with well-rounded top and flat bottom so NACA 4400-series was chosen. Calculations were simplified by modifying wing beyond 40% chord point by following equation.

$$\text{Camber (\% chord)} = 4 - \frac{(x-40)^2}{400} + \frac{(x-40)^{5/2}}{5580}$$



2. Structural Design - Skin 18-8 stainless steel 0.005" thick. Rest of structure 18-8 stainless frame spotwelded, skin screwed with 4-40 half hard shakeproof screws 1/2" on centers. No stiffeners except at leading edge. Laps 1/2" wide,

joggled. Ribs 24" on centers, diagonal stiffeners for compression due to negative torque and drag. Rib-flange elements 3/8"x 1/2" x 0.020" full hard angles, bent by crimping, cross braced by hat lattices. Skin made watertight by caulking. End bulkheads of solid steel plate, stiffened at edges.

3. Construction - Frame assembled without skin, then twisted in direction opposite to direction of air load twist, at a load factor of 1.90. Trailing edge was jacked up to reduce twist. Top skin was applied. Twisting force was reduced by 10%, then bottom skin was applied.

<u>Testing</u>

CAA Condition I: Critical for wing beam.

Dynamic pressure $q = 36.9$
Load factor $n = 4.67$
$C_N = 1.35$
$C_C = -0.29$
$C_M = -0.08$ about AC at 25% chord

Condition III: Maximum wing torque

$q = 78.4$
$n = 3.20$
$C_N = 0.44$
$C_C = 0$
$C_M = -0.08$

Condition VII: 30° flaps - more critical than condition III because lower pressure difference on skin leads to skin wrinkles.

$q = 25.6$
$n = 2.00$
$C_N = 0.84$
$C_C = 0.14$
$C_M = -0.15$

Assume span loaded in proportion to chord, wing weight distributed similarly. Wing load = 10.7 lb-ft^2. Wing weight = 1.5 lb-ft^2. Effective load = 9.2 n lb-ft^2.

Observations of wing before water added:

Tension wrinkles on bottom.
Slight purkers along seam lines.
Seams wavy due to caulking between screws.

Hydrostatic testing: Wing attached to test stand in inverted position, water added to simulate air loads, air pressure superimposed to simulate internal pressure. Torque and beam loads were applied to a beam and arm attached to the spar at the narrow end of the test section.

Results: Only permanent set observed up to limit loads was bow in forward rib flanges at high pressures. Under static load conditions (n=1) no wrinkles on top. Bottom wrinkles smoothed out only at maximum dynamic pressure (24.4 $lb\text{-}in^2$). Top skin bulged under large bending moments, with large water heads. Caused short wrinkles along seams, toward center of panel. Diagonal braces appeared to increase wrinkles but not restrict twist. Diagonals cut, wrinkles reduced. Wrinkles appeared first at root, spread to tip as torque was applied, up to 230% greater than half-limit load under condition III.

Bottom rib flanges bowed out with large water head. Caused by high outward pressure, which should not occur in flight, but was necessary in test to get proper loads on top skin. Final test destruction was made under Condition I. Buckling of compression flange produced no failure or leakage in skin.

Conclusions: Results indicate feasibility of simplified all metal construction. Thin skin carries tension only. Stiffeners and diagonals are omitted. Rib spacing 2ft. Static loads, including torque, carried without wrinkling; wrinkling at higher loads confined almost entirely to edge attachments along chord lines. Initial stressing beneficial. Could be increased, especially at root. Spanwise tensioning of bottom skin could be decreased. Chordwise curvature helps carry loads but contributes to wrinkling. Internal pressure above atmospheric helps little on top but decreases bottom wrinkles.

Wing as built was 25% lighter than conventional. Fastenings (esp. welds) reduced by 75%. Wing is well above CAA requirements in stiffness. Drag reduced by 12% over countersunk rivets or 25% over brazier head rivets and plain laps. Waviness of skin increases drag by as much as 6%.

TN 789 EXTENSION OF PACK METHOD FOR COMPRESSIVE TESTS, C. S. Aitchison, NACA, 1940

Author extends method he developed in Rep. No. 649, NACA, 1939, for testing thin sheets in compression. Extends to thickness of 0.02" and 220 kips before instability failure limit reached. Modifications were support against instability by fusing pack together with varnish, and by special clamps. These do not affect shape of stress-strain curve, merely delay instability failure. Author concludes method to be satisfactory for research, but too cumbersome for inspection testing.

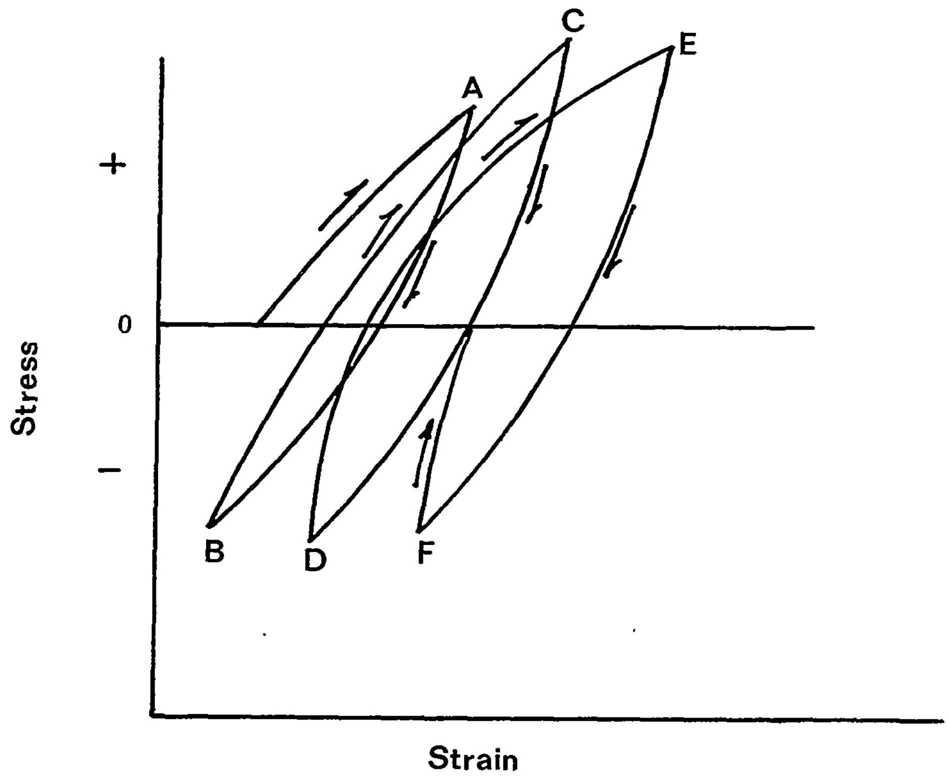
TN 790 CYCLIC STRESS-STRAIN STUDIES OF METALS IN TORSION, D. A. Paul and R. L. Moore, December 1940

(a) 17ST aluminum, mild steel, wrought iron, copper, brass and magnesium alloy AM75S were tested by applying increments of torque and determining the corresponding shear strains. Shear stress was calculated by:

$$S_s = \frac{2Tr_1}{\pi(r_1^4 - r_o^4)}$$

S_s = maximum shear stress, psi
T = torque, pound-inches
r_o = inner radius, inches
r_1 = outer radius

(b) The data in this report should only be considered preliminary, since a linear relationship was not found between shearing stress and strain. Therefore, the data should only be used to point out the type of change in the stress-strain relation due to torsion.



TN 791 SHEAR LAG IN CORRUGATED SHEETS USED FOR THE CHORD MEMBER OF A BOX BEAM, Joseph S. Newell and Eric Reissner, January 1941

The problem of the distribution of normal stress across a wide corrugated sheet used as a chord of a box-beam like structure is investigated.

For the symmetrical beam: the stress parallel to the x-axis at any point Y from the center of the sheet is:

$$\sigma_x = \frac{\dfrac{Pe_o(\ell-x)}{I_o}}{1 + \dfrac{wte_o^2}{I_o}\left(1 + \dfrac{I_o}{e_o^2 A_o}\right)\dfrac{\tanh kw}{kw}} \quad \frac{\cosh ky}{\cosh kw}$$

where:

P = load applied to beam at each loading point
ℓ = panel length
x = distance from midspan of beam and section under consideration
e_o = distance from centroid of H-beam and cover plate to centroid of flat portion of corrugated sheet
I_o = moment of inertia of H-beam and cover plate
w = one half developed width of sheet
t = thickness of corrugated sheet
A_o = area of H-beam and cover plates

$$K = \frac{1}{\ell}\sqrt{\frac{3E}{G}}$$

For the unsymmetrical beam with unsymmetrical loading the stress distribution is:

$$\sigma_x = (\ell-x)\left\{\frac{S_1(0) + S_2(0)}{2}\,\frac{\cosh ky}{\cosh kw} + \frac{S_1(0) - S_2(0)}{2}\,\frac{\sinh ky}{\sinh kw}\right\}$$

where:

$$S_1(0) = K_{11}P_1 + K_{12}P_2$$

$$S_2(0) = K_{21}P_1 + K_{22}P_2$$

$$K_{11} = \frac{\dfrac{e_1}{e_1^2 A_1 + I_1}}{\dfrac{I_1}{e_1^2 A_1 + I_1} + \dfrac{\lambda\alpha}{2}\,\dfrac{(1-\gamma_2) + 2\gamma_2}{(1-\gamma_2) + \alpha\gamma_{2/2}}}$$

$$K_{21} = \frac{\frac{e_1}{e_1^2 A_1 + I_1} [\frac{1}{2} \lambda_1 \beta]}{[1 + \frac{\lambda_1 \alpha}{2} \gamma_1] [1 + \frac{\lambda_2 \alpha}{2} - \gamma_2] - \frac{1}{4} \lambda_1 \lambda_2 \beta}$$

where:

$$\alpha \approx \frac{1}{(kw)^2} + \frac{4}{3} \quad \text{and} \quad \beta \approx \frac{1}{(kw)^2} - \frac{2}{3}$$

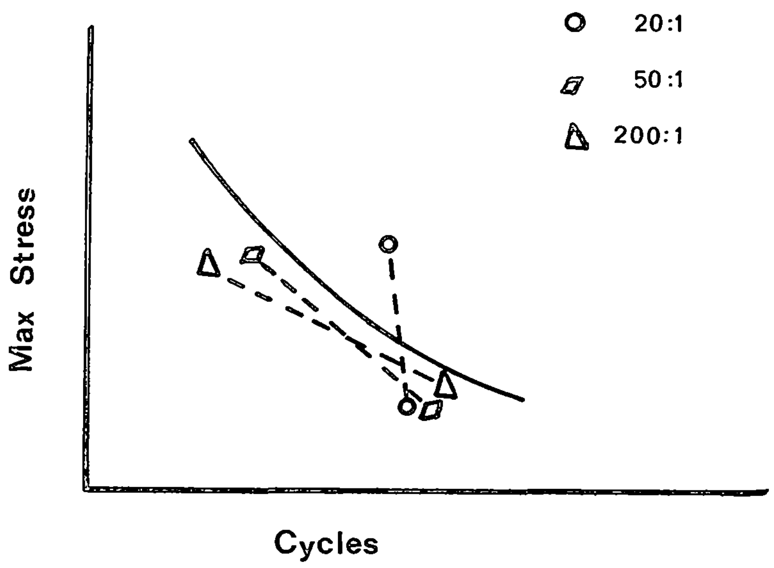
The results from experimental data agree quite well with the results gained from the above formulations.

TN 792 EFFECT OF ALTERNATELY HIGH AND LOW REPEATED STRESSES UPON THE FATIGUE STRENGTH OF 25ST ALUMINUM ALLOY, G. W. Stickley, January 1941

(a) Fatigue tests were made on 3/4 in. diameter rolled-and-drawn 25ST aluminum-alloy rod at 3500 cycles per minute in a R.R. Moore rotating beam fatigue-testing machine. The tests were made for three ratios (20:1, 50:1, and 200:1) of the number of cycles at low stress to the number applied at high stress.

(b) Failure occurred when the number of cycles at either the low stress or high stress approached the fatigue curve for the material. When the low stress was below the endurance limit there was no effect on the fatigue life at the higher stress; when low stress was above the endurance limit, the higher stress had no effect on the fatigue life at the lower stress.

Overstressing had very little harmful effect on the fatigue life of the material.



TN 793 THE COMPRESSIVE YIELD STRENGTHS OF EXTRUDED SHAPES OF 24S-T ALUMINUM ALLOY, R. L. Templin, F. M. Howell and E. C. Hartman, NACA, 1941

Object - To find a direct relationship between compressive yield strength and tensile yield strength. Large number of shapes and sizes tested, found to form 3 groups. Two relations found, compressive to tensile yield, and compressive yield to tensile strength.

Relations to Tensile Yield Strength

Thickness	Compressive Yield Strength (fraction of tensile yield)	Minimum Compressive Yield Strength
Less than 0.250"	0.88	37,000 psi
0.250" to 1.499"	0.91	40,000 psi
1.500" to greater	0.96	49,900 psi

Relations to Tensile Strength

Thickness	Compressive Yield Strength (fraction of tensile strength)	Minimum Compressive Yield Strength
Less than 0.250"	0.66	37,600 psi
0.250" to 1.499"	0.69	41,400 psi
1.500" and over	0.72	50,400 psi

Both relations are satisfactory for quality control work, being much better than equating compressive and tensile yield strengths. Less than 1% of specimens tested failed to reach minimum compressive yield determined by either method.

TN 798 COMPRESSION TEST OF SOME 17S-T ALUMINUM-ALLOY SPECIMENS OF I CROSS SECTION, H. N. Hill, March 1941

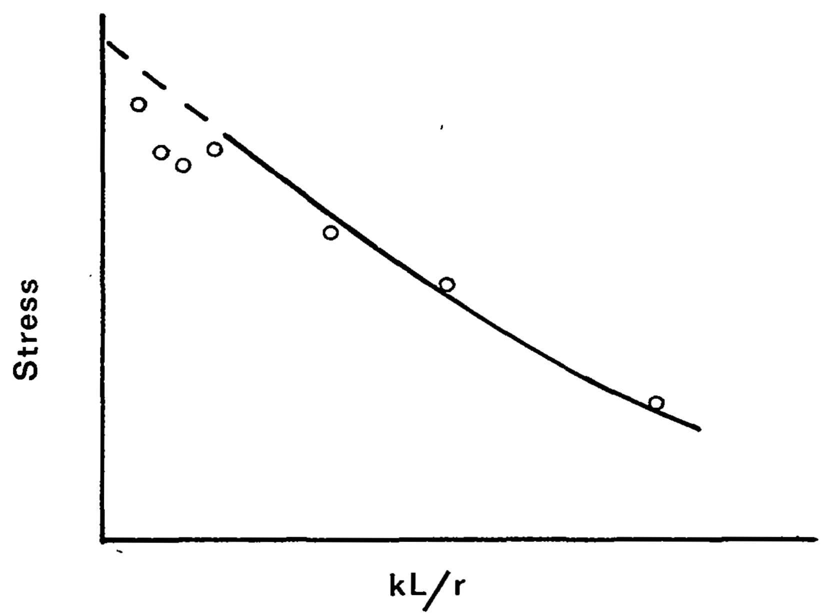
(a) Seven specimens of 17S-T aluminum of I cross section varying from 4 to 90 inches were loaded in compression by a 40,000-lb. capacity Amsler testing machine.

(b) Equation for stress as a function of the equivalent slenderness ratio, kL/r, from page 37 of reference 1 (Anon: Structural Aluminum Handbook. Aluminum Co. of Am., 2 ed., 1938) and a compressive yield strength of 37,000 lbs:

$$\frac{P}{A} = 43{,}800 - 350\,\frac{kL}{r}$$

L = length
r = least radius of gyration of column
k = coefficient defining the degree of end restraint (using experimental data k was calculated to be 0.55)

(c) The theoretical and experimental values were plotted and compared; it was concluded that the methods of calculation given on pages 37 to 41 of reference 1 give values that would be satisfactory for design purposes.



TN 800 TESTS ON STIFFENED CIRCULAR CYLINDERS, Marshall Holt, Alcoa, March 1941

Compressive tests made on two series of stiffened circular cylindrical shells under axial loads. All shells 16 inches in diameter by 24 inches in length. Made of aluminum alloy sheet curved and welded. Ratios of diameter to thickness of 258 and 572.

1. Spacing of circumferential stiffeners (0.67 times radius) was too great to obtain any appreciable strengthening of the shell wall when subjected to axial compressive loads.

2. Although the specimens with longitudinal stiffeners developed a greater compressive strength than the similar unstiffened shells, a consideration of the relationship between the strength and the proportions of the shell indicated that a still greater strength could be obtained by redistributing the material in the stiffeners so as to increase the thickness of the shell wall. An optimum stiffener size and spacing was not proposed due to the small number of tests and data.

3. There was no indication of buckling of the shell wall prior to collapse of the stiffened specimens under axial compressive load.

4. The compressive strengths of the two unstiffened cylinders were about half as great as predicted by the classical buckling theory of cylinders. From only these two cylinders, the author proposes that "In other words, it appears that the strength of well-made and carefully tested thin-wall cylinders may be calculated by the formula

$$s_{cr} = 0.3E \frac{t}{r}$$

where:

s_{cr} = critical buckling stress, pounds per square inch
E = modulus of elasticity, pounds per square inch
t = thickness of shell wall, inches
r = radius of cylinder, inches"

Two tested cylinders does seem to be <u>rather</u> <u>low</u> data to propose such a formula.

5. The large-deflection theory given by Donnell gives computed strengths slightly lower than these test results.

TN 805 EFFECTS OF AGING ON MECHANICAL PROPERTIES OF ALUMINUM-ALLOY RIVETS, Frederick C. Roop, National Bureau of Standards, 1941

Data represents the results of strength tests made during and after 2 1/2 years of aging on rivets and rivet wire of 3/16 inch diameter.

Specimens were of aluminum alloy: 24S, 17S, and A17S of the duralumin type and 53S of the magnesium-silicide type.

For each of the four alloys tested, the <u>ratio</u> of shearing strength to tensile strength of the undeformed wire remained constant independent of aging time at room temperature.

Aging times at room temperature to reach practically final strength values:

Alloy	24S	17S	A17S	53S
Undeformed wire	7 hours	3 days	8 months	More than 2 1/2 yrs.
Rivets driven before aging	3 months	1 1/2 yrs.	More than 2 1/2 years	

For a given total aging time after quenching, rivets driven after aging were always stronger than those driven before.

SHEARING STRENGTHS OF DEFORMED MATERIALS (DRIVEN RIVETS) AND UNDEFORMED MATERIALS (RIVET WIRE), ADJUSTED TO PROVIDE DIRECT COMPARISON

		As Quenched		Aged 4 Days			Aged 2 1/2 years		
Alloy	100% Shearing Strength (lb/sq in)	Undef (%)	*Def (%)	Undef (%)	Def Before Aging (%)	Def After Aging (%)	Undef (%)	Def Before Aging (%)	Def After Aging (%)
24S	43,400	80	84	97	97	--	100	101	--
17S	38,600	73	73	100	86	--	100	94	--
A17S	31,600	64	67	92	80	99	100	89	105
53S	24,500	63	65	91	71	86	100	86	101

*Def = Deformed.

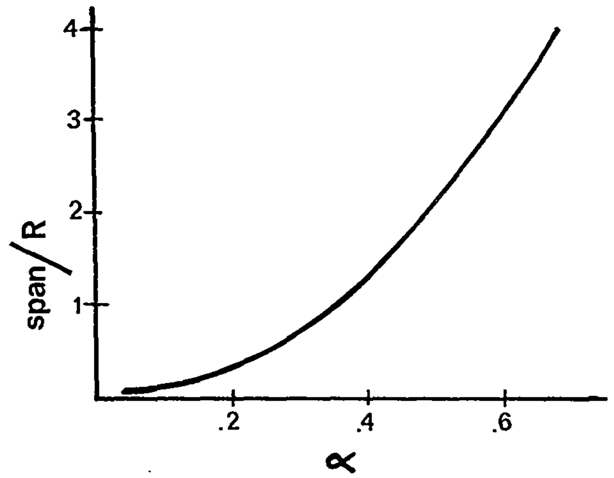
TN 806 STRESSES AND DEFLECTIONS IN THIN SHELLS AND CURVED PLATES DUE TO CONCENTRATED AND VARIOUSLY DISTRIBUTED LOADING, Raymond J. Roark, University of Wisconsin, May 1941

Tests made upon cylindrical and spherical shells. Results correlated with earlier experiments, and empirical formulas based on data are proposed.

Cylindrical shell: Measurements made of midspan deflection produced by a concentrated load, relative to points at the extremities of a longitudinal span. The formula adopted was

$$d = \alpha \frac{P}{Et} \left(\frac{R}{t}\right)^{1.2}$$

d = deflection of shell wall at the middle of a given span
P = total applied load
R = shell radius
t = thickness of shell wall
α = experimentally determined coefficient for deflection



Spherical shells: Deflections produced by progressively increased outwardly applied concentrated loading were measured for 4 and 8 inch spans in order to ascertain the nature of the load-deflection relationship. The load-deflection curve indicates a linear relationship. The deflections for an 8 inch span were almost exactly the same as for a 4 inch span, a fact consistent with the very rapid fade-out of stresses.

As in the case of the cylinder, the relative influences on deflection of bending strains and of membrane strains would be expected to vary with the R/t ratio and with the span. Only one test specimen was available and it was not possible to establish a formula for deflection.

TN 811 THE EFFECT OF METHODS OF TESTING ON THE ULTIMATE LOADS SUPPORTED BY STIFFENED FLAT SHEET PANELS UNDER EDGE COMPRESSION, Marshall Holt, NACA, 1941

Flat sheet panels tested under 3 conditions to determine effect of support conditions on loads carried. Conditions are (1) round ends (knife edge bearings), (2) flat ends, (3) continuous panels. Slenderness ratios < 20 so column instability close to yield or above.

Conclusions:

1. Length of specimen has insignificant effect on ultimate load.

2. Condition of ends has no effect if buckling stresses of sheet and stiffeners are nearly equal. Where strength of sheet and stiffeners are not equal, flat ends are best.

3. Centering of specimen under load is no better than measuring to find center.

4. Ultimate loads supported by panels are close to those supported by specimens with flat ends. Continuous panel test is better because one can be sure that the degree of end fixity does not exceed that of its application.

5. Precision with which ends are cut have little effect on ultimate loads carried but do lead to uniform distribution of stresses in the elastic range.

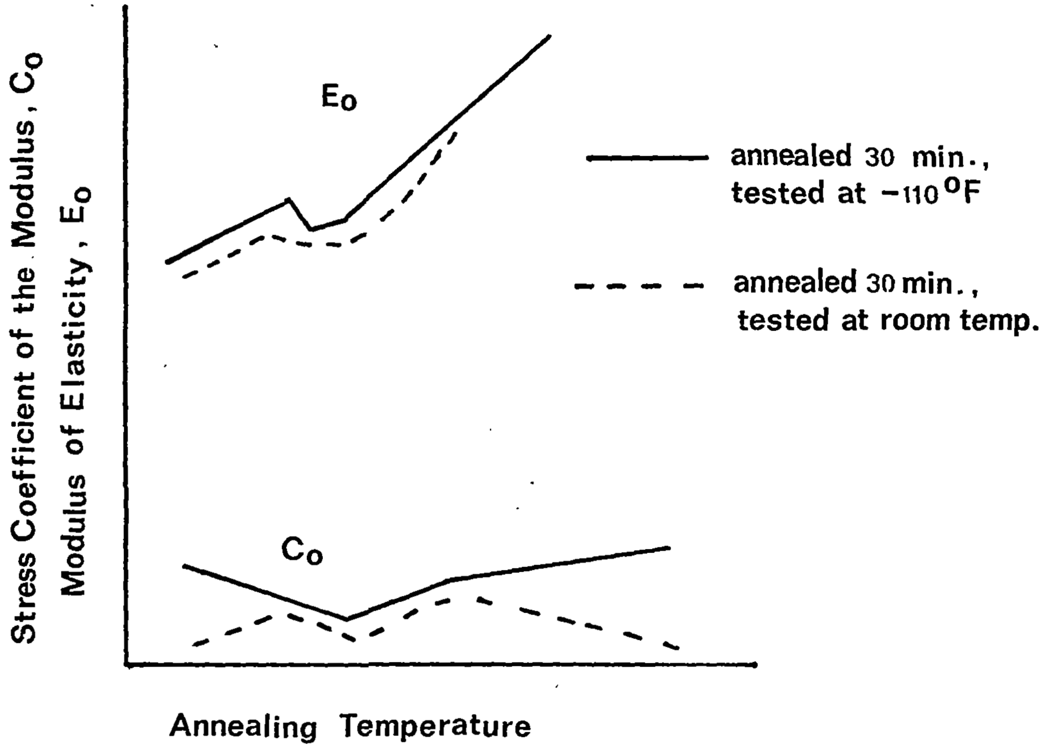
6. Short specimens tested in hydraulic and screw type machines behaved same.

TN 818 THE TENSILE ELASTIC PROPERTIES AT LOW TEMPERATURE OF 18:8 CR-NI STEEL AS AFFECTED BY HEAT TREATMENT AND SLIGHT PLASTIC DEFORMATION, R. M. Mebs and D. W. McAdams, Jr., July 1941

(a) The relationship between stress, strain, and permanent set for 18:8 Cr-Ni steel was measured at -110°F. The influence of annealing and slight plastic extension upon the elastic properties was also measured.

(b) A bar of 18:8 Cr-Ni steel was placed in a bath of carbon tetrachloride and chloroform with a Tuckerman optical strain gage to measure the strain and an extensometer was used in calculating the strain and the amount of permanent set. Several different bars were used so that the effect of the annealing temperature on stress and strain could be studied.

(c) The results of the test were qualitatively similar to test at room temperature. An elevation of proof stress and tensile modulus of elasticity with a decrease of test temperature was noted. It was concluded that room-temperature test would suffice to determine whether an 18:8 type Cr-Ni steel would meet minimum elastic property requirements for applications in the temperature range below normal.



TN 819 COMPARISON OF STRESS-STRAIN CURVES OBTAINED BY SINGLE-THICKNESS AND PACK METHODS, D. A. Paul, F. M. Howell and H. E. Grieshaber, August 1941

(a) The purpose of the investigation was to find a cheaper method than the Pack method for making compression test. The proposed method, the Single-Thickness Method, makes use of two sets of rollers, between which the specimen moves, to apply varying loads without buckling the specimen.
(b) It was found that the single thickness method determined within acceptable limits the compressive yield strengths of thin sheet metals, and the method may be used for aluminum-alloy sheets of 0.020 inches or greater in thickness.
(c) The single-thickness method was developed by the Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Penna.

TN 821 SOME COMPARATIVE TESTS OF PLAIN AND ALCLAD 24S-T, R. L. Moore, NACA, 1941

Comparison of plain and Alclad 24S-T aluminum sheeting to determine factors by which protective coating reduces strength. Flexural stiffness and buckling obey established relationships if only 93% of thickness is considered effective. Yield and ultimate strengths are similarly reduced. In practice, thickness of Alclad sheet should be 7% greater than plain sheet except where flexural stiffness or buckling resistance is governing factor, where thickness should be increased 11%. Alclad exhibits much greater permanent set in single sheets but this does not affect load carrying capabilities greatly. Conclusions may be extended to cover Alclad 24S-RT and 17S-T sheet though such materials were not tested, since materials are much alike.

TN 824 COMBINED BEAM COLUMN STRESSES OF ALUMINUM-ALLOY CHANNEL SECTIONS, J. O. Hutton, September 1941

(a) The purpose was to test a number of aluminum channel and graph stresses due to axial and bending loads as functions of the ratio of length of specimen to its radius of gyration. This graph is to be used as a design chart aluminum channels under combined loads.
(b) Side and end loads were applied to 65 aluminum channels and the data from these was graphed.
(c) The critical stress as calculated by Eugene E. Lundquist and Claude M. Fligg: <u>A Theory for Primary Failure of Straight Centrally Loaded Columns</u>. Rep. No. 582, NACA, 1937:

$$f_{cr} = \frac{\overline{G}J}{I_p} + \frac{C_{BT}}{I_p}\frac{n^2\pi^2\overline{E}}{L_o^2} + \frac{K_1\,E(t_s)^3}{6(1-u^2)}\frac{L^2}{dI_p\,n^2\pi^2}$$

E = tension-compression modulus of elasticity.
G = shear modulus of elasticity.
u = Poisson's ratio for material.
I_p = polar moment of inertia of cross section about axis of rotation.
L_o = effect length of column.
J = torsion constant for section.
C_{BT} = torsion-bending constant. (To evaluate see Report 582)
d = distance between stiffeners.
t_s = skin thickness
L = stiffener length
n = 1, 2, 3, 4, etc., the number of half waves that develope in the stiffener in the length L.

$$K = \left[2 + \frac{\pi^2}{3}\left(\frac{d}{L_o}\right)^2 + \frac{\pi^4}{60}\left(\frac{d}{L_o}\right)^4\right]$$

$\overline{E}$ = effective modulus $= \dfrac{2EE'}{E + E'}$

$\overline{G}$ = effective shear modulus.
E' = slope of stress curve for the stress concerned.

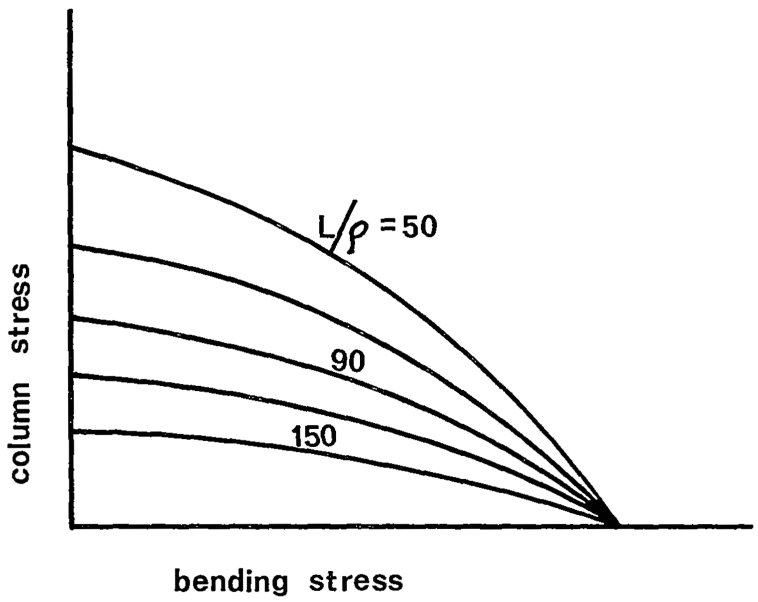
When the channel fails in bending,

$$(R_c)^{0.5} + R_b = 1.0$$

relates R_c, the ratio of column stress at failure to the ultimate column stress of the member and R_b, the ratio of primary bending stress at failure to the ultimate bending stress of the member. When the channel fails in torsion;

$$(R_c)^{1.5} + R_b = 1.0$$

relates R_c to R_b.

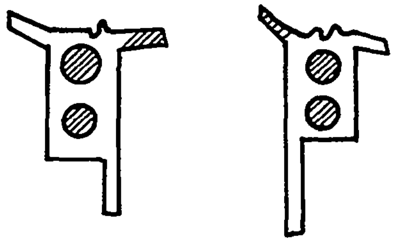


TN 826 VARIATION OF PROPERTIES THROUGHOUT CROSS SECTION OF TWO EXTRUDED SHAPES, F. M. Howell, NACA, 1941

Tensile and compressive properties of 24S-T aluminum at different locations on an extruded shape were compared. Testing by Navy specifications yields following data:

	K-16840	K-16841
Tensile Strength	83,210	84,240
Yield Strength	61,550	67,050
Elongation (%)	13.5	12.5
Compressive Yield	58,400	61,500

Test samples were taken from cross-hatched area of each specimen to determine tensile properties.



K-16840 K-16841

Specimens from fins were weaker than main body.

Tensile strength	5,000 to 10,000 lb/in^2 less
Tensile yield strength	4,000 to 9,000 lb/in^2 less
Compr. yield strength	4,000 to 9,000 lb/in^2 less

Compressive yield strength lower than tensile by 1,000 to 6,000 lb/in^2.

TN 830 DAMPING CHARACTERISTICS OF DASHPOTS, John B. Peterson, October 1941

(a) An investigation of the damping characteristics of dashpots was carried out combining theory and experiment.
(b) Assuming laminar flow and the piston coaxial in the cylinder, the velocity is:

$$V = \frac{Wg}{6\pi uL}\left(\frac{C}{R}\right)^3$$

Piston non-coaxial:

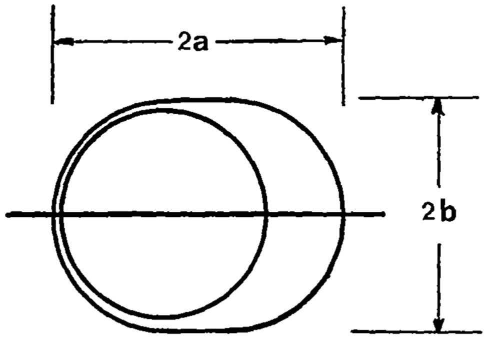
$$V = \frac{5\ Wg}{12\pi uL}\left(\frac{C_o}{R}\right)^3$$

Wg = force exerted on piston.
u = coefficient of absolute viscosity.
L = length of piston.
C = radial clearance between piston and cylinder.
R = one-half the sum of the radii of cylinder and piston.
C_o = base clearance.

A cylinder with the piston touching the walls:

$$V = \frac{Wg}{12\pi uL}\left(\frac{C_1}{R}\right)^3\left(5 + \frac{45k}{4C_1} + \frac{39k^2}{4C_1^{\ 2}}\right)$$

Where C_1 and K can be obtained from the figure below.



(c) At high piston velocities, when turbulent flow exists, the observed velocities were much lower than the velocities calculated on the basis laminar flow. It was experimentally determined that the piston is normally eccentric in the cylinder.

TN 832 RELIEF OF RESIDUAL STRESS IN STREAMLINE TIE RODS BY HEAT TREATMENT, R. E. Pollard and Fred M. Reinhart, November 1941

(a) The purpose of this report was to find some method of relieving the residual stress, caused by cold-working, in streamline tie rods.
(b) Two-thirds of the residual stress in cold-worked 1050 steel tie rods was relieved by heating 30 minutes at 600°F. Cold-worked austenitic stainless-steel tie rods could be heated at temperatures up to 1000°F without lowering the important physical properties. The corrosion resistance, of straight 18:8 and titanium-treated 18:8 steel exhibited improved stability over a wide range of temperatures. Tie rods of either material could be heated 30 minutes with safety at any temperature up to 1000°F. At this temperature most of the residual stress could be relieved.

TN 833 ULTIMATE STRESSES DEVELOPED BY 24S-T SHEET IN INCOMPLETE DIAGONAL TENSION, Paul Kuhn, Langley Memorial Aeronautical Lab., December 1941

Eighteen aluminum alloy sheer panels were tested to verify the dependence of the ultimate stress on the degree of developments of the diagonal-tension field. Two thicknesses of sheet were tested with the sheet either clamped between the flange angles or riveted to the outside of the angles.

Results indicated that clamped sheet develops higher stresses than sheet laid on the angles.

"The results obtained on sheer panels may require some modification before they are applied to the analysis of beam webs. Few useful test results are available thus far, and in some cases, additional questions of analysis arise."

TN 840 TENSILE AND PACK COMPRESSIVE TESTS OF SOME SHEETS OF ALUMINUM ALLOY, 1025 CARBON STEEL, AND CHROMIUM-NICKEL STEEL, C. S. Aitchison and James A. Miller, February 1942

(a) 17S-T, 24S-T, and 24S-RT aluminum; 1025 carbon steel; and chromium-nickel steel sheets of varying thickness were loaded in tension and compression in longitudinal and transverse directions. Stress-strain, stress-deviation, and secant modulus curves were plotted.
(b) The compressive test of the aluminum alloy and the carbon steel sheets were made by the pack as described in reference 1 (Aitchison, C. S., and Tuckerman, L. B.: Rep. No. 649, NACA, 1939).
(c) Values of the compressive and tensile yield strength of 24S-T, and 24S-RT may be found in Bruhn. The yield strength of the other materials should be available in a good material handbook. TN 840 is available in the NCSU Library.

TN 842 TIDEWATER AND WEATHER EXPOSURE TESTS ON METALS USED IN AIRCRAFT II (1942), Willard Mutchler and W. G. Galvin, National Bureau of Standards

This report is an addendum to NACA Note 736 on the same subject. (#736 is not in the present set of reports. It is presumed that this report was made prior to 1940.)

Exposures were begun in June 1938 and were terminated in June 1941 for this series.

1. Panels were more corroded at end of second year than first, particularly those with dissimilar metals in contact. In most instances, rate of corrosion during second year was not as rapid as during first.

2. Alloys Alclad 24S-T and 52S-1/2H proved most resistant to corrosion of aluminum alloys tested and were only slightly attacked during 2 years. 53S-T and anodized 24S-T were somewhat more susceptible to attack, while alloys containing copper, such as 24S-T, 14S-T, and major metals were more susceptible.

3. Anodized Dowmetal M was more resistant to Dowmetal H during first year but developed considerably larger pits than Dowmetal H during second year.

4. Stainless steels with 2.5% molybdenum were slightly more susceptible to corrosion than those with 3.5%, judging from rust

at 2 years. At 3 years, stainless steel with 3.7% molybdenum was much less rusted than steels with additions of columbium or titanium, or than those without additional alloying elements. A 16:1 chromium-nickel alloy was more susceptible to attack than any of the others and was practically the only one with rust in the tidewater tests. Flexure fatigue tests on corroded panels demonstrated that endurance limit losses were lower for the steels containing molybdenum or titanium (9,000 lb/sq in.) than for those containing columbium or no additional alloy element (14,000 lb/sq in.).

5. Anodized 17ST rivets proved far better than 53ST or anodized A17ST rivets for joining Aluminum 24ST. All three were satisfactory for joining Aluminum alloys 52S-1/2H, 53ST, or Alclad 24ST, but the 53ST rivets heads on these alloys, in the weather exposure tests only were somewhat more corroded and exhibited intercrystalling attack.

6. AM55S rivets were far superior to 53ST or anodized 17ST rivets for joining magnesium alloys. Anodized AM55S rivets were more resistant to attack and paints adhered better than unanodized rivets. Anodization was not so effective in improving adherence of paints to AM55S as it was to alloy 24ST.

7. The welds on alloys 52S-1/2H, 53ST, or Alclad 24ST were anodically protected in the tidewater tests but were corroded in the weather tests. Gas welds were the least attacked, spot welds next, and seam welds the most attacked. Welds on 53ST were more prone to attack than on the other two.

8. Anodized gas welds on Dowmetal M proved as resistant to corrosion as the rest of the sheet, but spot welds were severly attacked. Welds on painted panels practically unattacked after 2 years.

9. Shot (sic) welds on stainless possessed heavier rust than rest of panel. Rusting was superficial on welds on steels containing molybdenum.

10. Area ratio between dissimilar metals in contact was the determining factor in the amount of corrosion. Anodic metal was usually much more severely corroded when its area was small as compared with that of the cathodic metal.

11. Alloys 52S-1/2H, 53ST, and Alclad 24ST were slightly corroded when in contact with each other but all were anodic to alloy 24ST and were attacked when in contact with it.

12. Alloy 52S-1/2H was least attacked of aluminum alloys when in contact with dissimilar metals. Alloy 53ST was usually considerable more corroded, while attack on 24ST and Alclad 24ST alloys

was severe. This results does not necessarily reflect the true potential relationship involved, owing to inherent differences in the resistance of the various aluminum alloys to corrosion.

13. Aluminum alloys were anodic to stainless steel, nickel, monel, and Inconel and were very severely attacked when exposed in contact with them.

14. Electrodeposited coatings of cadmium on SAE X4130 steel strips attached to aluminum alloy panels were in excellent condition and intact after 2 years of weather exposure. Electrodeposited zinc coatings on the same steel were mostly corroded off when joined to Alclad 24ST and 53ST sheets. When joined to 52-1/2H and 24ST sheets, the zinc was attacked but not corroded off to the same extent.

15. Magnesium alloys very anodic to aluminum alloys, or stainless steel. Adjacent aluminum alloys, especially 24ST and Alclad 24ST, were in turn severely corroded by a base produced during the formation of the resulting corrosion product, which was a basic magnesium carbonate Dowmetal M proved anodic to Dowmetal H. Painted panels exposed for 2 years were but slightly corroded.

16. Corrosion products at faying surfaces of the dissimilar metals raised the stresses in some instances enough to cause cracks to form in the strips. Such cracks were found on 24ST and Alclad 24ST strips coupled with nickel alloys or stainless steel, on Dowmetal H strips coupled with aluminum alloys or stainless steel, and on stainless steel strips coupled with Dowmetal M.

17. Painted anodized 24ST panels, with paint schedules utilizing good grades of aluminum pigmented varnishes conforming to Navy Department specifications V10, V11, or 52V15b, were in excellent condition after 2 years of exposure.

18. Magnesium alloy panels, painted with good grades of aluminum pigmented varnishes, were in excellent condition after 2 years of exposure to the weather, except for slight failures at the edges of the rivet heads from which paints were off. Paint failures in the tidewater tests became advanced during the second year on three-coat paint schedules. Schedules of two coats of P27 type (zinc-chromate pigments) primers and two additional coats of aluminum-pigmented varnishes of good grade usually remained in good condition, especially when the second coat of primer was also aluminum pigmented. Primers of the P23 type (iron-oxide pigments) reacted to accelerate attack on the magnesium alloys, after coatings failures had occurred.

19. Paint failures were considerably more advanced on the anodized (PT13a) Dowmetal M panels than on those given the

chrome-pickle (sic) surface treatment. On Dowmetal H panels, after 2 years of exposure, no differences were observed in the amount of paint failure regardless of which method of surface treatment was used.

Exposures conducted at Boush Creek at the Naval Air Station, Hampton Roads, Va.

Reported by Willard Mutchler and W. G. Galvin, National Bureau of Standards, October 2, 1941.

TN 843 A SUMMARY OF RESULTS OF VARIOUS INVESTIGATIONS OF THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS AT LOW TEMPERATURES, E. C. Hartmann and W. H. Sharp, Alcoa, May 1942

A listing of sources of data on the mechanical properties of aluminum alloys at low temperatures. Also, a short summary of each report.

TN 848 NORMAL PRESSURE TESTS OF CIRCULAR PLATES WITH CLAMPED EDGES, Albert E. McPherson, Walter Ramberg and Samuel Levy, Natonal Bureau of Standards, June 1942

A fixture is described for making normal pressure tests of flat plates. It worked.

TN 849 NORMAL PRESSURE TESTS OF RECTANGULAR PLATES, Walter Ramberg, Albert E. McPherson and Samuel Levy, June 1942

Normal pressure tests were made on rectangular plates with clamped edges and with freely supported edges. The relation between center deflection and pressure was linearly varying at very low loads. At higher loads the variance was not linear.

Many of the plates with low loads did not obey the linear variance but this was attributed to deviations from the theoretical clamping conditions at the edges

With the beginning of permanent set both the total deflection and the permanent set at the center of the plates with clamped edges again increased linearly with the pressure.

When under pressure the thick plates tended to yield by bending near the edges while the very thin plates yielded like a membrane.

The following reference was used often in the report:

Timoshenko, S.: Theory of Plates and Shells. McGraw-Hill Book Book Co., Inc., 1940.

TN 851 STRENGTH TESTS OF THIN WALLED ELLIPTIC DURALUMIN CYLINDERS IN PURE BENDING AND IN COMBINED PURE BENDING AND TORSION, Eugene E. Lundquist and Elbridge Z. Stowell, Langley Memorial Lab., June 1942

Analysis presented on results of tests made at M.I.T. and by NACA on thin walled circular and elliptic cylinders. In each of the loading conditions, the bending moments were applied in plane of the major axis of the ellipse.

Conclusions:
1. The ratio of length to semi-major axis of the ellipse is an unimportant factor in the strength of thin walled elliptic cylinders subjected to pure bending in the plane of the major axis.

2. For any ratio of semi-major axis to wall thickness, the bending stress on the extreme fiber at failure for pure bending of thin walled elliptic cylinders in the plane of the major axis <u>increases</u> with the eccentricity of the elliptical shape. This increase in strength with eccentricity evidently arises from the increased stability of the more highly curved portions of the cylinder wall at the ends of the major axis where the bending stresses are highest. As the ellipse becomes more and more eccentric the increase in strength cannot be maintained indefinitely, for in the limit the cylinder becomes a deep narrow beam that is laterally unstable. Data indicate that the strength in pure bending is a maximum when the ratio of minor to major axis is in the neighborhood of 0.4 to 0.6.

3. Thin walled elliptic cylinders subjected to combined torsion and pure bending in the plane of the major axis will fail when the stress ratio satisfy the equation:

$$R_s^2 + R_b^2 = 1$$

where: R_b = ratio of bending stress at failure in combined pure bending and torsion to bending stress at failure in pure bending alone.

R_s = ratio of shearing stress at failure in combined pure bending and torsion to shearing stress at failure in pure torsion alone.

TN 852 EFFECTS OF RANGE OF STRESS AND OF SPECIAL NOTCHES ON FATIGUE PROPERTIES OF ALUMINUM ALLOYS SUITABLE FOR AIRPLANE PROPELLERS, Thomas J. Dolan, June 1942

Three types of tests were made on X76S-T aluminum alloy to determine the ordinary mechanical properties as well as the fatigue strengths: (1) Static tests were made of notched and unnotched tensile specimens. (2) Impact tests were made of both notched and unnotched specimens. (3) Repeated fatigue tests were made on notched and unnotched specimens.

The results were as follows:

(1) There was no apparent difference in fatigue tests for frequencies ranging from 1750 RPM to 13,000 RPM. The resulting properties were the same.
(2) The endurance limit of the alloy was greatly decreased when the specimens were notched.
(3) A polished rectangular specimen had an endurance limit of about 30% less than that for round specimens.
(4) The metal was found to be able to withstand a greater alternating stress range without the formation of fatigue cracks when the mean stress in the cycle was changed from a tensile to a compressive stress.
(5) It was found that the tensile yield strength of X76S-T is quite high in relation to its ultimate strength, more so than the other commonly used aluminum alloys such as 25S-T. These results can be used in relation to airplane propellers. Small notches are often introduced by small stones thrown up by the backwash of the propellor during take-off or when taxing on the field. Thus if the areas of the propellor blade that are most likely to be nicked or scratched could be designed to operate with a compressive mean stress, the blade would offer more resistance to the formation of fatigue cracks. Also, if cracks did form they would develop very slowly.

TN 856 EFFECT OF RIVET AND SPOT WELD SPACING ON THE STRENGTH OF AXIALLY LOADED SHEET STRINGER PANELS OF 24S-T ALUMINUM ALLOY, Samuel Levy, Albert E. McPherson, and Walter Ramberg, National Bureau of Standards, August 1942

Eighteen 24S-T aluminum alloy sheet string panels tested in end compression under carefully controlled edge conditions.

Buckling load of the sheet between stringers and the deflection of the sheet between stringers were compared with Timoshenko's theory.

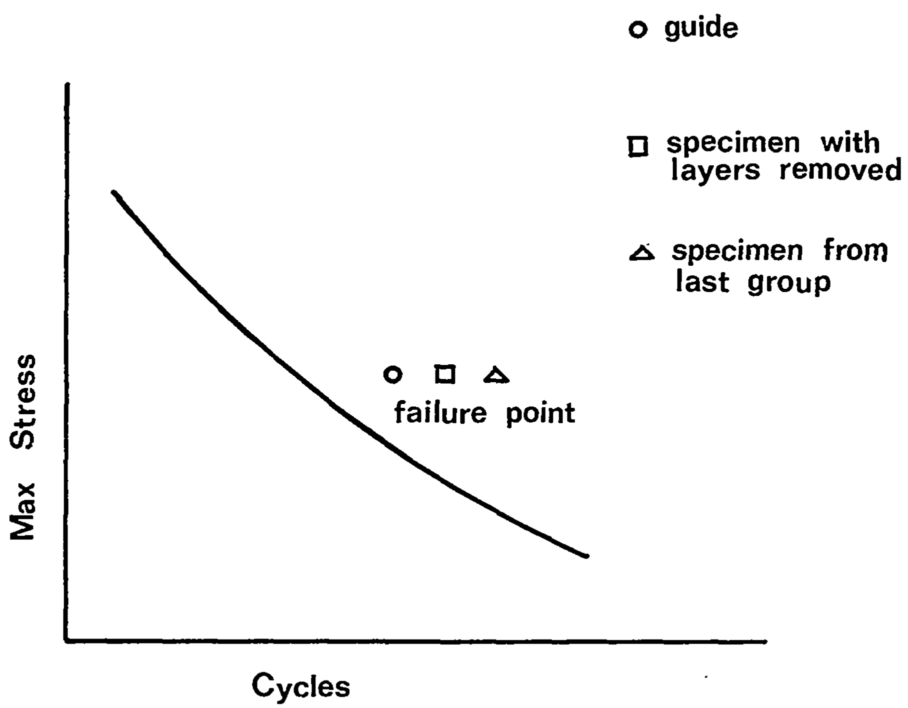
"Most of the observed buckling loads and deflections were in agreement with these theories and indicated that the two types of buckling were substantially independent of each other for the specimens tested."

The stringers were fastened to the sheet by brazier head rivets spaced 0.5 inch to 6 inches between centers for 9 panels, by spot welds spaced 0.5 to 4 inches between centers for 6 panels, and by round head rivets spaced 0.5 to 2 inches between centers for the other three panels.

As noted above, this report was in agreement with Timoshenko.

TN 857 IMPROVEMENT OF FATIGUE LIFE OF AN ALUMINUM ALLOY, G. W. Stickley, August 1942

(a) The object of this note was to determine whether the increase in the fatigue life when highly stressed outer layers are removed is caused by removing the damaged layers or whether the increase in fatigue life is caused by overstressing.
(b) Specimens made of 17S-T aluminum were loaded using either a 2-inch rotating simple beam fatigue machine or a R.R. Moore machine. One specimen was run to failure at a maximum stress of 22,000 lbs/in.^{2}. Two specimens were also run at 22,000 lbs/in.^{2} with thin layers removed periodically. The final specimens were started at a low initial stress and increased periodically to a maximum of 22,000 lbs/in.^{2}. By periodically increasing the load in the final specimens the same amount of overstressing was achieved as by removing the layers. The first specimen was used as a guide.
(c) The fatigue resistance of 17S-T aluminum can be increased by moderately overstressing. It appears that the increase in fatigue life obtained when surface metal was removed is due to overstressing and not from the removal of the metal.



TN 862 AN INVESTIGATION OF THE EFFECTIVENESS OF STIFFENERS OF SHEAR-RESISTANT PLATE-GIRDER WEBS, R. L. Moore, Alcoa, September 1942

Objects: (1) To determine experimentally the influence of size and spacing of stiffeners upon the buckling characteristics of shear resistant plate girder webs within the elastic range. (2) To evaluate, as far as possible, certain methods of stiffener design that have been proposed. (3) To obtain some information on the influence of stiffener size and spacing upon ultimate web strengths.

All tests made on two plate girders fabricated from 17S-T aluminum alloy plates, angles, and rivets.

Conclusions:
1. Definite values for the flexural rigidity of stiffeners required to stiffen panels of given proportions, such as have been obtained by application of the buckling theory, apparently cannot be experimentally determined. Measurements of lateral deflection in these tests were useful only in presenting a relative picture of web and stiffener behavior. They do not permit a quantitative determination of buckling resistance or stiffener effectiveness. Perhaps the most significant observation made, and the one that is also the most confusing from the standpoint of analysis, is that the buckling resistance of a web always may be increased by increasing the size of stiffener used until a condition of complete edge fixity is obtained for the subdivided panels.

2. The relative lateral deflections observed for the different sizes and types of stiffeners, whether of single or double angle type, were reasonably consistent with the computed stiffener moments of inertia. Effective widths of web equal to 25% of the clear depths were assumed for the single angle stiffeners, although essentially the same results would have been obtained for most of the sizes considered if moments of inertia had been computed about the face of the web in contact with the stiffeners. This procedure is simpler from the standpoint of design but implies an appreciably different effective width of web for each size of angle, a condition that is not believed to be consistent with actual behavior. For large angles, moments of inertia computed about the face of the web may correspond to effective widths far greater than the stiffener spacing or the available web for each stiffener.

3. Single angle stiffeners appear to be more effective than double angle stiffeners from the standpoint of stiffness-weight ratio.

4. The selection of stiffener proportions on the assumption that buckling will occur in the web for the load computed as critical

for a condition of simply supported edges, as is done conservative procedure as far as stiffener design is concerned in view of the appreciable edge restraint indicated for the web panels in many of the tests.

5. The following formula is proposed as a <u>tentative</u> basis for the design of stiffeners on shear resistant webs:

$$L = \frac{14}{(\frac{b}{d})^3}$$

L = ratio of flexural rigidity of one stiffener to flexural rigidity of web panel between adjacent stiffeners.
b = stiffener spacing, inches.
d = clear depth of web, inches.

6. For most cases, the formula given provides stiffeners having more flexural rigidity than was indicated as necessary by two other stiffener-design methods. Since there is no accepted basis for the determination of the requirements of an adequate stiffener for purposes of design, it is obviously difficult to evaluate different design methods.

7. From ultimate load tests on only two girders, the proposed design method seems to provide ample margin of strength against ultimate failure in the stiffeners. These maximum shear stresses also exceeded the theoretical buckling values for the weakest web panels by approximately 40% and 90%.

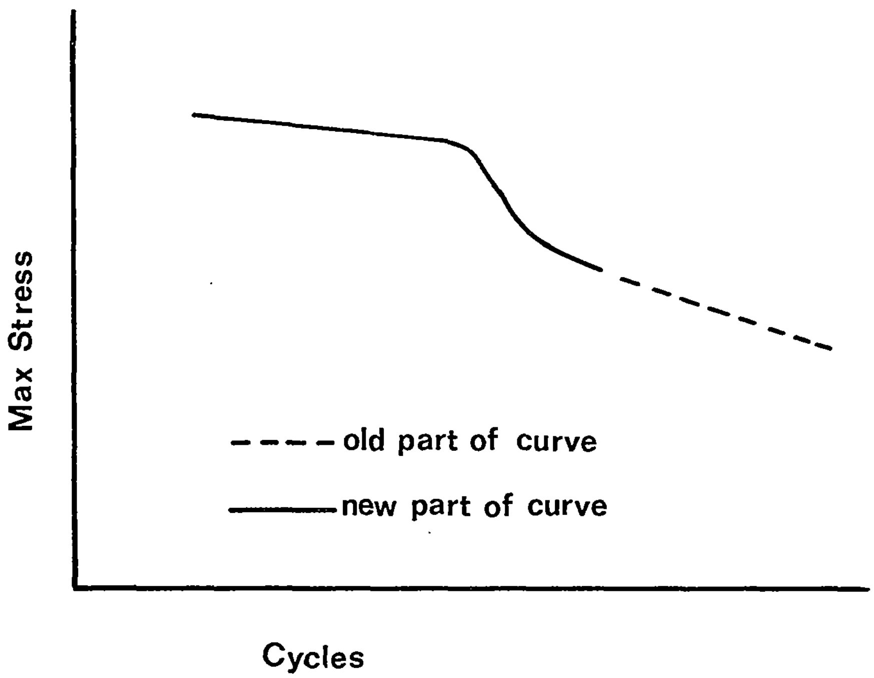
8. Although strengths developed in the two girders were as high as would normally be considered obtainable in the design of shear resistant webs of aluminum 17S-T, it is significant that ultimate collapse and fracture did not occur until the connections between webs and stiffeners on the weaker half of the girders were broken.

9. Within the apparent elastic range, the measured vertical deflections at the center of the spans were in very close agreement with the computed values. Approximately two-thirds of these deflections were computed to be the result of shear, and the remaining one-third were computed to be the result of flexure.

TN 865 THE DIRECT-STRESS FATIGUE STRENGTH OF 17S-T ALUMINUM ALLOY THROUGHOUT THE RANGE FROM ONE-HALF TO 500,000,000 CYCLES OF STRESS, E. C. Hartmann and G. W. Stickley, September 1942

(a) The purpose of this report was to extend the fatigue-strength curve for 17S-T aluminum from static loading to the endurance limit.
(b) From 17S-T rod specimens for use in a direct tension-compression fatigue testing machine with a nominal-minimum diameter of 0.200 inch were made. The specimens were tested by repeatedly applying and releasing a load equal to a pre-determined percentage of the tensile strength. One specimen was run statically to determine the tensile strength.
(c) The values of the stress and the number of cycles are shown below as is the curve.

Specimen	Stress (psi)	Cycles
1	60,970	1/2
2	59,750	76
3	56,090	did not fail
4	55,150	19,100
5	50,100	54,200
6	44,500	75,700



TN 866 A STUDY OF GENERAL INSTABILITY OF BOX BEAMS WITH TRUSS-TYPE RIBS, Eugene E. Lundquist and Edward B. Schwartz, November 1942

(a) The design of truss-type ribs for box beams is theoretically treated with regard to the function of the ribs.

(b) Equations, for calculating the strain energy and stress of each part of the structure, were formulated. Because of their number and length the only equations given in this summary are:

Short-column of 24S-T Al, pinned ends

$$\frac{P}{A} = 48{,}500 - \frac{(48{,}500)^2}{4\ \pi^2}\ \frac{(\frac{L}{\rho})^2}{10^7}$$

Long-column of 24S-T Al, pinned ends

$$\frac{P}{A} = \frac{\pi^2\ 10^7}{(\frac{L}{\rho})^2}$$

The theoretical values give higher allowable loads than the experimental data. In the experimental part of this report it was found that the tubes joining the ribs fail or the ribs buckled. TN 866 is in the NCSU Library.
(c) Since the theoretical values are not correct the suggestion was made that the distance between the panel points of the rib truss be reduced and that additional web members be added.

TN 867 BEAM AND TORSION TESTS OF ALUMINUM-ALLOY 61S-T TUBING, R. L. Moore and Marshall Holt, October 1942

(a) 61S-T aluminum-alloy tubing was tested to determine the effect of ratios of diameter to wall thickness upon the flexural and torsional moduli of failure.
(b) An Amsler universal testing machine was used to load the tubing. The modulus of failure was calculated by:

$$F_b = 1.57\ F_{cy} - 1.7\ \frac{(F_{cy})^2}{E}\ \frac{D}{t}$$

F_{cy} = compressive yield strength
E = modulus of elasticity
D/t = ratio of diameter to wall thickness

Modulus of failure by elastic buckling:

$$F_{st} = \frac{T}{2\pi r^2\ t}$$

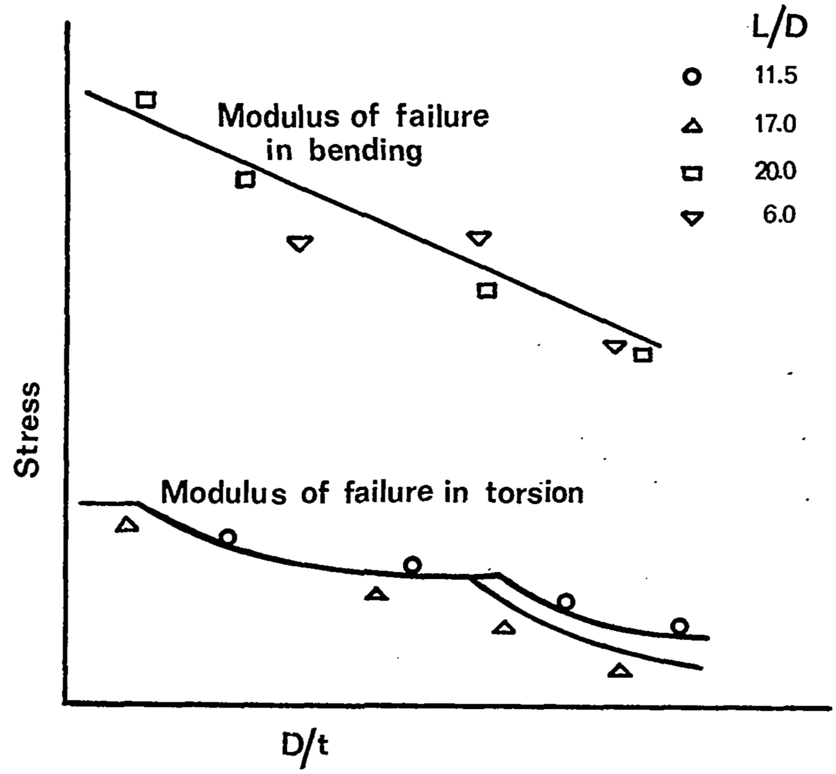
F_{st} = modulus of failure in torsion (lb/in^2).
T = torque producing failure, in.-lb.
r = mean radius, inches

Modulus of failure in torsion for plastic buckling:

$$F_{st} = \frac{F_{tu}}{2}\left(3.7\,\frac{t}{D} + 0.93\right)$$

F_{st} = modulus of failure in torsion (lb/in^2).
F_{tu} = tensile strength (lb/in^2)

(c) The modulus of failure in bending was found to bear a linear relationship with diameter-thickness ratios and were independent of span. The equations used to calculate the moduli of failure agree very well with the experimental data.



TN 868 THE INFLUENCE OF IMPACT VELOCITY ON THE TENSILE CHARACTERISTICS OF SOME AIRCRAFT METALS AND ALLOYS, Donald S. Clark, October 1942

(a) The report deals with the effect of rates of deformation up to about 150 ft/sec. on 16 metals and alloys.
(b) It should be noted that longer gage lengths than the 1 inch gage length used in this investigation would change the results. In general the materials withstood stresses above their static yield point for very short duration with little deformation. All materials except Dowmetal M and 18%Cr-8%Ni stainless steel showed little change in percent elongation

with increasing rate of deformation. Dowmetal M is very sensitive to velocity.

(c) Metals:

Aluminum	Steels
Pure	1112
17S-T	1020
24S-T	1035
Magnesium	X4130
Dowmetal M	6140
Dowmetal J	Stainless Steel
Dowmetal X	16%Cr-2%Ni
Copper	18%Cr-8%Ni
Brass	
Silicon-bronze	

TN 869 SUMMARY OF RESULTS OF TESTS MADE BY ALUMINUM RESEARCH LABORATORIES OF SPOT WELDED JOINTS AND STRUCTURAL ELEMENTS, E. C. Hartmann and G. W. Stickley, Alcoa, November 1942

Available information concerning spot welding is summarized and comparisons made of the relative merits of spot welded and riveted aluminum alloy structural elements.

Results indicated that spot welding was as satisfactory as riveting insofar as resistance to static loads is concerned. Spot welds showed slightly lower resistance to impact loads but definitely lower resistance to repeated loads than rivets.

TN 871 STABILITY OF ELASTICALLY SUPPORTED COLUMNS, Alfred S. Niles and Stephen J. Viscovich, NACA, 1942

Report develops a method for analyzing an elastically supported column for stability, where end load,

$$P < \frac{\pi^2 EI}{L^2} \, .$$

column is taken to be a series of rigid links, pin-jointed at elastic supports, with support taken as a spring. Then solve for spring constants, which tell how rigid each support must be. This estimate is conservative, as it does not include rigidity of continuous structure. Covered in Timoshenko, Theory of Elastic Stability.

TN 872 TORSION TEST OF A MONOCOQUE BOX, Samuel Levy, Albert E. McPherson, and Walter Ramberg, November 1942

(a) A monocoque box of aluminum alloy was subjected to torque applied at both ends. The twist, the strain, and the buckling load was measured. The twist was measured. The twist was found to be 20 to 50 percent less than that given by Bredt's

(on page 270 of Timoshenko, S.: Theory of Elasticity, 1st ed., 1934.) theory for thin-wall boxes without reinforcement, and the shear stress was about 18% greater than predicted by Bredt.
(b) To get better agreement between theory and experiment equations were formulated for a monocoque box reinforced by stringers, corner posts, and bulkheads. Because of the length and number of equations, the equations were left out of this report, TN 872 is available in the NCSU Library.
(c) The data from the new equations agreed within 10% of the measured values. The shear stress in the shear web was independent of the position between bulkheads; the ratio of measured shearing stress in the shear web and corner post was inversely proportional to the wall thickness at the point of measurements.

TN 873 BENDING TEST OF A MONOCOQUE BOX, Albert E. McPherson, Walter Ramberg, and Samuel Levy, November 1942

(a) A monocoque box beam consisting of a 24S-T aluminum alloy sheet, reinforced by four bulkheads and longitudinal stringers and corner posts, was subjected to bending loads about the lift axis, cantilever bending about the lift axis, and pure bending about both lift and drag axes.
(b) Theoretical: Bending about the lift axis, strain in the inner and the outer flange of the Z-stringers

$$\varepsilon_y = My/EI$$

ε_y is the compressive strain for a fiber at a distance y from the neutral fiber

Cantilever bending about the lift axis,

$$\frac{y}{d} = \frac{8}{3(1-2a/\ell)^2} \left(\frac{a}{\ell}\left(\frac{a}{\ell} - 1\right) + \left(1 - \frac{a}{\ell} + \frac{a^2}{\ell^2}\right)\frac{x}{\ell} - \frac{a^3}{\ell^3}\right)$$

y = deflection at a point a distance x from the free end of the beam relative to a line through points a distance a from the load points.
d = center deflection (y(1/2))
ℓ = length of beam between load points

Pure bending about both lift and drag axis, effective flexural rigidity about the lift and drag $(EI)_L$ and $(EI)_D$

$$(EI)_L = E(I_{L_0} - \int_{-12}^{+12} S^2\ (tdx-da))$$

where S is the distance of the sheet from lift axis.

$$(EI)_D = E(I_{D_O} - \int_{-12}^{+12} x^2 \ (tdx-da))$$

Magnitude of rotation of the neutral axis

$$\theta = \frac{M_D \ (EI)_L}{(EI)_D \ M_L}$$

(c) When the box was tested within the elastic range by pure bending about the lift axis the strains across the compression face were uniform at all loads. The effect of the bulkheads on stringer strain was negligible. Testing within the elastic limit by cantilever bending produced stringer strains which varied linearly with the distance from the end loads. Testing by pure bending about the lift and drag axis produced strains that differed from linearity by 4% across the compression face and 6% for the tension face. The corner-post strains increased linearly with the moment. Center deflection increased almost linearly with all loads. Experimental and theoretical values (from simple beam type theory using the effective width of the buckled sheet)agreed within 10%.

TN 876 THE LIMITING USEFUL DEFECTIONS OF CORRUGATED METAL DIAPHRAGMS, W. A. Wildhack and V. H. Goerke, December 1942

(a) The information in this document was intended for use in designing pressure measuring devices. Since flat corrugated metal diaphragms are no longer used in most airplane instruments, it is felt that this material is out of date.

TN 877 AN EXPLORATION OF THE LONGITUDINAL TENSILE AND COMPRESSIVE PROPERTIES THROUGHOUT AN EXTRUDED SHAPE OF 24S-T ALUMINUM ALLOY, D. A. Paul, December 1942

Tensile and compressive properties were investigated of specimens cut from an extruded shape of 24S-T aluminum alloy. The tensile strengths, tensile yield strengths, elongation and compressive yield strengths of both the unrecrystallized and recrystallized portions were determined. The object was to determine the tensile and compressive properties at various locations in the extruded shape.

The tests were performed on Amser machines which measured results on tensile strengths, yield strength, elongation and reduction of area. The different samples were cut from varying sections of a 36 foot aluminum beam. Samples were taken from both the central unrecrystallized portion and the outer recrystallized portion.

The tensile strength of the unrecrystallized portion was about 80,000 psi. The tensile yield strengths of the same portion was 58,000 psi.

The tensile strengths, the tensile yield strengths and elongation of the recrystallized portions was 64,000 psi, 49,000 psi, and 17% respectively.

The samples taken from portions which are part recrystallized and part unrecrystallized have strengths which are weighted averages of the strengths of recrystallized and unrecrystallized areas. The strengths depend on the proportional amounts.

TN 879 TORSIONAL STRENGTH OF ALUMINUM ALLOY ROUND TUBING, R. L. Moore, Alcoa, January 1943

An analysis of existing data on aluminum alloy tubing with a wide range of plastic properties in order to establish a useful empirical relationship between tensile yield and ultimate strengths, diameter-thickness ratios, and torsional strengths within the range of plastic buckling.

1. The upper limit of torsional strength for a round tube is determined by the shear strength of the material. Specimens for the determination of this property may have a variety of proportions, provided that failure occurs by plastic yielding or fracture in shear without buckling. Unless restrictions are placed upon the length of the specimen used for this purpose, however, diameter-thickness ratios should not exceed about 10.

2. Shear strength of the heat-treated wrought aluminum alloys in torsion may be taken conservatively at about 65 percent of the tensile strength. This value is based upon the assumption of a uniform distribution of shear stress at failure, which seems to be a reasonable procedure in the case of ductile materials of the kind considered.

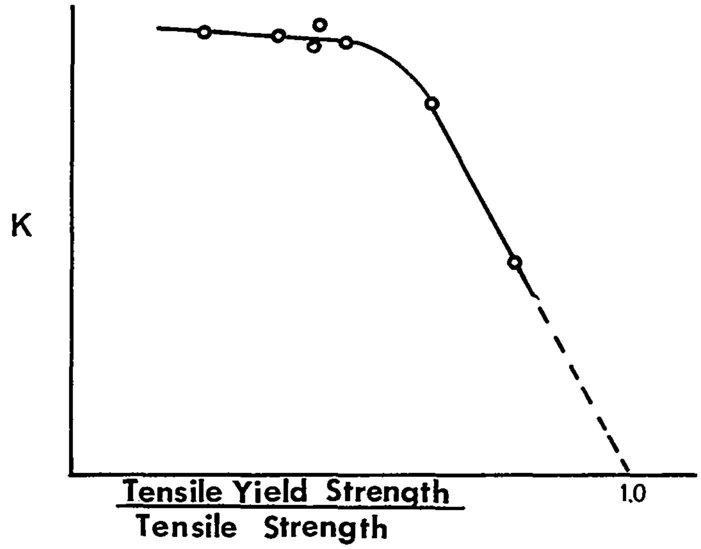
3. For round tubes having diameter-thickness ratios ranging from about 10 to 50 or 60 and lengths greater than about 3 diameters, failures in torsion may be expected by plastic buckling at stresses below the shear strength of the material. Torsional strengths within this range may be predicted by means of the formula:

$$T = s\ [0.65 - K\ (0.10 - \frac{t}{D})]$$

T = torsional strength based on a uniform distribution of shear stress (not to exceed 0.65s), pounds per square inch.
s = tensile strength, pounds per square inch.
K = factor based upon ratio of tensile yield to ultimate strength, given on attached figure graph.
t = wall thickness, inches.
D = diameter outside, inches.

4. The inclusion of the ratio of tensile yield to ultimate strength as a significant factor makes the method applicable to alloys having a considerable range of plastic properties.

5. Although plastic bulklong failures may be expected in aluminum alloy round tubes with diameter-thickness ratios as high as 50 or 60 without regard to length effects, the limit of applicability of the above equation for plastic buckling is presumably reached when torsional strengths so computed exceed theoretical values for elastic buckling.



TN 882 TESTS OF FLAT PANELS WITH FOUR TYPES OF STIFFENERS, Alfred S. Niles, Stanford University, January 1943

Fifty-one aluminum alloy panels tested as flat-end columns. Test specimens included all possible combinations of two lengths, four stiffener spacings, and four stiffener designs, and were mostly in duplicate pairs. Stiffeners were 24S-O material 0.064 inch thick and 2.54 inches wide. Panels were 0.025 inch 24S-T sheet.

This report gives a detailed report of the bending and compression tests of the panels, with remarks at various load readings throughout the loading.

Although, a fine description is given of the tests, there are <u>no conclusions</u> whatsoever.

NO GENERAL APPLICATION IS MADE OF THE RESULTS OF THIS TEST.

TN 883 TESTS OF ALUMINUM-ALLOY STIFFENED-SHEET SPECIMENS CUT FROM AN AIRPLANE WING, Marshall Holt, NACA, 1943

Material: 24S-T, 24R-ST(Alclad), 24S-T(Alclad). Typical panels cut from airplane wings were tested as flat and curved plates. Stiffeners were left in. Longitudinal strains were measured at various locations on panel. Stiffeners not exactly parallel.

Results:
1. Critical buckling strain of stiffened curved sheet varies linearly with ratio of thickness to radius of curvature.

$$\varepsilon_c = \frac{\sigma_c}{E} = 5\left(\frac{t}{b}\right)^2 + 0.3 \left(\frac{t}{R}\right)$$

t = thickness of sheet
b = unsupported width
R = radius of curvature

2. Suddenness and violence of buckling increases with decreasing R.
3. For R/t > 1000, buckling is elastic.
4. Rivet spacing > 98t is a source of weakness. Spacing less than 36t does not add to strength.

5. For specimens with slenderness ratios between 36 and 66 and rivet spacing = 36t, ultimate loads based on stiffener area alone and compressive yield strength of material are within 11% of test results.

TN 884 LARGE DEFLECTION THEORY FOR END COMPRESSION OF LONG RECTANGULAR PLATES RIGIDLY CLAMPED ALONG TWO EDGES, Samuel Levy and Philip Krupen, 1943

For rigidly clamped edges the Von Kārmān equations are solved and tabulated for flat plates with edge strains up to eight times the buckling strain.

The values are compared with values obtained from a previous analysis by H. L. Cox, Ref. (4), page 13.

For edge strains less than three times the critical edge strain the results agree closely. Above this strain level, the values obtained by Cox are as much as 6% low.

Reference: (4) Cox, H. L: The Buckling of Thin Plates in Compression R. & M. No. 1554, British A.R.C., 1933.

TN 885 TORSION TEST OF 24S-T ALUMINUM ALLOY NONCIRCULAR-BAR AND TUBING, R. L. Moore and D. A. Paul, January 1943

(a) Tests of 24S-T aluminum alloy were made to determine the yield and ultimate strengths in torsion of noncircular bar and tubing.

(b) Relating twist and torque:

$$\theta = + \frac{T}{Bbc^3G}$$

θ = twist, radians per inch
T = torque, pound-inch
b = long side, inches
c = short side, inches
G = modulus of elasticity in shear assumed to be 3,900,000 psi.
B = factor depending upon b/c.

Maximum shear at the center of the long side:

$$t_{max} = \frac{T}{abc^2}$$

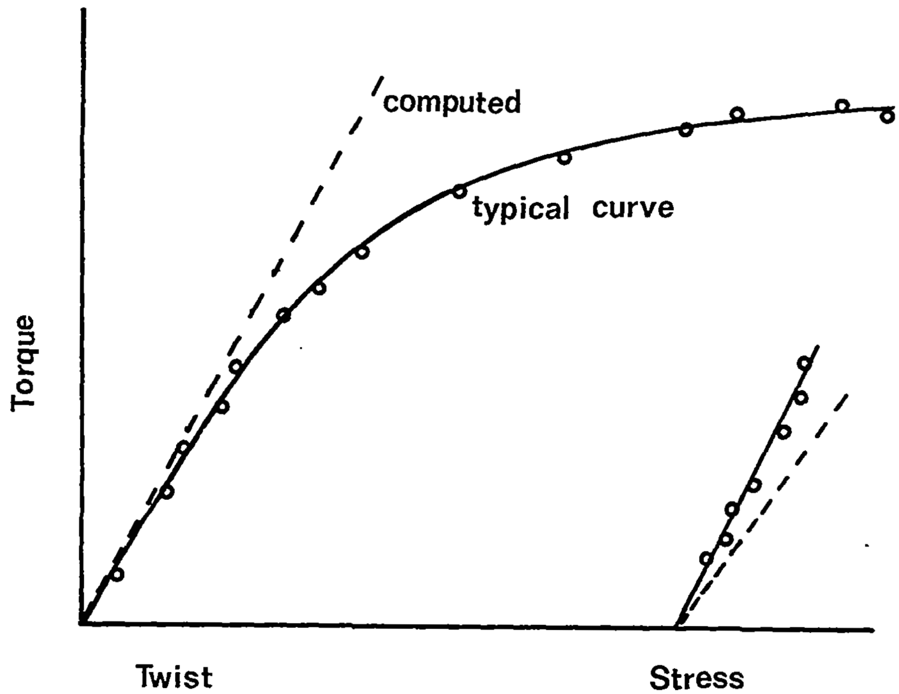
t_{max} = maximum shear stress psi
a = factor depending upon the ratio b/c.

The shearing stresses in thin-wall tubes:

$$t = \frac{T}{2At} \left(1 \pm \frac{t}{2} \left(\frac{P}{A} - \frac{1}{R}\right)\right)$$

t = shear stress at the inner or outer surface, psi
P = mean perimeter of cross section, in.
R = radius of curvature of the mean perimeter at the point considered.

(c) Within the elastic range, torsional stiffness and maximum shearing stresses may be predicted quite closely by existing formulas. The yield point is somewhat less than the shearing strength based upon a 0.2% offset.



TN 886 TORSIONAL ELASTIC PROPERTIES OF 18:8 CHROMIUM-NICKEL STEEL AS AFFECTED BY PLASTIC DEFORMATION AND BY HEAT TREATMENT, R. W. Mebs and D. J. McAdams, Jr., January 1943

(a) A study was made of the influence of plastic extension, plastic torsion, and annealing temperature upon the torsional elastic properties. A study of the relationship between torsional stress, strain, and permanent set for 18:8 Cr-Ni steel in the annealed, half-hard, and hard condition was made.
(b) A 18:8 Cr-Ni steel tube was loaded cyclically in torsion to produce plastic shear strain or torsion set in order that stress-set and stress-strain curves could be determined.
(c) For the annealed specimen the initial shear proof stress increased from 10,000 psi at 0.001 percent proof set to 23,000 psi at 0.1 percent proof set. For the half-hard specimen the initial shear proof increased from 21,000 psi at 0.001 percent proof set to 53,500 at 0.1. The hard specimen increased from 11,000 psi at 0.001 percent proof set to 66,900 at 0.1. Annealing the harden specimens from 300 to 900°F. produced an increase in shear proof for all percentages of proof set. From 900°F. to 1900°F. there was a decrease in shear proof stress. An increase from 0.5 to 20 percent extention produced an increase in initial shear proof stress for all percentages of proof set.

TN 888 TORSION OF FLANGED MEMBERS WITH CROSS SECTIONS RESTRAINED AGAINST WARPING, H. N. Hill, March 1943

(a) A study was made of the longitudinal stress and the stiffness of flanged members. I-beams, channels, and Z-bars were subjected to torque with constraint against cross-sectional warping.
(b) Torque was applied at the center of the beams while the ends were restrained from warping. For torque at midspan the angle of twist is:

$$\theta = \frac{T}{GJ}\left(x - a\,\frac{\sinh \frac{x}{a}}{\cosh \frac{L}{2a}}\right)$$

$$a = \sqrt{\frac{EC_{BT}}{GJ}}$$

$$C_{BT} = \int u^2 dA$$

T = twisting moment
θ = angle of twist
x = distance along axis of shear centers
G = modulus of rigidity
J = section factor for torsion
E = Young's modulus
C_{BT} = torsion-bending factor for section about shear center

u is the "unit warping" of the area dA from a reference plane through the shear center and normal to the axis, when $d\theta/dx = 1$.

The longitudinal stress is calculated by:

$$\sigma = \frac{ET}{GJ}\,\frac{\sinh \frac{x}{a}}{a \cosh \frac{L}{2a}}\,u$$

These equations are from: NACA T.M.'s 807, 784, 851, and from NACA Rep. No. 582.
(c) Comparison of experimental and calculated data showed very good agreement for the I-beam and Z-bar. Rotation was off 5% and longitudinal stress was off 4% for the channel. This was the worst case. Therefore the equations gave reasonably good values.

TN 889 EFFECTS OF PRIOR FATIGUE STRESSING ON THE IMPACT RESISTANCE OF CHROMIUM-MOLYBDENUM AIRCRAFT STEEL, J. A. Kies and W. L. Holshouser, National Bureau of Standards, March 1943

Fatigue cracks of detectable dimensions usually cannot be found until after a relatively long period during which suitable preparation for such cracks is made by continued stressing. Once such a crack is started, complete failure may be anticipated within a short time, often 10% or less of the total service life.

In attempt to detect and evaluate damage of this kind, the impact behavior of normalized SAE S4130 steel was studied after a variety of repeated stress treatments. Fatigue specimens of several types were used and the effects of surface finish, rest periods, stress amplitude, mean stress, stress concentration, and temperature during repeated stress received consideration. Comparative impact-test results were obtained for several temperatures ranging from room temperature to -78°C. The results serve to emphasize the seriousness of fatigue cracks, particularly at low temperatures, but are reassuring in the cases in which fatigue cracks, particularly at low temperatures, but are reassuring in the cases in which fatigue cracks are absent or have not developed to a size permitting detection.

Tests were conducted on 1/2 inch square bars of chromium-molybdenum steel of three different heats.

1. No loss in impact resistance resulted from repeated stressing below the fatigue limit. This fact was established for the notched Krouse specimens and for the unnotched Moore and Haigh specimens.

2. For the notched specimens stressed above the fatigue limit, all losses in impact resistance were accompanied by fatigue cracks at the roots of the notches.

3. Fatigue damage in the notched specimens was detected equally early by impact tests at room temperature, at -20°C., and at -78°C.

4. For the notched specimens it was shown for a given percentage loss of initial impact energy, a much deeper crack can be tolerated at room temperature than at -20°C. or at -78°C., but the low temperature effect was not appreciably greater for cracked than for uncracked specimens until the cracks had become visible when viewed at a magnification of 8.

5. The fact that notched rotation cantilever fatigue specimens had received a given number of cycles of a given overstress was of small importance compared with the question of whether fatigue cracks had started.

6. Tensile impact tests of unnotched specimens stressed as rotating beams and axially loaded specimens stresses in equal tension and compression gave no indication of any loss in elongation or impact energy until surface fatigue cracks were present. These cracks were not always found in advance of the impact tests. Damage was detected no sooner at -33°C. than at the room temperature.

7. For the specimens referred to in 6, there was no difference between the impact energy at -33°C. and at room temperature during the pre-crack stage. However, the elongation was slightly less at the lower temperature.

8. Axially loaded specimens subjected to repeated overstress superimposed on mean tensile stress varying from 17,400 to 77,000 pounds per square inch extended plastically during the first few thousand cycles of stress, after which no further extension took place during the pre-crack stage of the fatigue. Small losses in elongation and tensile impact energy accompanied this initial extension, but these losses were also restricted to the first few thousand cycles of stress. No further change in elongation or impact energy took place until the advent of fatigue cracks.

9. Two different surface finishes, aloxite and 4/0, made no difference in the fatigue or impact results obtained on unnotched Moore specimens. For Haigh specimens, for which mean tensile stresses during fatigue ranged from 17,400 to 77,000 pounds per square inch, the endurance at a given overstress was somewhat higher for the specimens having the finer 4/0 polish.

10. Moore and Haigh specimens, for which the mean tensile stress during fatigue was zero, developed five cracks at the most in any single specimen regardless of the finish used.

11. Haigh specimens given the aloxite polish and then subjected to mean tensile stresses of 17,400, 31,000, and 50,000 pounds per square inch during fatigue developed numerous (maximum about 100) fatigue cracks if allowed to run to failure or near failure. Specimens given the 4/0 finish and stressed under these conditions developed a maximum of from 2 to 5 cracks.

12. Haigh specimens subjected to a mean tensile stress of 77,000 pounds per square inch developed large numbers of fatigue cracks (maximum about 200) regardless of the finish used.

13. It was evident that with the coarser polish large numbers of cracks formed only where some plastic deformation occurred during fatigue. If the mean tensile stress was sufficiently high, this difference was either nonexistent or masked by the effects of plastic deformation.

14. Axially loaded fatigue specimens that had developed fatigue cracks were used to study the relationship between crack dimensions and tensile impact behavior. Even the smallest cracks measured produced losses in impact energy and elongation.

15. The average impact energies of cracked specimens were the same at room temperature and at -33°C. for cracks less than a certain critical size. For cracks larger than the critical size, the average impact energies were less at -33°C.

16. The specimens fatigue stresses by axial loading sufficiently to produce fatigue cracks were machined to remove the surface layer containing the cracks. The tensile impact resistances of the remaining specimens were slightly less than for comparable specimens not fatigue stressed. This loss was attributed mainly or wholly to the plastic extension received during repeated stress.

17. Specimens fatigue stressed by flexure in the temperature interval, -40 to -45°C., showed no evidence of lowered impact resistance at either room or low temperature, provided no detectable cracks were formed.

18. The ratio of the fatigue limits of specimens of normalized SAE X4130 steel stressed by repeated flexure at -40 to -45°C. and at room temperature was 1.24.

TN 893 LEAST WORK ANALYSIS OF THE PROBLEM OF SHEAR LAG IN BOX BEAMS, Francis B. Hildebrand and Eric Reissner, M.I.T., May 1943

Similar to Bruhn.

The distribution of stress in the cover sheets of thin wall box beams is analyzed with regard to the effect of shear deformation in the cover sheets, by the method of least work.

TN 894 THE EXACT SOLUTION OF SHEAR LAG PROBLEMS IN FLAT PANELS AND BOX BEAMS ASSUMED RIGID IN THE TRANSVERSE DIRECTION, Francis B. Hildebrand, M.I.T., June 1943

A mathematical procedure is developed. The method is based on the assumption that the amount of stretching of the sheets in the direction perpendicular to the direction of essential normal stresses is negligible.

The theory is considered to be a refinement of approximate methods devised by Reissner, and by Kuhn and Chiarito.

The above mentioned assumption is the only assumption, and the problems considered are then solved in an exact manner, as boundary-value problems in the theory of plane stress.

The shear-lag analysis of this paper presents mathematically exact solutions of several problems that have been previously treated in general by approximate methods. Although the results strictly apply only to beams and panels that are theoretically rigid in the transverse direction, it seems probable that they are applicable with reasonable accuracy in actual cases when stiff chordwise ribs are present. The solutions are obtained in the form of rapidly convergent infinite series that are much more adaptable to numerical computation than exact solutions that have been given elsewhere in certain special cases.

On the basis of comparisons of the present results with approximate solutions given by Reissner and by Kuhn and Chiarito, it appears that in cases when both the approximate solutions are applicable, for example, uniform rectangular box beams without cut-outs, the Reissner solutions are in better agreement with the exact solutions than are the solutions given by the methods of Kuhn and Chiarito. In other cases for which the Reissner procedure was not designed, for example, box beams with cut-outs and panels loaded by concentrated axial forces, the solutions given by the procedure of Kuhn and Chiarito predict shear-lag effects that are in general considerably large than those given by the "present" method.

Present method = method in this report.

References:

1. Reissner, Eric: Least Work Solutions of Shear Lag Problems. Jour. Aeron. Sci., vol. 8, no. 7, May 1941, pp. 284-291.

2. Kuhn, Paul, and Chiarito, Patrick T.: Shear Lag in Box Beams-Methods of Analysis and Experimental Investigation. Rep. No. 739,NACA, 1942.

3. Kuhn, Paul: Stress Analysis of Beams with Shear Deformation of the Flanges. Rep. No. 608, NACA, 1937.

TN 895 LARGE DEFLECTION THEORY OF CURVED SHEETS, Samuel Levy, National Bureau of Standards, May 1943

It may be concluded that for small deflections the initial curvature has a large effect on the load carried in axial compression and may increase the buckling load several hundred percent. When the buckle depth becomes comparable with the sheet thickness, however, the effect of the initial curvature on the load carried in axial compression becomes negligible.

In terms of effective width this may be expressed as follows: The effective width ratio is increased considerably by an increase in curvature for loads near the buckling load. When the edge strain is several times the critical buckling strain of the corresponding flat sheet, however, the effect of curvature on the effective width ratio is negligible.

TN 896 ROUND HEAT-TREATED CHROMIUM-MOLYBDENUM-STEEL TUBING UNDER COMBINED LOADS, William R. Osgood, July 1943

(a) Round heat treated chromium-molybdenum-steel tubing was subjected to axial, bending, torsional, combined bending and axial, combined bending and torsional, and combined axial, bending, and torsional loads. The problem of designing a tubular cantilever beam was also solved.
(b) The experimental data was used to formulate the following equations: Axial loading:

$$\frac{1}{\delta} = \frac{Et}{Sdm}$$

$$\sigma_A = 0.67 + 0.112 \frac{1}{\delta} - 0.0099 \frac{1}{\delta^2} + 0.0003 \frac{1}{\delta^3}$$

$$4 < \frac{1}{\delta} < 16$$

$\overline{M}$ = maximum bending moment
Z = section modulus of the cross-sectional area
P = axial load
A = cross-sectional area
S = compressive yield strength
E = Young's modulus
t = wall thickness
d = tube diameter
dm = mean diameter
f_a = axial stress
f_b = bending stress

Bending load:

$$\sigma_B = 0.7 + 0.16 \frac{1}{\delta} - 0.015 \frac{1}{\delta^2} + 0.000485 \frac{1}{\delta^3} \qquad 4 < \frac{1}{\delta} < 16$$

Torsion:

$$\frac{1}{\delta_s} = \left(\frac{E}{S}\right)^{2/3} \frac{t}{dm}$$

$$\tau_T = 0.06 \left(\frac{1}{\delta_s} - 0.8\right) + 0.5 \qquad 0.8 < \frac{1}{\delta_s} < 3.2$$

Combined Axial and Bending Loads:

$$f_a = \frac{P}{A} \qquad f_b = \frac{\overline{M}}{Z}$$

$$\left(\frac{\sigma_a}{\sigma_A}\right)^{9/10} + \left(\frac{\sigma_b}{\sigma_B}\right)^{9/10} = 1 \qquad \frac{\sigma_a}{\sigma_A} < 1$$

Combined Bending and Torsional Loads:

$$f_t = \frac{\overline{M}t}{2Z} \qquad \tau = \frac{f_t \ dm}{S \ d}$$

$$\left(\frac{\sigma_b}{\sigma_B}\right)^{5/2} + \left(\frac{\tau}{\tau_T}\right)^{5/2} = 1$$

Combined axial, bending, and torsional loads:

$$\frac{\left(\frac{\sigma_b}{\sigma_B}\right)^{5/2}}{\left[1 - \left(\frac{\sigma_a}{\sigma_A}\right)^{9/10}\right]^{25/9}} + \frac{\left(\frac{\tau}{\tau_T}\right)^{5/2}}{\left(1 - \frac{\sigma_a}{\sigma_A}\right)^{5/2}} = 1, \ \frac{\sigma_a}{\sigma_A} < 1$$

TN 897 BEARING TESTS OF MAGNESIUM-ALLOY SHEET, W. H. Sharp and R. L. Moore, June 1943

(a) Bearing yield and ultimate strengths were determined for AM-3S, AM-52S, and AM-C57S magnesium-alloy sheet in various tempers and thickness for different edge distances and various ratios of loading-pin diameter to sheet thickness. Alloys of -0 and -H tempers of 0.064 in. and of -R temper between 0.125 in. and 0.250 in. were used.
(b) A 40,000 pound capacity Amsler testing machine using 1/2 in. 1/4 in. steel pins was used in the bearing test. Edge distances o 1, 1.5, 2.3, and 4 times the pin diameter were used with the 1/2 in. pin and 1.5, 2, and 4 were used with the 1/4 in. pin. A filar micrometer microscope was used to measure hold deformation.
(c) Ultimate bearing strengths increased with edge distance up to 1.5 to 2 times the pin diameter. Above 2 times the pin diameter there was no appreciable gain in strength. The strength of the sheets increased between 8,000 and 16,000 pounds per square inch from a ratio (pin diameter to sheet thickness) of 8 to 4, no effect of ratio and strength was noticed for ratios of 4 or less. For ratio (pin diameter to sheet thickness) of 8 and edge distances of 1.5 diameters or greater local buckling occurred, for ratios of 4 or less and for edge distances of 2 diameters the failures were characterized by shearing or crumbling. Bearing yield strength is not sensitive to ratios of pin diameter to

sheet thickness. While no stress-corrosion cracking was found in AM-3S, AM-C57S and AM-52S are susceptible to stress-corrosion cracking.

TN 898 ADAPTOR FOR MEASURING PRINCIPAL STRAINS WITH TUCKERMAN STRAIN GAGE, A. E. McPherson, National Bureau of Standards, June 1943

Common practice, common knowledge, or not applicable.

TN 899 COLUMN STRENGTH OF MAGNESIUM ALLOY AM-57S, Marshall Holt, NACA, 1943

Report summarizes a series of tests made on a magnesium alloy to develop an equation for column strength. It is concluded that the compressive properties should be used, not tensile, as compressive yield strengths were lower.

Material	Composition
AL	6.5%
Mn	0.2% Min.
Zn	0.8% Max.
Mg	Remainder

The material was furnished in the form of extruded angle (2-1/2 x 2-1/2 x 1/4 inch) in the extruded condition.

First the tensile and compressive properties of alloy were tested.

Tensile Strength	41 to 44 Kips/in^2.
Tensile Yield	28 to 31 Kips/in^2.
Compressive Yield	14 to 16 Kips/in^2.
Elongation	11 to 15%

Alloy was next tested for column. The equation was developed for column strength:

$$P/A = \frac{48000}{1. + 0.00075 \left(\frac{KL}{r}\right)^2}$$

P/A = ultimate load
L/r = slenderness ratio
K = end condition co-efficient (= 1.00 for round ends
= 0.50 for flat ends)

Conclusions:
1. Compressive yield strength = 3/4 tensile yield strength thus compressive properties should be used for column strength.

2. Compressive yield strength can be obtained from the stress-shortening curve determined by measuring the relative movement of the heads of the testing machine.

3. Tentative formula for column strengths of magnesium alloys subject to more testing on more alloys.

TN 900 EFFECT OF RIVET PITCH UPON THE FATIGUE STRENGTH OF SINGLE ROW RIVETED JOINTS OF 0.025 TO 0.025-INCH 24-ST ALCLAD, Victor Seliger, Lockheed Aircraft, July 1943

S-N curves at range ratio of 0.2 experimentally obtained for rivet pitch, P, as used in a single row lap joint of 0.025 to 0.025-inch 24S-T Alclad with one-eighth AN430 round head rivets; P = .5, 0.75, 1.0, 1.5.

1. Fatigue strength per rivet increases with increasing rivet pitch P at least to P = 1.5 in.

2. The greatest fatigue strength per linear inch of joint is obtained for values of P between 0.25 and 0.4 inches.

3. The effective peak stress increases with rivet pitch.

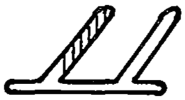
4. The effective stress concentration factor in fatigue varies inversely as the load.

5. For low stresses the possibility presents itself of predicting, on the basis of photoelastic analysis, the values of the effective stress concentration factor in fatigue.

6. The use of materials with high ratios of yield strength to ultimate strength may actually result in lower fatigue strengths. "Since tests have been started on joints of secondary heat treated materials, this point will be established in the very near future."

TN 901 BEARING STRENGTHS OF SOME WROUGHT-ALUMINUM ALLOYS, R. L. Moore and C. Wescoat, August 1943

(a) This note determined the bearing yield and ultimate strengths of the following aluminum alloys: 17S-T, 24S-T, Alclad 24S-T, 24S-RT, 52S-1/2H, 52S-T and 61S-T sheet; A51S-T and 14S-T forgings; 24S-T, 53S-T, and 61S-T extrusions.
(b) The sheets were 0.064 x 10 x 20 inches. Extrusions were obtained from die No. K-22934. The forgings were 1/4 x 3 x 12 inches machine to 1/8 in. thickness. The samples were tested in bearing, using a 0.250 in. diameter steel pin and a 40,000 lb. capacity Amsler machine, edge distance of 1.5, 2, and 4 times the pin diameter were used.



specimen

(c) Specimens with edge distances of 1.5 and 2 times the pin diameter failed by shear or tear-out, while those with 4 times the pin diameter by crushing.

TN 902 DESCRIPTION OF STRESS-STRAIN CURVES BY THREE PARAMETERS, Walter Ramberg and William R. Osgood, July 1943

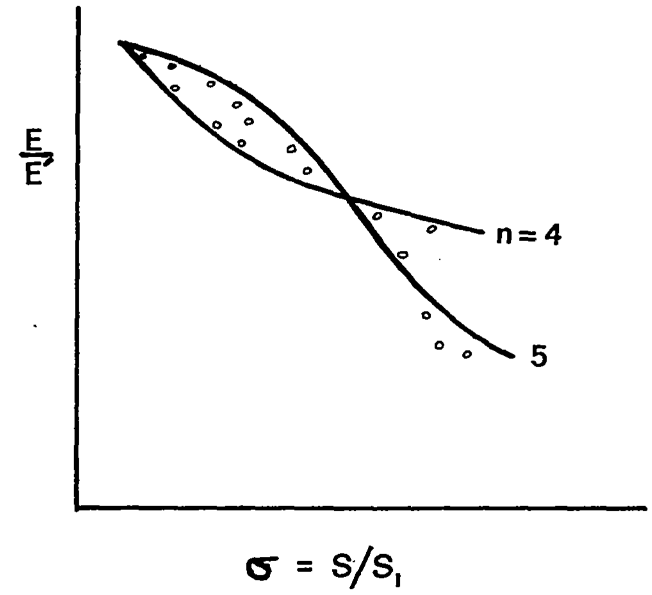
(a) This report formulates an equation that relates stress-strain using three parameters, Young's modulus and two secant strengths.
(b)

$$e = \frac{s}{E} + K\left(\frac{s}{E}\right)^n \qquad e_y\left(\frac{E}{s_y}\right)^n = K \qquad n = 1 + \frac{\log \frac{m_2}{m_1}\,\frac{1-m_1}{1-m_2}}{\log \frac{s_1}{s_2}}$$

$$\frac{1}{m_1} = 1 + \frac{0.002}{s_1/E} = 1 + \frac{0.002}{s_{0.2}/E} \quad \text{(0.002 comes from .2\% offset)}$$

K = constant
s_y = yield strength
m_1 = a chosen constant ($0 < m_1 < 1$) such that m_1E is a secant modulus.
m_2 = a second chosen constant as was m_1. It is chosen so that a shape parameter can be derived.
e = strain
s = stress
e_y = strain corresponding to yield strength s_y
s_p = proportional limit
n = constant

(c) There is good agreement between theory and experimental data. These experimental curves are in good agreement with tangent modulus stress curves.



TN 903 A METHOD FOR DETERMINING THE COLUMN CURVE FROM TESTS OF COLUMNS WITH EQUAL RESTRAINTS AGAINST ROTATION ON THE ENDS, Eugene E. Lundquist, Carl A. Rossman, and John C. Houbolt, August 1943

A curve is shown relating the fixity coefficient to the critical load, the length of the column, and the magnitude of the elastic restraint. The expression for the column curve for columns equally restrained against rotation at each end is:

$$\frac{P_{cr}L}{M} = -\pi\sqrt{c}\tan\left(\frac{\pi}{2}\sqrt{c}\right)$$

P_{cr} = critical buckling load
L = length
c = column fixity coefficient
M = restraint coefficient

c can be found by:

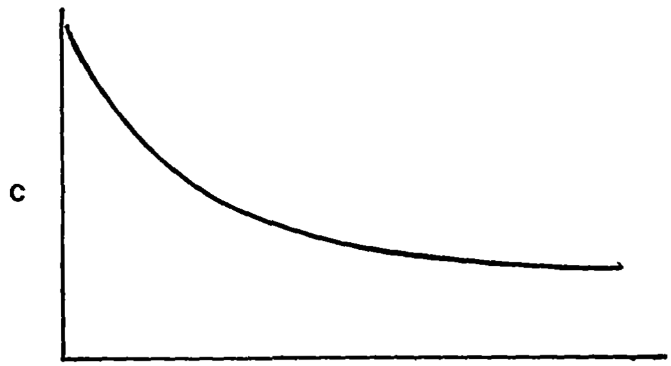
$$c = \frac{P_{cr}L^2}{\pi^2 EI}$$

Thus M can be found since P_{cr} and L can be found.

All equations come from:

Timoshenko, S.: Theory of Elastic Stability. McGraw-Hill Book Co., Inc., 1936.

A column is shown below:



$$\frac{P_{cr}L}{M} = -\pi\sqrt{c}\tan\left(\frac{\pi}{2}\sqrt{c}\right)$$

TN 904 THE STRENGTH OF THIN WALL CYLINDERS OF D CROSS SECTION IN COMBINED PURE BENDING AND TORSION, A. W. Sherwood, University of Maryland, September 1943

Test specimens formed by riveting together thin semi-cylindrical sheets of aluminum alloy to channels of the same thickness so that the web of the channel formed a diameter of the semi-cylinder. Tests made on specimens of 24S-T of thickness 0.0125" and 0.020", and varying lengths from 3 to 20 inches.

1. The average buckling stress in pure torsion of the tubes can be calculated by applying Donnell (Stability of Thin-Walled Tubes under Torsion. Report No. 479 by: L. H. Donnell); a formula to circumscribing circular cylinders of the same dimensions and material:

$$F_{st} = \frac{KE}{\left(\frac{D}{t}\right)^{5/4} \left(\frac{L}{D}\right)^{1/2}}$$

K = .90 for hinged ends
F_{st} = unit buckling stress
K = constant
D = diameter
L = length of cylinder
t = thickness of cylinder

2. The average buckling stress in pure bending can be computed with the formula:

$S_b = K_b E$

E = modulus of elasticity
S_b = unit bending stress at failure for cylinder subjected to bending alone
K_b = is given as a constant varying with L/r

3. The average buckling strength for D section cylinders subjected to combined torsion and pure bending can be represented by an equation of the formula:

$$R_B^2 + R_T^2 = 1$$

R_B is the ratio of the average bending stress at failure to the calculated stress in pure bending and R_T is the ratio of the average shearing stress at failure to the calculated shearing stress. The minimum strength in combined loading can practically be represented by the equation:

$$R_B^2 + R_T^2 = (0.88)^2$$

TN 905 SOME INVESTIGATIONS OF THE GENERAL INSTABILITY OF STIFFENED METAL
906 CYLINDERS, Guggenheim Aero. Lab. and Cal. Tech., July 1943-May
907 1947
908
909 This group of reports appears to be one of the first detailed
910 studies into the uses of the cylindrical design in aircraft
911 fuselage.
1197
1198 There are 72 references for the theory (many in German).

Tests were conducted on wire braced specimens, unstiffened circular cylinders, and stiffened circular cylinders. Both theoretical and experimental solutions are derived.

Discussion with Langley indicated:
One significant point about this report is that the stiffeners used were of <u>oval</u> and bar cross sectional shape. This shape of stiffener has been <u>abandoned</u> since this report was written. The theory is still considered to be important and the experimental data is correct for the work done.

Basically this information is valid and little NASA work has been done to supersede it, but more current information using C and Z-shape stringers is available in any of many publications of the last 10 years. (Like Kuhn.)

TN 912 A SUBPRESS FOR COMPRESSIVE TESTS, C. S. Aitchison and James A. Miller, National Bureau of Standards, December 1943

A subpress is described which was developed for investigating methods for testing thin sheet metal in compression. Provision was made for testing fixed-end and flat-end specimens with or without various types of lateral support against buckling.

Nothing particularly unique.

"The compressive tests made with the subpress gave very consistent results. Practically identical stress-strain curves were obtained by the pack method and by the single-thickness method for 0.032-inch aluminum alloy 24S-RT sheet."

Ref. TN 789 EXTENSION OF PACK METHOD FOR COMPRESSION TESTS.

TN 913 TENSILE AND COMPRESSIVE TESTS OF MAGNESIUM ALLOY J-1 SHEET, C. S. Aitchison and James A. Miller, Washington, 1943

Magnesium alloy J-1 sheet was tested for tensile and compressive strength in transverse and longitudinal direction. Specimen type described in Ref. 2 complies with Ref. 3. Tensile tested in manner described in Ref. 1. Compression tested in manner described in Ref. 5 and 4 except that middle specimen was 0.52 in. wide and the supporting specimens were 0.50 in. wide. Used Bostick cement, let dry overnight, then pressed together for 4-1/2 hours at 65°C. Pack ground to length = 3.24 in. Tuckerman 1 in. optical strain gages used. See Ref. 6. Stress-strain, stress-deviation, secant modulus-stress, tangent modulus-stress, nondimensional tangent modulus-stress, and reduced modulus-stress curves are given for 0.032 in. and 0.102 in. thick specimens.

Tensile Test	
Young's Modulus	6250 kip/in^2
Yield Strength	37 kip/in^2
Tensile Strength	46 kip/in^2
Elongation	6 to 13.5%
Compressive Test	
Young's Modulus	6520 kip/in^2
Yield Strength	
Longitudinal	24.5-27 kip/in^2
Transverse	28.5-30.2 kip/in^2

References:
1. Aitchison, C. S., and James A. Miller, Tensile and Pack Compressive Tests of Some Sheets of Aluminum Alloy 1025 Carbon Steel, and Chromium-Nickel Steel, T.N. 840, NACA, 1940.

2. Anon.: General Specifications for Inspection of Metals, Federal Specification QQ-M-151a, Federal Standard Stock Catalogue, Sec. 4, Pt. 5, November 27, 1936.

3. Anon: Tentative Methods of Tension Testing of Metallic Materials, 1940 Supplement to ASTM Standards, Pt. 1, Metals. (E 8-40T). ASTN (Philadelphia) p. 453-463.

4. Aitchison, C. S., and James A. Miller: A Subpress for Compressive Tests. TN 912, NACA, 1943.

5. Aitchison, C. S., and L. B. Tuckerman: The Pack Method for Compressive Tests of Thin Materials Used in Thin Wall Structures. Rep. No. 649, NACA, 1939.

6. Aitchison, C. S.: Extension of the Pack Method for Compression Testing. TN 789, NACA, 1940.

TN 914. CERTAIN MECHANICAL STRENGTH PROPERTIES OF ALUMINUM ALLOYS 25S-T and X76S-T, Thomas J. Dolan, October 1943

(a) The information in this report is believed to be general knowledge and should be available in any good handbook.

TN 916 THE EFFECT OF THE TYPE OF SPECIMEN ON THE SHEAR STRENGTHS OF DRIVEN RIVETS, W. H. Sharp, Alcoa, November 1943

Tests of various types of riveted joint composed of 24S-T and 1/8-inch A17ST rivets have been made in order to determine the effects of specimen type in shear strengths.

The results indicated that there was only slight variations in shear strength with considerable variation in the types of specimen. Lap joints gave a shear strength about 2% greater than joints with a single-butt strap and about 4% greater than double-shear or double-butt strap joints. Joints in which a single rivet resists the shearing forces gave about 0.5% greater shear strengths than joints with two or more rivets. The double-shear joints generally resisted deformations better than other types of joints.

TN 917 THE EFFECT OF SURFACE FINISH ON THE FATIGUE PERFORMANCE OF CERTAIN PROPELLER MATERIALS, H. W. Russell, H. W. Gillett, L. R. Jackson and G. M. Foley, Battelle Memorial Institute, December 1943

Effect of various surface finishes on endurance of normalized X4130 and 4140 steels and 25S-T aluminum alloy investigated. Found that the smoothness of the surface of a fatigue specimen was of less importance than other properties of the surface. All mechanically formed surfaces tested were stronger than electropolished surfaces. It is concluded that a smooth electropolished surface is an unstrengthened one. For this reason,

Type Joint	Sketch		Max Load (lb)	Shear Strength (lb/sq in.)
Lap joint with single rivet		Average of 4 tests	474.5	36,500
Lap joint with two rivets in line		Average of 4 tests	942.5	36,250
Lap joint with three rivets in line		Average of 4 tests	1417.5	36,325
Single-butt-strap joint with 2 rivets		Average of 4 tests	459.0	35,275
Single-butt-strap joint with 4 rivets		Average of 4 tests	915.0	35,200
Single-butt-strap joint with 6 rivets		Average of 4 tests	1389.0	35,625
Single-butt-strap joint with 4 rivets, 2 rows		Average of 4 tests	916.0	35,250
Single-butt-strap joint with 8 rivets, 2 rows		Average of 4 tests	1871.0	36,025
Double-butt-strap joint with 2 rivets		Average of 4 tests	910.0	35,000
Double-butt-strap joint with 4 rivets		Average of 4 tests	1816.0	34,925

removal of damaged surface by electropolishing is not so effective as mechanical methods of removal in prolonging fatigue life, because mechanical removal also strengthens the surface while electropolishing does not.

Aerodynamics of these surfaces are not mentioned.

TN 918 THE STABILITY OF ISOTROPIC OR ORTHOTROPIC CYLINDERS OR FLAT OR CURVED PANELS, BETWEEN AND ACROSS STIFFENERS, WITH ANY EDGE CONDITIONS BETWEEN HINGED AND FIXED, UNDER ANY COMBINATION OF COMPRESSION AND SHEAR, L. H. Donnell, Chance Vought Aircraft, December 1943

A detailed discussion of the processes in theory. The material discussed is derived from the references listed which are believed to be readily available.

1. ANC Handbook on the Design of Wood Aircraft Structures, ANC Committee on Aircraft Design Criteria. July 1942.

2. March, H. W.: Buckling of Flat Plywood Plates in Compression, Shear, or Combined Compression and Shear. Mimeo. No. 1316, Forest Products Lab., April 1942.

3. von Karman, Theodore, Earnest E. Sechler, and L. H. Donnell: The Strength of Thin Plates in Compression. Trans. A.S.M.E., vol. 54, 1931, pp. 53-57.

4. Timoshenko, S.: Strength of Materials, D. Van Nostrand Co., 2nd ed., 1941.

5. Donnell, L. H.: Stability of Thin Walled Tubes under Torsion. Rep. No. 479, NACA, 1933.

6. Donnell, L. H.: The Problem of Elastic Stability, A.S.M.E. Trans., Aero. Div., 1933.

7. von Karman, Theodore, and H. S. Tsien: The Buckling of Cylindrical Shells under Axial Compression. Jou. Aero. Sci., June 1941, pp. 303-312.

8. Sechler, Earnest E. and Louis G. Dunn: Airplane Structural Analysis and Design. John Wiley and Sons, Inc., 1942.

9. Dunn, Louis G.: An Investigation of Sheet Stiffener Panels Subjected to Compression Loads with Particular Reference to Torsionally Weak Stiffeners. T.N. # 752, NACA, 1940.

TN 920 BEARING STRENGTHS OF BARE AND ALCLAD XA75S-T AND 24S-T81 ALUMINUM ALLOY SHEET, R. L. Moore and C. Wescoat, December 1943

(a) This note was a continuation of note 901 and gives the bearing yield and ultimate strengths of XA75S-T and 24S-T81 in bare and Alclad sheet.
(b) Single thicknesses of 0.064-inch sheet, 2 inches wide, cut parallel to the direction of rolling, in bearing on a 0.250 inch diameter steel pin were tested. Tests were made in triplicate for edge distances of 1.5, 2, and 4 times the pin diameter.

TN 921 REQUIREMENTS FOR AUXILIARY STIFFENERS ATTACHED TO PANELS UNDER COMBINED COMPRESSION AND SHEAR, Merit Scott and Robert L. Weber, Penn. State College, December 1943

Panels of aluminum alloy sheets, framed by side and end stiffeners were subjected to combined loading by means of offset knife edges applying loads to top and bottom end plates with reacting forces against the end plates supplied by laterally acting rollers.

Specimens were 17S-T aluminum alloy sheet 0.040 inch thick, 10 inches wide and three lengths (10, 20 and 30 inches).

Experimental values exceed the theoretical values given by Timoshenko for the case of simply supported sheets with uniformly distributed boundary stresses. In all cases the experimental ribs were mounted upon only one side of the sheet. However, the ribs may not have bent with the neutral axis in the plane of the sheet, to offer a maximum moment of inertia, as is assumed by Timoshenko.

The experimental values of the effective shear modulus of the panels are in as good agreement as could be expected with the values published by Lahde and Wagner.

References:
Timoshenko, S.: Theory of Elastic Stability. McGraw-Hill, 1936.

Lahde, R., and H. Wagner: Tests for the Determination of the Stress Condition in Tension Fields. T.N. # 809, NACA, 1936.

TN 922 OVALIZATION OF TUBES UNDER BENDING AND COMPRESSION, L. J. Demer and E. S. Kavanaugh, University of Notre Dame, March 1944

An empirical equation developed that gives approximate amount of ovalization for tubes under bending loads. Investigation proposed because cantilever landing struts on large planes fail to telescope properly when subjected to side loads.

Tests done on tubes with D/t range from 5 to 14. Latter d/t ratio is in the normal landing gear range.

Inside diameter constant at 3.225". O.D. at 4.610, 4.375, 4.251, 3.929, and 3.650 inches. SAE X-4130 tube.

Tests used compression loads in combination with bending. Compression loads created no noticable change in ovalization even though the additional bending moment caused by the eccentric compression load would seem to indicate that the ovalization should increase.

Maximum compression used - 11,500 lbs. with a 6,000 pound bending load. These test made on tubes with smallest wall thickness. Since compression proved to have little effect, it was omitted in further tests.

Much data supports the equation which follows:

M = cantilever bending moment, in-pounds
D = outside diameter of tube, inches
t = wall thickness of tube, inches
w = ovalization, inches
L = cantilever length of tube, inches
J = distance between opposite bearing faces, inches
a = constant of the material and dimensions
b = slope of curve of ovalization versus bending.

$$w = \frac{a\ M_4^b}{10^4} \qquad \log w = \log a + b \log M - 4.0$$

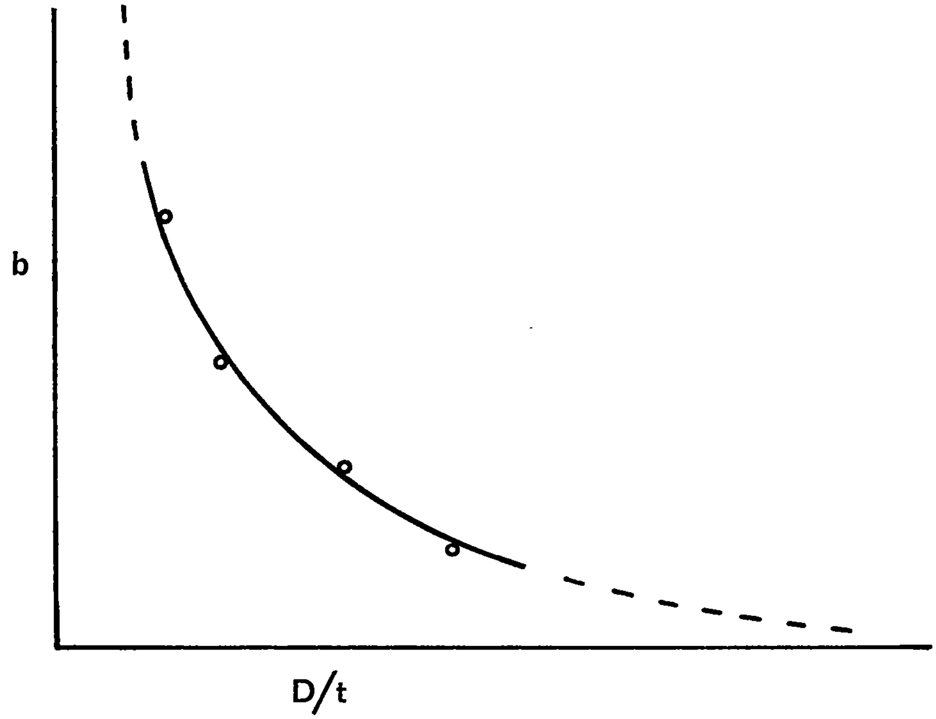
Usable equation: $\log w = -\ 10^{\left(0.10 + s \frac{J}{D/t}\right)} + b \log M - 4.0$

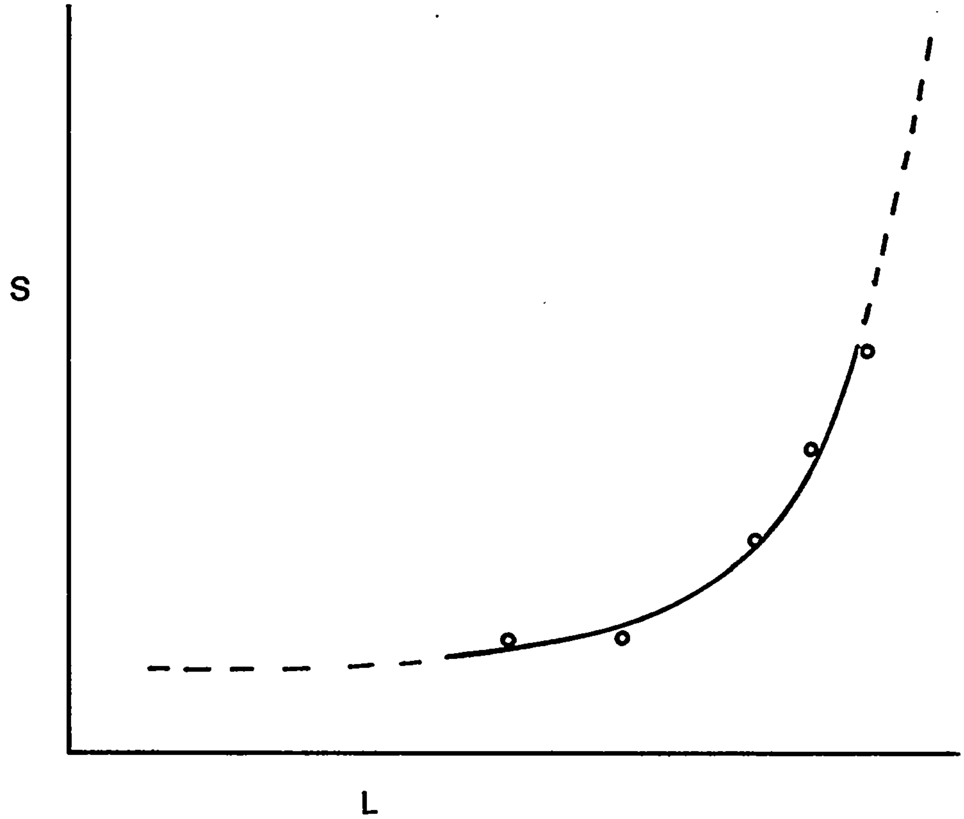
Where: $\log (10s) = 0.000343\ (\log L)^{14.1920}$

$$b = \frac{\log (D/t) - 1.143}{3.060 - 5.90 \log (D/t)} + 0.75$$

Plot can be made of b and s to make their values readily available for use in the equation defining w.

b and s plots to follow.


b
D/t


S
L

TN 924 ELASTIC PROPERTIES OF CHANNELS WITH UNFLANGED LIGHTENING HOLES, Alfred S. Niles, March 1944

(a) The purpose of this report was to determine the influence of plain round holes in the web of a channel on:

1. Stiffness against bending produced by forces parallel to the principal axis of the cross sections.
2. Stiffness against torsional deformation.
3. The location of the resultant axial compression compatible with zero transverse deflection.
4. The position of the shear center of the cross section.

(b) It was found that the position of the centroidal axis parallel to the back of a channel lightened by unflanged holes and the moment of inertia about that axis could be computed by decreasing the width of the back by:

$$\left(0.2 + 1.5\,\frac{D^2}{Pb}\right) D$$

D = diameter of the holes
P = pitch of the holes
b = distance between midlines of channel flanges

The moment of inertia obtained from the above may be used for the practical estimation of deflections, or critical loads according to Euler formula.

In computing the effective stiffness about the axis of symmetry of a channel with unflanged holes, the effect of the holes maybe disregarded for most purposes. For conservative figures the cross section may be reduced as much as $tD^3/12$, where t is the thickness of the material. The deflections due to loads parallel to the back of the channel may be calculated from:

$$\delta_s = \int \frac{s\ V\ dx}{K\ b\ t\ G}$$

s = shear on a section due to a unit loading at the point for which the deflection is being calculated.
V = total shear on section
K = $0.5 - D^2/Pb$
D = diameter of holes
P = pitch of holes
b = distance between centerline of holes
t = thickness of material
G = shearing modulus of elasticity
δ_s = deflection due to shear deformation

TN 927 DETERMINATION OF STRESS-STRAIN RELATIONS FROM OFFSET YIELD STRENGTH VALUES, H. N. Hill, NACA, 1944

Report develops a method for defining a mathematical relation between stress and strain from Young's modulus and 2 values of offset yield strength corresponding to offsets of .001 and .002. From an equation from Rambert and Osgood ("Description of Stress-Strain Curves by 3 Parameters," TN 902, NACA, 1943).

$$e = \frac{S}{E} + K\left(\frac{S}{E}\right)^n$$

e = unit strain
S = unit stress
K & n = constants for the curve

S_1 = yield strength at offset $d_1 = 0.001$

S_2 = yield strength at offset $d_2 = 0.002$

One gets:

$$n = \frac{0.301}{\log\left(S_2/S_1\right)} \qquad (2) \quad K = \frac{.002}{(S_2/E)^n} = \frac{.001}{(S_1/E)^n}$$

One can also relate stress to effective modulus

$$\frac{S}{E_t} = \frac{S}{E} + 0.002n\left(\frac{S}{S_2}\right)^h$$

E_t = tangent modulus

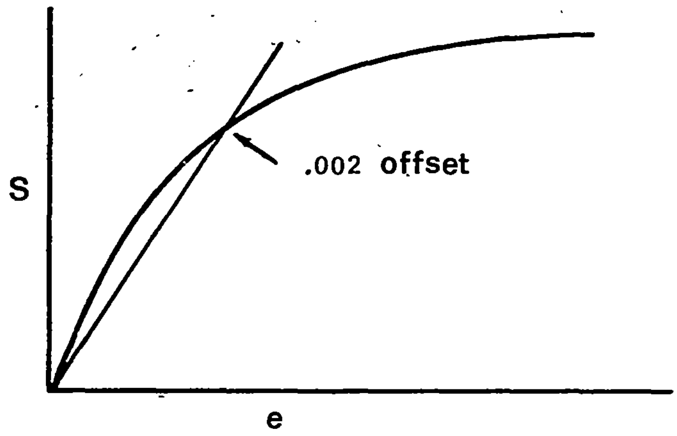
From Timoshenko, Theory of Elastic Stability, McGraw-Hill Book Co., Inc., p. 156, 384.

From the stress-strain curve defined by Equation 1, one can predict behavior of the material into the plastic region, which cannot be done knowing only Young's modulus and yield strength.

Equation 1 becomes

$$e = \frac{S}{E} + 0.002\left(\frac{S}{S_2}\right)^h$$

From this equation stress-strain curve can be plotted, knowing E and 2 yield strengths, from .001 and .002 offsets. Note that although 2 alloys with same E behave same in elastic region, behavior may diverge in plastic region.



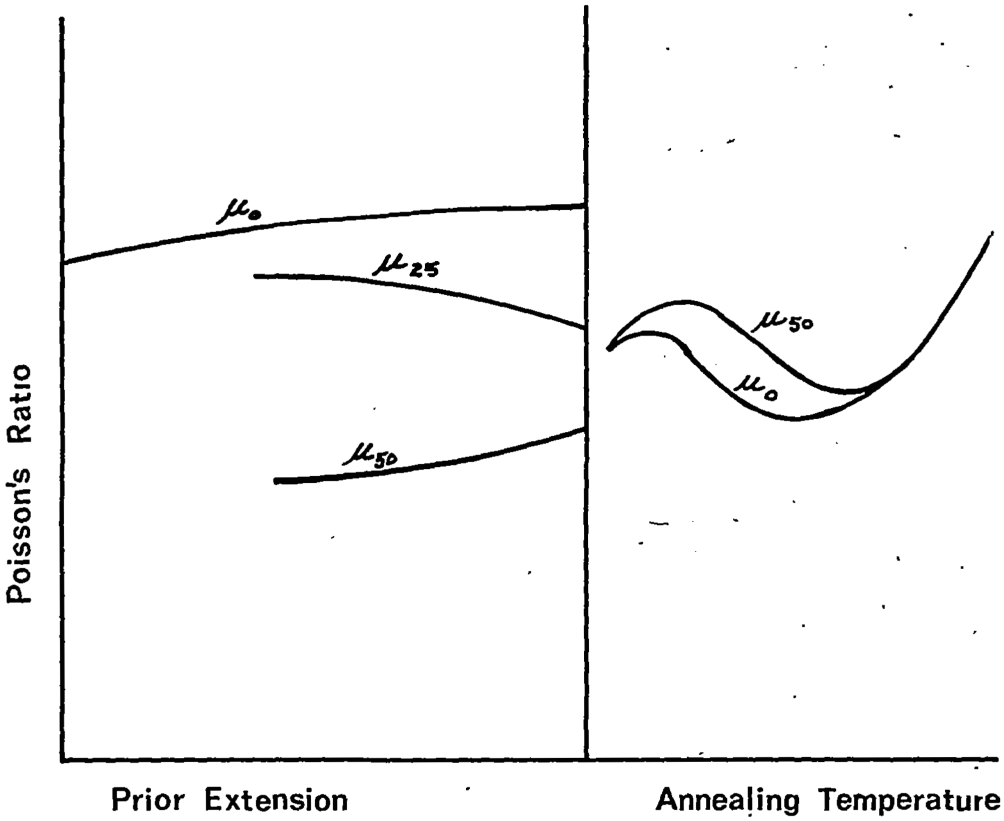
TN 928 THE INFLUENCE OF PLASTIC DEFORMATION AND OF HEAT TREATMENT ON POISSON'S RATIO FOR 18:8 CHROMIUM-NICKEL STEEL, R. W. Mebs and D. J. McAdam, Jr., February 1944

(a) The value of Poisson's ratio for 18:8 Cr-Ni steel was computed from values of tensile and torsional modui of elasticity obtained from earlier investigations (TN 818 and 886) by use of an appropriate formula.

$$u = \frac{E}{2G} - 1$$

u = Poisson's ratio
E = secant tension
G = shear moduli

(b) Poisson's ratio at zero stress, u_o, increased from 0.32 to 0.40 with prior extension, of the annealed metal, of between 12 and 20 percent. u_{25} and u_{50} show very little change, suggesting that the elastic anisotropy produced by the extension of the metal becomes less evident upon application of a moderate stress. The rise in u_o was caused by a rise in E_o upon the extension of the metal. During heat treatment u_o and u_{50} stay between 0.21 and 0.22 from 100°F. to 1000°F.; at higher temperatures u_o increases to 0.31 at 1800°F. The rise in u_o is caused chiefly by the removal of preferred orientation that takes place during recrystallization.



TN 929 ANALYSIS OF CIRCULAR SHELL SUPPORTED FRAMES, J. E. Wignot, Henry Combs and A. F. Ensrud, May 1944

In the past it was frequently assumed that the ring is very stiff and remains circular throughout the load process, and that VQ/I and T/2A are shear flow distribution. For small diameter shells with rings, the assumption is satisfactory for design purpose. As the size of aircraft increase the rings become relatively more flexible so that the assumption of infinite ring stiffness may lead to a large error. In order to obtain results more nearly representing the actual aero shells, it is essential that the deformation of the frame and deformation of the shell be consistent with each other.

This paper deals with the single problem of circular shell supported by frames subjected to concentrated loadings. A mathematical method is developed and presented in the form of non-dimensional coefficient curves. These curves may be used for nearly any practical frame which has curvature in the region of applied loading. The bending moment, axial load and transverse shear in a ring, and the corresponding shear flow acting on the ring from the supporting shell may be readily obtained from these curves by proper interpolation and superposition.

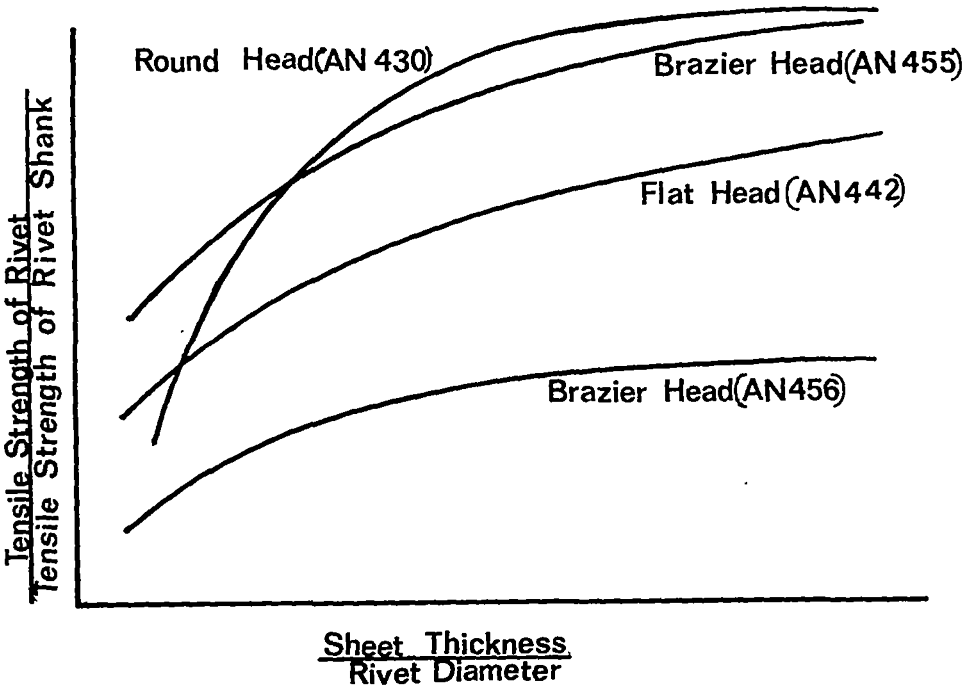
In later reports the method is extended to more general applications of fuselage frame analysis.

TN 930 TENSILE TESTS OF ROUND-HEAD, FLAT-HEAD, AND BRAZIER-HEAD RIVETS, Evan H. Schuette, Leonard M. Bartone and Merven W. Mandel, Langley Memorial Aero. Lab., Langley Field, Va., 1944

A determination of the tensile strength of round-head (AN430), flat-head (AN442), and brazier-head (AN455 and AN456) aluminum alloy rivets is made.

1. When the ratio of the sheet thickness to the rivet diameter was greater than 0.5, the round-head (AN430) rivets developed the full tensile strength of the rivet shank, the brazier-head (AN455) rivets carried only slightly less load than the round-head rivets, and the flat-head (AN422) and brazier-head (AN456) rivets failed at loads approximately nine-tenths and seven-tenths, respectively, of loads at which the round-head rivets failed.

2. The tensile strength of all four types of rivets decreased in thinner sheet; the strength of the round-head rivets decreased more than that of the other rivets, probably because of the greater tendency of the small-diameter heads to tear through the sheet.



TN 931 GUIDES FOR PREVENTING BUCKLING IN AXIAL FATIGUE TESTS OF THIN SHEET METAL SPECIMENS, C. C. Brueggeman and M.Mayer, Jr., National Bureau of Standards, April 1944

Guide fixtures are described by means of which axial fatigue loads may be applied to thin sheet-metal specimens.

Further mention not applicable.

TN 934 NUMERICAL PROCEDURES FOR THE CALCULATION OF THE STRESSES IN MONOCOQUES I-DIFFUSION OF TENSILE STRINGER LOADS IN PANELS, N. J. Hoff, Robert S. Levy and Joseph Kempner, June 1944

(a) The purpose of TN 934 was to find an numerical method for computing the stresses in monocoques. A step-by-step approximation is used to determine the stress distribution in a structure under specific loads. In each step the state of distortion of the structure is arbitrarily modified and the stresses are calculated. The procedure must be continued until the internal stresses balance the external loads.
(b) The two equations used in the analysis are:

Stress in vertical bar between points M and N

$$\sigma = (V_N - V_M)\ E/L_{MN}$$

Shear stress on sheet between adjacent verticals P and Q

$$\tau = (V_Q - V_P)\ G/b$$

b = distance between verticals
V_A = vertical displacement at point A
E = modulus of elasticity
G = shear modulus of elasticity
L_{MN} = distance between points M and N
(c) The stresses were measured experimentally and good results were obtained. The convergence of successive approximation procedure was rapid.

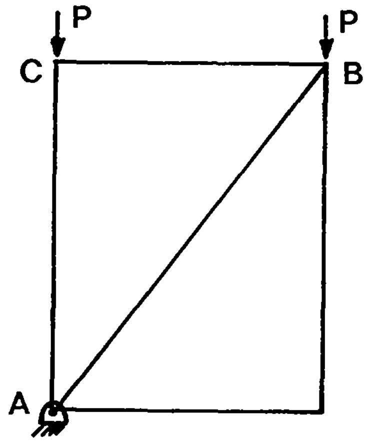
TN 937 SIMPLIFIED TRUSS STABILITY CRITERIA, W. B. Ballhaus and A. S. Niles, July 1944

The purpose was to develop a simple and practical method for predicting the critical intensity of loading for a pin-connected planar truss, also a simple procedure for the design of zero or lightly loaded members is considered.

This method uses the method of virtual work by applying unit loads and unit couples. The criterion for stability of an individual member is: If the rotation of a member due to actual loads is less than its rotation due the unit couple, that member is in stable equilibrium; while if the rotation due to actual loads exceeds its rotation due to a unit couple, that member is in unstable equilibrium. In a staticly determinate truss if any member is in unstable equilibrium, the whole truss is unstable. (The method of unit loads and couples is found in Bruhn.) The above method is that of Viscovich, but it is inadequate in the respect that the results vary depending on how the unit couples are applied. A better method (an extinction of Viscovich) is explained below.

This simplified method consist of isolating and analyzing small portions of the truss. An example illustrating the method will be shown. The purpose is to determine the minimum size that a member can have and the structure will be stable. This involves assuming rigid support for the pins at which the isolated portion is attached to the remainder of the structure.

Consider the following truss:



Here member AB is subjected to an axial compression P_{ab}.

The minimum allowable size for the sectional area of BC is found to be:

$$A_{bc} = \frac{2P_{ab}}{E_{bc}} \eta$$

Where P_{ab} = external load

E_{bc} = modulus of elasticity of member

$\eta = L_{bc}/L_{ab}$
L = original length

TN 938 THE INWARD BULGE TYPE BUCKLING OF MONOCOQUE CYLINDERS I - CALCULATION OF THE EFFECT UPON THE BUCKLING STRESS OF A COMPRESSIBLE FORCE, A NONLINEAR DIRECT STRESS DISTRIBUTION, AND A SHEAR FORCE, N. J. Hoff and Bertram Klein, October 1944

The inward bulge type buckling of monocoque cylinders the buckling load in combined bending and compression is derived. Next the reduction in the buckling load because of a nonlinear direct stress distribution is determined. In experiments nonlinearity may result from an inadequate stiffness of the end attachments.

The total load carried by the most highly compressed stringer, together with its effective width of sheet, in a circular monocoque cylinder loaded simultaneously in bending and compression can be written in the form

$$P_{cr\ tot} = n^2 \sqrt{\frac{d}{L_1}}\ \frac{\pi^2 \sqrt{E_{str} I_{str} E_r I_r}}{r^2} - \frac{0.9}{n^2}\ \nu\ d$$

TN 939 THE INWARD BULGE TYPE BUCKLING OF MONOCOQUE CYLINDERS II - EXPERIMENTAL INVESTIGATION OF THE BUCKLING IN COMBINED BENDING AND COMPRESSION, N. J. Hoff, S. J. Fuchs and Adam J. Cirillo, October 1944

This paper is the second part of a series of reports on the inward bulge type buckling of monocoque cylinders. It was found that the theory developed in part I of the present series predicts the buckling load in combined bending and compression with the same degree of accuracy as the older theory does in pure bending. In the realm covered by the experiments no systematic variation of the parameter n was observed. The analysis of the test results afforded a check on the theories of buckling of a curved panel. The agreement between experiment and theory was reasonably good. In addition, the effect of the end conditions upon the stress distribution under loads and upon initial stresses was investigated.

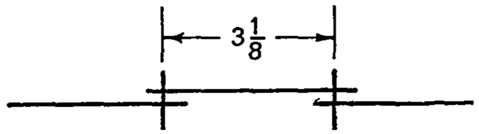
The experimentally established strains in the most highly compressed stringer at buckling are consistent with the values obtained from the theoretical relationship:

$$\varepsilon_{cr} = n^2 \sqrt{\frac{d}{L_1}}\ \frac{\pi^2}{A_{str}}\ \frac{\sqrt{I_{str} I_r}}{r^2} - \frac{(0.9/n^2)\ \nu d}{A_{str} E}$$

TN 942 THE SHEAR STRENGTH OF ALUMINUM ALLOY DRIVEN RIVETS AS AFFECTED BY INCREASING DIAMETER THICKNESS RATIOS, E. C. Hartmann and C. Wescoat, Alcoa, July 1944

This is a report on single shear of rivets. Occassional mention is given to the "previous report" concerning double shear conducted at Aluminum Research Laboratories in 1942. The report also includes the results of the previous investigation on double shear joints.

All specimens were button-head aluminum alloy rivets 1/2 inch in diameter. Rivet alloys 53S-0, 53S-T61, 53S-T, and 17S-T were used. 17S-T rivets driven immediately after quenching. Others driven in tempered condition. 24S-T alloy plate and sheet were used in thicknesses of 1/2, 3/8, 1/4, 3/16, 1/8, 0.081, and 0.064 inch. Test panels were single-butt-strap 2-3/8 inches wide with 3-1/8 inch between rivet centerlines, like so:



With a seemingly small amount of data, the author proposes new, linear, relationship to relate the data. Ratios of shear strength to basic shear strength are used as ordinates and ratios of bearing stress to basic shear strength as abscissas, thus providing the non-dimensional plot.

Basic shear strength here is the shear strength obtained when the ratio of rivet diameter D to plate thickness t is unity (D/t = 1).

The data shows that the ratio of shear strength to basic shear strength reduces at nearly the same rate regardless of rivet alloys.

NOTE: Throughout this discussion, only protruding-head rivets are under consideration and the proposed rules are not intended to apply to countersunk rivets.

"Through the use of simple straight-line formulas the shear strength of protruding-head aluminum alloy rivets driven in aluminum alloy plate can be readily predicted for various plate or sheet thicknesses as follows:

Single Shear

For values of D/t up to 3, single shear strength = basic allowable single shear strength.

For values of D/t greater than 3, single shear strength = basic allowable single shear strength X [1-0.04(D/t-3)].

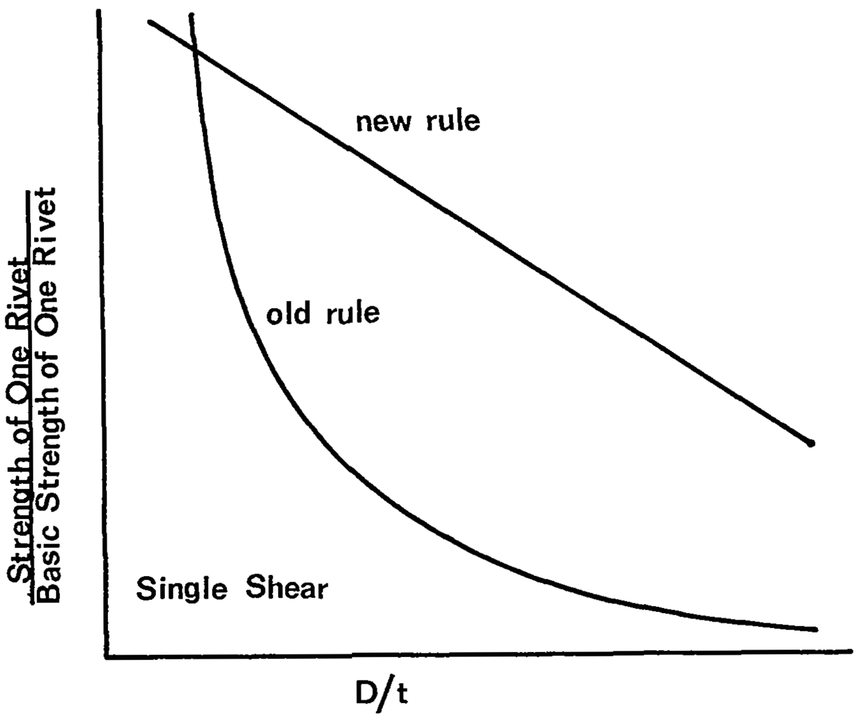
Double Shear

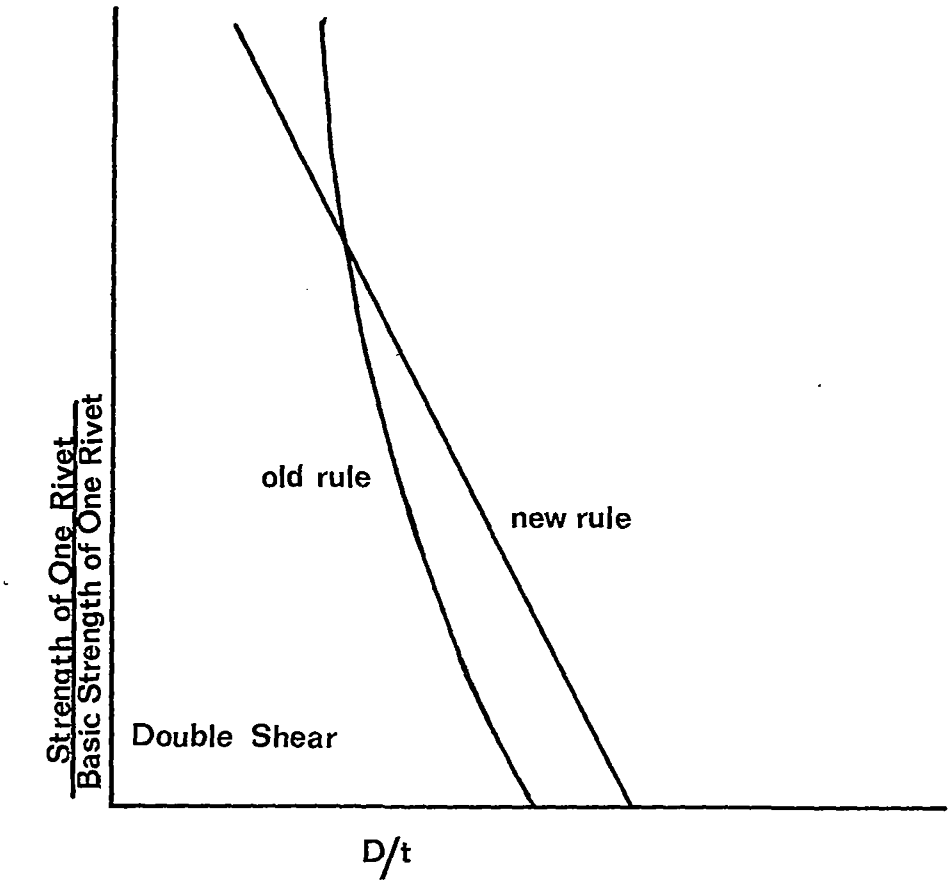
For values of D/t up to 1.5, double shear strength = basic allowable double shear strength.

For values of D/t greater than 1.5, double shear strength = basic allowable double shear strength X [1-0.13(D/t-1.5)].

D = nominal diameter of rivet, inches.
t = thickness of plate, inches.
(See graph below.)

In one group of specimens with 53S-T61 rivets, a study was made of the effect of varying the thickness of the strap plate while holding the thickness of the main plate constant. It was evident that there was practically no difference in the results whether the main plate is the same thickness as the strap plate or whether it is thicker than the strap plate."





TN 943 NORMAL PRESSURE TESTS ON UNSTIFFENED FLAT PLATES, Richard M. Head and Ernest E. Sechler, California Institute of Technology, September 1944

Flat sheets of aluminum alloy 17S-T tested under normal pressures with clamped edge supports. Thicknesses ranged from 0.010 to 0.080 inch. Pressure ranged from 0 to 60 lb.

Deflections were measured and maximum tensile strains in the center of the panels were determined by electric strain gages.

Results compared with corresponding strains and deflections as calculated by the simple membrane theory and by large deflection theories.

Plates were chosen so as to have dimensions approximating the larger plates on aircraft structures (since larger plates usually give more trouble) and the pressure used ranged from pressures found in pressurized cabins and extended on up into the range of pressures that might be encountered in fuel tanks and hull bottoms.

Experiment was executed using a pressure tight welded steel box.

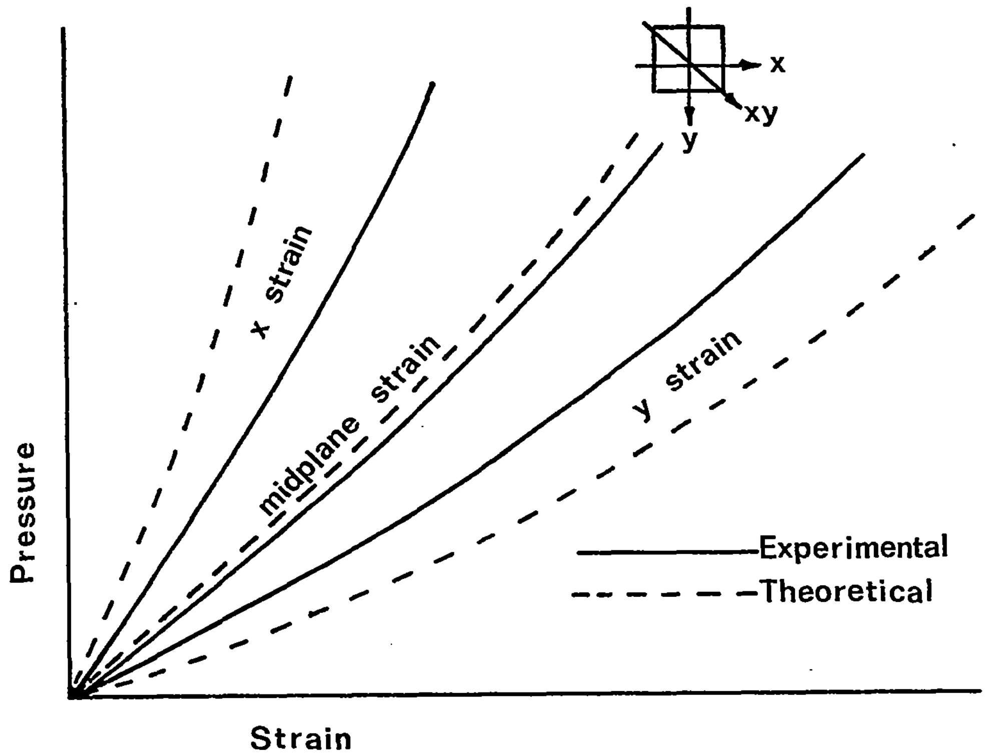
The clamped plates were 10 x 10 in., 10 x 20 in., 10 x 30 in., and 10 x 40 in. giving ratios of 1, 2, 3, and 4. (a = short side; b = long side).

Strain gages were mounted at the center of the plate parallel, perpendicular and at a 45° angle to the long side. A great deal of data was taken to support the comparisons resulting. Plots were made relating strain to the pressure applied for each sheet thickness. Both theoretical and experimental lines were drawn for each of the three directions of the strain gages.

In all instances, the strain was greatest in the direction perpendicular to the long side.

In all instances, the theoretical value for strain at a given pressure was slightly greater than the experimental value.

For design purposes, a plate would have to be designed to withstand the strain in the perpendicular direction (perpendicular to the long side). Since, in all cases, the theoretical value left a margin of safety (sometimes only slight) this value could be used as the maximum strain. An example graph follows.



TN 944 EFFECT OF CURVATURE ON THE STRENGTH OF AXIALLY LOADED SHEET-STRINGER PANELS, Walter Ramberg, Samuel Levy and Kenneth L. Fienup, NACA, 1944

Compressive tests were made on each of 21 24S-T panels 12 in. long and 16 in. wide reinforced by 4 Z stringers spaced 4 in. apart. Radii of curvature ranged from 19 in. to infinity; sheet thickness from 0.025 in. to 0.190 in.; rivet spacing from 0.5 in. to 2 in.

Curvature increased strain for buckling between stringers up to 5.35 times. Critical strain for panels with heavy sheet within a range of b^2/Rt (b = stringer spacing) up to 6.4 agreed with a formula by Leggett (The Buckling of a Long Curved Panel Under Axial Compression, R & M No. 1899, British A.R.C., 1942) for simple support. Critical strain for panels with thin sheet agreed with a formula by Leggett for clamped support.

Panels of intermediate thickness for $b^2/Rt < 16$ buckled at strains given by Wenzek's formula (NACA TM #880, 1938). Strengths of panels agreed with nomogram given by NACA TN 856.

TN 945 NONDESTRUCTIVE TEST METHODS FOR SPOT WELDS IN ALUMINUM ALLOYS, R. C. McMaster, J. F. Manildi and C. C. Woolsey, California Institute of Technology, November 1944

Purpose: Investigate proposed nondestructive tests methods to determine the feasibility of such tests, and to recommend those research methods found suitable for development and reduction to practical application.

The most promising nondestructive method was radiography. It is not necessary to locate the weld nugget accurately in order to measure the diameter, or to detect the presence of cracks, porosity, and spitting.

The most reliable nonradiographic test was the ring-penetrator or profile penetrator test which can measure weld nugget diameter reliably under normal conditions or production welding. It does not measure the nature or extent of cracking, porosity, and spitting, except insofar as these defects change the penetration of the loaded test penetrator.

The ring electrode two side direct current test measures the bonded area at the faying plane of the spot weld, but does not discriminate between nugget and Alclad corona bonding. In conjunction with the ring-penetrator test, it provides a good measure of the strength of production spot welds.

Neither the electrical nor the penetrator test is capable of determining the extent of the Alclad inclusion into the weld nugget at the faying plane, or the decrease in weld strength resulting from this cause.

For the measurement of extent of cracking and porosity without the use of X-rays the eddy-current test offers the advantages of a direct and reliable measurement subject to some error due to indentations of the sheet surface.

TN 948 ARTIFICIAL AGING OF RIVETED JOINTS MADE IN ALCLAD 24S-T SHEET USING A17S-T, 17S-T, AND 24-T RIVETS, A. N. Zamboly, September 1944

(a) The object of this investigation was to study the effect of artificial aging on the shear strength of joints prepared from Alclad 24S-T sheet using A17S-T, 17S-T, and 24-T rivets.
(b) The effect of the artificial aging treatment on the rivets was measured by the changes produced in the shear strength of the rivets.
(c) The change in shear strength resulting from the artificial aging treatment of 10 hours at 475°F. applied to the driven rivets is as follows:

24S-T rivets increased 6%.

17S-T rivets driven refrigerated showed no change.

17S-T rivets driven in the full T temper decreased about 8%.

A17S-T rivets decreased about 10% in strength.

17S-T rivets driven in the full temper is higher than that of 17S-T rivets driven refrigerated whether aged or not.

Rivet Alloy	Average Shear Strength (psi)
A17S-T	30,500
17S-T refrigerated	36,900
17S-T	38,000
24S-T refrigerated	46,900

TN 949 SIMPLY SUPPORTED LONG RECTANGULAR PLATE UNDER COMBINED AXIAL LOAD AND NORMAL PRESSURE, Samuel Levy, Daniel Goldenberg, and George Zibritosky, National Bureau of Standards, October 1944

The sheet in airplane wings, fuselages, and hull bottoms constructed of sheet metal reinforced by stringers frequently is subjected to normal pressure as well as forces in the plane of the sheet. It is important, therefore to determine the effect of normal pressure on the load-strain curve of a long rectangular plate which approximates the sheet between stringers.

The buckling load is considerably increased by normal pressure. For the highest pressure considered, the theoretical buckling load is 3.1 times the buckling load for zero normal pressure. Normal pressure causes a decrease in effective width at strains below the normal buckling strain and an increase in effective width for strains somewhat greater than the normal buckling strain. If the buckling load is considerably exceeded, however, normal pressure causes less than 1% increase in effective width. For some combinations of normal pressure and axial load the sheet can be in equilibrium in more than one position. Under such circumstances it is possible for the sheet to be either unbuckled or buckled, depending on the previous history of loading.

The results indicate that a conservative design in the elastic range can be obtained by neglecting the effect of lateral pressure on the buckling load of the sheet and on the load carried by the sheet after buckling.

TN 950 NUMERICAL PROCEDURE FOR THE CALCULATION OF THE STRESSES IN MONOCOQUES II - DIFFUSION OF TENSILE STRINGERS LOADS IN REINFORCED FLAT PANELS WITH CUTOUTS, N. J. Hoff and Joseph Kempner, November 1944

(a) This report followed the same procedure as TN 934. An indirect approximation method was used. Members of the structure were distorted until the internal stresses balanced the external loads.
(b) The same steps were followed as in TN 934 except for:

The stresses were calculated as if the structure were complete, and these values were used as the first approximations when the effective area of the structure with cutouts was used.

(c) This procedure is limited to cases where the end points of the reinforced strips are free to move, and where the cutout is not disproportionately large.

TN 951 TESTS ON THIN-WALLED CELLULOID CYLINDERS TO DETERMINE THE INTERACTION CURVES UNDER COMBINED BENDING, TORSION, AND COMPRESSION OR TENSION LOADS, Elmer F. Bruhn, Purdue University, January 1945

This material is included in one of his publications after 1945.

TN 953 TORSION TEST TO FAILURE OF A MONOCOQUE BOX, A. E. McPherson, D. Goldenberg and G. Zibritosky, October 1944

(a) The torsion test of a monocoque box of 24S-T aluminum alloy was carried to failure. The twist and strains in the stringers, sheet, corner posts, and bulkheads were measured for loads

practically up to failure. Failure occurred by tearing of the cover sheet subsequent to failure of rivets joining antirolls to corner posts.
(b) The theoretical part of the report comes from Wagner's diagonal tension field theory as presented in Langhaar, H. L.: Theoretical and Experimental Investigations of Thin-Webbed Plate-Girder Beams, vol. 65, October 1943, pp. 799-802; with the following exceptions. It includes the effects of longitudinal stiffeners and of Poisson's ratio and it develops an expression for the effective area of a buckled side of the box.
(c) The buckling loads of the cover sheets and of the shear webs agreed with the computed values. The measured twist agreed within 6×10^{-5} radians per inch.

TN 955 AXIAL FATIGUE TESTS AT ZERO MEAN STRESS OF 24S-T ALUMINUM ALLOY SHEET WITH AND WITHOUT A CIRCULAR HOLE, W. C. Bruggeman, M. Mayer, Jr. and W. H. Smith, NACA, 1944

Very good presentation of procedures for fatigue testing sheet metal. Some data. No general conclusions.

TN 957 THE STRENGTH OF SEMI-ELLIPTICAL CYLINDERS SUBJECTED TO COMBINED LOADINGS, E. E. Sechler and J. L. Frederick, February 1945

Since the nose of the wing section can be approximated closely by portions of ellipse, elliptical cylinders has been used in this test.

The tests made on elliptical cylinder with a center support which were subjected to various simple and combined loadings.

The loadings were:

1. pure torsion
2. pure bending
3. bending plus torsion
4. bending plus vertical shear

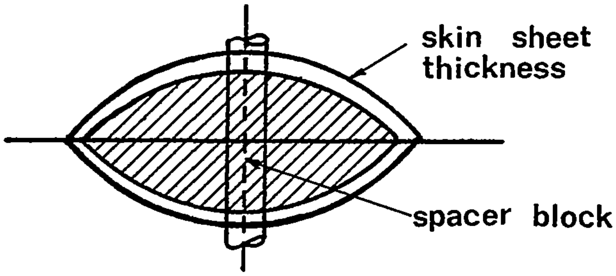
The bending moment and shears were applied in the plane of minor axes.

The physical parameters tested were:

1. the degree of the ellipiticity
2. the length of the cylinder
3. the thickness of the sheet covering

The specimens are made of 24S-T aluminum alloy.

The data contained in this report are intended to serve as a guide to the buckling and ultimate load carrying abilities of wing nose section.



Specimen Cross Section

The equation for buckling and ultimate at various simple and combined loadings on the elliptical cylinder has been derived.

TN 958 FAIRING COMPOSITIONS FOR AIRCRAFT SURFACES, Philip S. Turner, Jewel Doran and Frank W. Reinhart, November 1944

(a) The purpose of this report was to find a fairing composition with a satisfactory performance in respect to low moisture absorption, a softening temperature no higher than the temperature of application, and a coefficient of thermal expansion at low temperatures equal to that of the metal.
(b) The following equation was formulated from experimental data:

$$A_m = \frac{A_r\, C_r\, P_r + A_f\, C_f\, P_f + \ldots}{C_r\, P_r + C_f\, P_f + \ldots}$$

A = coefficient of thermal expansion
C = a constant
P = proportion by weight
m = mixture
r = resin or plastic
f = filler

$$\text{Tensile stress} = (Aa - Ab)\ (T_1 - T_2)E_a$$

A = coefficient of thermal expansion
E = modulus of elasticity
T = temperature
a = plastic
b = metal
1 and 2 refer to different temperatures

(c) It was found that the best method of application was to use solvents. Mixtures of acetone and ether were found to make the fastest drying vinyl acetate resin compositions. It was observed that increasing the percentage of fillers would shorten the drying time. The best composition was found to be 20% vinyl acetate AYAF, 55% asbestine 3X, and 25% zinc dust dispersed in a mixture of 2 parts ethyl ether and 1 part acetone to a solvent content of 20%.

TN 959 AXIAL FATIGUE TEST OF 10 AIRPLANE WING-BEAM SPECIMENS BY THE RESONANCE METHOD, W. C. Brueggeman, P. Krupen, and R. C. Roop, December 1944

(a) The purpose of the investigation was to determine the effect on the fatigue strength of a full-size structure of several important types of stress concentration and to determine whether it was practicable to design such structure on the basis of test results obtained on small, relatively simple coupon specimens containing typical stress raisers.
(b) The method used to test the wing-beams came from NACA TN 660.
(c) The wing beams showed a greater fatigue stress concentration factor for the wing beam specimens than for the drilled coupons. The investigation failed to disclose a method for determining the fatigue strength of the wing beam by fatigue test of small simple specimens. The high stress concentration factor in the wing beams was believed to have been caused by the notch effect of web splices.

TN 962 ANALYSIS OF SQUARE SHEAR WEB ABOVE BUCKLING LOAD, Samuel Levy, Kenneth L. Fienup and Ruth M. Woolley, NACA, 1945

An analysis of shear web of wing beams, from buckling to pure diagonal tension. Timoshenko (Theory of Elastic Stability, pp. 353-367, 1936 edition) develops methods for determining buckling. Wagner's theory on diagonal-tension-field theory is used in the extreme buckling region (NACA TM 604, 605, 606). This report deals with intermediate region, where web is taken to have some flexural rigidity, based on Von Kārmān's large deflection equations.

Fundamental equations: Von Kārmān (Timoshenko, Theory of Elastic Stability, McGraw-Hill Book Co., Inc., 1936, pp. 322-323.)

Equilibrium
Median fiber stress and strain
Extreme fiber stress

Equilibrium of Median Fiber Forces: E. SeyDel, Uber Das Ausbeulen Von Rechteckigen Isotropen Oder Orthogonal-Anistropen Platten Bei Schubbeanspruchung. Ing - Archiv., vol. 4, 1933, pp. 169-191.

Assumed solution:

$$F = \frac{\sigma_x y^2}{2} + \frac{\sigma_y x^2}{2} - \tau_{xy} + \sum_{m=o}^{6} \sum_{n=o}^{6} b_{m,n} \cos \frac{m\pi x}{a} \cos \frac{n\pi y}{a}$$

$$+ \sum_{m=1,3,5} A_m \cos \frac{m\pi x}{a} \left[\left(\frac{1-\mu}{1+\mu} - \frac{m\pi}{2} \tanh \frac{m\pi}{2} \right) \sinh m\pi \left(\frac{y}{a} - \frac{1}{2} \right) \right.$$

$$\left. + m\pi \left(\frac{y}{a} - \frac{1}{2} \right) \cosh m\pi \left(\frac{y}{2} - \frac{1}{2} \right) \right] + \sum_{m = 2,4,6} A_m \cos \frac{m\pi x}{a} \left[\left(\frac{1-\mu}{1+\mu} \right. \right.$$

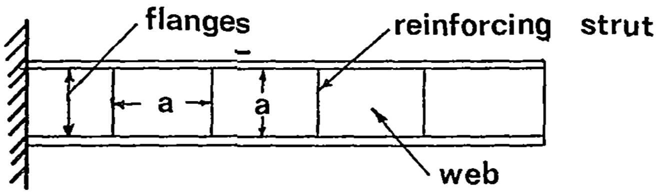
$$\left. \left. - \frac{m\pi}{2} \coth \frac{m\pi}{2} \right) \cosh m\pi \left(\frac{y}{a} - \frac{1}{2} \right) + m\pi \left(\frac{y}{2} - \frac{1}{2} \right) \sinh m\pi \left(\frac{y}{2} - \frac{1}{2} \right) \right]$$

$$+ \sum_{n = 2,4,6} B_n \cos \frac{n\pi y}{a} \left[\left(\frac{1-\mu}{1+\mu} - \frac{n\pi}{2} \right) \cosh n\pi \left(\frac{x}{a} - \frac{1}{2} \right) \right.$$

$$\left. \sinh n\pi \left(\frac{x}{a} - \frac{1}{2} \right) \right] + \sum_{n = 1,3,5} B_n \cos \frac{n\pi y}{a} \left[\left(\frac{1-\mu}{1+\mu} - \frac{n\pi}{2} \tanh \frac{n\pi}{2} \right) \right.$$

$$\left. \sinh n\pi \left(\frac{x}{a} - \frac{1}{2} \right) + n\pi \left(\frac{x}{a} - \frac{1}{2} \right) \cosh n\pi \left(\frac{x}{a} - \frac{1}{2} \right) \right]$$

Solve previous equation by method in NACA Rep. No. 737 or NACA TN 846 (Samuel Levy, 1942).



Beam Diagram

TN 964 BONDING STRENGTHS OF ADHESIVES AT NORMAL AND LOW TEMPERATURES, B. M. Axilrod and D. H. Jirauch, January 1945

Ardux 1 and cycleweld C-3 cement produced bonds sufficiently strong that the lap joint specimens of phenolic laminate failed in laminate rather than adhesive.

Maximum shearing strength obtained when specimen heated and machined before glueing.

In tests on plywood, strength of wood is governing factor adhesive is stronger than wood.

TN 965 THE EFFECT OF TEMPERATURE ON SHEET METALS FOR AIRPLANE FIREWALLS, Willard Mutchler, National Bureau of Standards, December 1944

Tests were conducted on several coated and uncoated steels to determine the effect of temperature on the tensile properties, ductility, and surface characteristics. The necessity for conducting such tests was a wartime shortage of certain critical materials, such as steel alloys containing nickel. Three type tests were conducted. They are:

1. Furnace heating tests
   1000°F. to 2000°F. temperature range
   2-1/2, 5, 15, and 60 minute heating periods
2. Flame-impingement tests
3. Airplane fire tests (engine fires)

The sheet metals tested and their characteristics were:

(a) Plain carbon and alloy steels without surface coating
    1. very low carbon steels
    2. steel with about 1% silicone
    3. low carbon alloy steel with about 5% chromium and 0.5% molybdenum
    4. stainless steel with about 20% chromium and 10% nickel (18:8 type).
(b) Low carbon steels with protective coatings surface coatings
    1. stainless cladding
    2. chromium-nickel alloy
    3. aluminum
    4. zinc

Pictures of the specimens after heating are also presented as well as tables summarizing the tests. Graphs of the relationships between the different types of steels are also presented.

A summary of results yields:

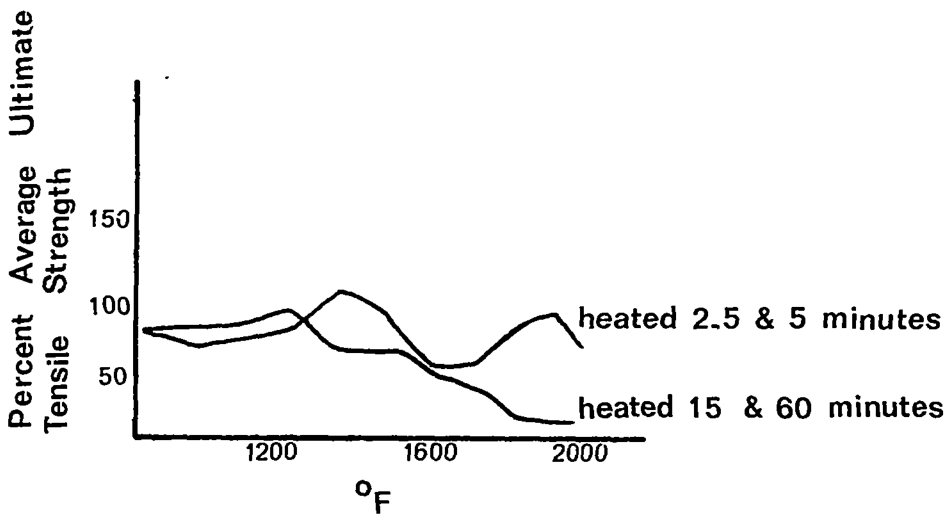
1. With the possible exception of steel containing 5% chromium and 0.5% molybdenum, all materials investigated withstood temperatures of 1700°F. for about 15 minutes.

2. Stainless steel proved to be the best of uncoated alloys while low carbon steels containing 1% silicon were superior to those without silicon.

3. Stainless-clad plain carbon steel sheet proved superior to ordinary stainless steel sheet.

4. Chromium-nickel alloy coatings and aluminum coatings on plain carbon steel sheets proved more resistant to elevated temperature than coatings of zinc over nickel. Chromium-nickel alloys and aluminum coatings applied by metal spraying show less change in surface appearance than aluminum coatings applied by hot dipping or the electro-deposited zinc coatings.

A graphical summary of the effect of heating on tensile properties for 1% silicon steel shows:



TN 966 THE ELASTIC CONSTANTS FOR WROUGHT ALUMINUM ALLOYS, R. L. Templin and E. C. Hartmann, January 1945

The purpose was to outline the methods employed for the determination of some of the elastic constants such as Young's modulus, Poisson's ratio, and the shear modulus.

The shear modulus was determined from torsion test of solid round specimens tested in an Amsler torsion machine.

Poisson's ratio was calculated from the following formula:

E = Young's modulus
E_s = shear modulus

Poisson's ratio is:

$$\mu = \frac{E-2E_s}{2E_s}, = \frac{E}{2ES} - 1$$

This gave an average value of Poisson's ratio of 1/3 which is recommended as suitable for most engineering design purposes.

Values of the elastic constants of tension and compression were determined by the usual tensile tests.

The values for the elastic constants were given for different alloys of aluminum. These values are given in any book of tables giving constants for aluminum.

TN 968 THE INWARD BULGE TYPE BUCKLING OF MONOCOQUE CYLINDERS III - REVISED THEORY WHICH CONSIDERS THE SHEAR STRAIN ENERGY, N. J. Hoff and Bertram Klein, April 1945

A revised theory which considers the shear strain energy stored in the sheet covering of the monocoque cylinders is applied to the theory of buckling in pure bending. This was an attempt to extend the theory of general instability in pure bending.

The following seven assumptions for the distortions of the rings were made:

1. distortions must be inextensional.
2. the maximum radial displacement should occur at the location of the most highly compressed stringer.
3. the tangential displacement must vanish at the location of the most highly compressed stringer.
4. the radial displacement must vanish when $\phi=\phi_o$ [ϕ= angular measure and ϕ_o = angle defining end of circumferential wave].

5. the tangential displacement must vanish when $\phi=\phi_o$.
6. the tangent to the deflection curve must be perpendicular to the radius of the nondistorted cylinder at the end of the bulge.
7. the radius of curvature of the deflected shape at the end of the bulge must be equal to the original radius of the cylinder.

The strain energy stored in a ring can be calculated from the equation:

$$U = \oint \left(\frac{1}{2}\right) \quad (EI)_r \; [1/\rho) - (1/r)]^2 r \; d \; \phi$$

$(EI)_r$ = bending rigidity of ring for bending in the plane of ring.
r = original radius of cylinder.
ρ = radius of curvature at any point after distortions.

The strain energy stored in all of the rings is:

$$U_r = \Sigma \left(\frac{1}{2}\right) (EI)_r \int_{-\frac{\pi}{n}}^{+\frac{\pi}{n}} \left(\frac{1}{r^4}\right) [Wr + (\partial^2 Wr/\partial\phi^2)]^2 r \; d\phi$$

Where:

$$W_r = -\beta[2 \cos (n\phi/2) + 9 \cos (3n\phi/2) + 5 \cos (5n\phi/2)]$$

n = ratio of total circumference to that involved in buckling; or $n = \pi/\phi_o$.

The critical strain in the most highly compressed stringer at buckling is:

$$*\varepsilon_{max} = \{(L_{1/V_s}) \; f_r \; (n) \; (m + 1)^2 + (2\pi/L_1)^2 \; F_{str}(s,n)$$

$$|(m + 1)^2 + 0.0307 \; (tr/s) \; f \; (m + 1) \; F_{sh} \; (s,n)\}|[A + 2wt)$$

$$fw \; (s,n)]$$

Where:

L_1 = distance between adjacent rings measured axially along cylinder.
fr(n)=function of n arising in connection with ring strain energy.

$$V_s = (\tfrac{4}{3})\,\pi r^3 \qquad\qquad (m + 1) = L/L_1$$

The maximum strain may also be calculated approximately from:

$$\varepsilon_{cr} = \frac{1}{A} n^2 \sqrt{\frac{d}{L_1}}\ \frac{\pi^2 \sqrt{I_{str\ o}\, I_{r\ o}}}{r^2}$$

d = stringer spacing measured along circumference.
$I_{str\ o}$ = moment of inertia of stringer cross section.

$I_{r\ o}$ = moment of inertia of ring cross section.

TN 971 FATIGUE TESTS ON 1/8-INCH ALUMINUM ALLOY RIVETS, H. J. Andrews and M. Holt, February 1945

The purpose was to summarize all the results of fatigue tests that have been made (to date) of lap joints having 1/8-inch aluminum alloy rivets. The following results were noted.

1. For 17S-T and A17S-T rivets, the joint can be divided into three groups according to strength, the strongest being the dimpled sheet, the next strongest those with plain drilled holes, and finally those with countersunk holes.

2. The effect of the depth of the countersink on the strength of the joint could not be determined definitely.

3. As a rule the joints with plain drilled holes failed by shearing the rivets; while in the case of those with countersunk holes the type of failure could not be definitely defined.

4. The fatigue strength of joints in 24S-T sheet is a little greater than that of similar joints in Alclad 24S-T.

5. In static tests and in fatigue tests of small numbers of cycles (high stresses) 17S-T rivets are stronger than A17S-T rivets; whereas for large numbers of cycles the strengths are practically the same.

6. The thickness of the sheet was found to be rather unimportant when failure is concerned except at high stresses (low number of cycles). For the high stress case a thicker sheet resulted in a stronger joint.

7. 24S-T rivets were stronger in fatigue than 17S-T and A17S-T rivets.

TN 974 BEARING STRENGTHS OF 75S-T ALUMINUM-ALLOY SHEET AND EXTRUDED ANGLE, C. Wescoat and R. L. Moore, February 1945

The object was to give bearing yield and ultimate strengths of 75S-T aluminum alloy in the form of sheet. The specimens were 2-inch wide strips of 0.064-inch sheet, loaded in bearing on a 1/4-inch pin.

Failures by shear and tension in the margin above the pin were predominate for edge distances of 1.5 and 2 inches diameters for edge distances of 4-inches failures were by bearing. The bearing properties did not show any directional characteristics the average ultimate tensile strength was found to be 80,300 psi. The average yield strength was 68,000 psi.

The bearing strengths varied according to the edge distance of the whole.

(a) For the edge distance equal to 1.5-times the pin diameter:
Ultimate = 133,000 psi. Yield = 101,500 psi.
(b) For the edge distance equal to 2-times the pin diameter:
Ultimate = 160,000 psi. Yield = 117,500 psi.
(c) For the edge distance equal to 4-times the pin diameter:
Ultimate = 184,700 psi. Yield = 124,000 psi.

Angle specimens were also tested and the bearing strengths were found to be quite close to those of the sheet specimens.

TN 975 DATA ON MATERIAL PROPERTIES AND PANEL COMPRESSIVE STRENGTH OF A PLASTIC-BONDED MATERIAL OF GLASS CLOTH AND CANVAS, George W. Zender, Evan H. Schuette and Robert A. Weinberger, NACA, 1944

Material tested: "Valinite," composed of #162 fiberglas fabric and 8 oz. canvas, bonded with plaskom 700 resin.

Results: Tensile strength increased with increase fiberglas content. Compressive strength decreased with increase fiberglas content. Tensile strength: 27 kips at 50% fiberglas (longitudinal). 23 kips at 100% fiberglas (transverse). Compressive Strength: 13 kips at 25% fiberglas. 8-10 kips at 100% fiberglas.

Conclusion: Material is not good enough to compete on a strength to weight basis with aluminum. It had a low compressive strength which may be improved upon. Waviness of threads in weaving hinders compressive strength. Creep was excessive except for 100% fiberglas material.

TN 981 BEARING STRENGTHS OF 24S-T ALUMINUM ALLOY PLATE, R. L. Moore and C. Wescoat, June 1945

Tests were made to determine the bearing strength of 24S-T aluminum. The following results were obtained.

Edge Distance in Terms of Pin Diameter D	Bearing to Tensile Ultimate for all Thicknesses	Bearing to Tensile Yield for Various Thicknesses		
		Less than 0.249 in.	0.250 to 1.000 in.	1.001 to 2.001 in.
1.5 D	1.5	1.64	1.6	1.5
2.0 D	1.9	1.87	1.8	1.7

There was no significant difference between with-and cross-grain bearing yield and ultimate strengths.

The values found in this report are in close agreement with those found in:

Strength of Aircraft Elements. Army-Navy-Civil Committee on Aircraft Design Criteria. (ANC-5), 1942.

Since the bearing and ultimate strengths can be found in the above reference they will not be tabulated. It will be noted that the ultimate bearing strengths ranged from 80,000 psi to 110,000 psi.

TN 983 AXIAL FATIGUE TESTS AT TWO STRESS AMPLITUDES OF 0.032-INCH 24S-T SHEET SPECIMENS WITH A CIRCULAR HOLD, W. C. Brueggeman, M. Mayer, Jr. and W. H. Smith, July 1945

(a) This report was intended to investigate the effect of varying stress amplitude on 24S-T Al sheet.
(b) It was proposed that

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \ldots + \frac{n_n}{N_n} = 1$$

Where n_n is the number of cycles at stress amplitude S_n, and N_n is the number of cycles to failure at S_n, N_n is obtained from the S-N curve as the cycles to failure at a constant stress amplitude.
(c) Specimens showed considerably higher endurance when the low stress was applied first than when the high stress was applied first. It was found that a simple formula such as the following

equation,

$$N = n_1 + n_2 + \ldots. + n_n$$

is adequate to describe the endurance when many cycles at low stress amplitude are followed by many cycles at high stress amplitude. It is apparent from this investigation that an equation to describe the endurance must take the sequence of the low stress and high stress into consideration.

TN 984 STRESSES AT CUT-OUTS IN SHEAR RESISTANT WEBS AS DETERMINED BY THE PHOTOELASTIC METHOD, Benjamin F. Ruffner and Calvin L. Schmidt, NACA, November 1945

Investigation of stress concentrations around lightening holes in plates and beam webs. Conclude round holes, square holes with sides at 45° to neutral axis and radiused corners to have lower stress levels than comparable rectangular holes, especially those with edges parallel to neutral axis. Addition of stiffeners further reduces stresses.

Stress in uncut web calculated by conventional method. Stress in cut web obtained from stress concentration factors plotted in report. Reinforcement width should be about 1/2-width of cut-out or less.

Reinforcement thickness = 1.2 x stress concentration factor x web thickness reduces stress level approximately to that of uncut web.

Width of reinforcement determines stiffness. Thickness of reinforcement determines stress level.

TN 986 NONDESTRUCTIVE MEASUREMENT OF RESIDUAL AND ENFORCED STRESSES BY MEANS OF X-RAY DIFFRACTION, I-CORRELATED ABSTRACT OF THE LITERATURE, G. Sachs, C. S. Smith, Jack D. Lubahn, G. E. Davis and L. J. Ebert, September 1945

It was found that stress measurements by x-ray diffraction methods could have many applications in commercial problems, but the conditions in commercial structures are not conducive to practical execution of the method. An attempt was made to determine whether it is feasible to measure stress this way in commercial practice. This is the only non-destructive method which fundamentally permits the measurement of stress and strain.

The different methods used up to this time were mentioned. Surely in the 23 years since the publication of this report better, easier methods are available so the ones in this report will not be mentioned.

At the time of publication the practical application of x-ray diffraction was not in a workable method.

TN 987 NONDESTRUCTIVE MEASUREMENT OF RESIDUAL AND ENFORCED STRESSES BY MEANS OF X-RAY DIFFRACTION, II-SOME APPLICATION TO AIRCRAFT PROBLEMS, G. Sachs, C. S. Smith, J. D. Lubahn, G. E. Davis and L. J. Ebert, November 1945

The purpose was to determine if the x-ray diffraction method of stress determination could be used practically on aircraft structures. The methods of x-ray diffraction that were used were explained but they were too long to be summarized on cards. Also there are probably better methods used today.

The conclusions that were drawn are:

1. X-ray diffraction methods can be used to determine surface stresses in metals provided that the stress gradients are not too great.

2. Measurement of stresses in the interior of a metal is not possible at this time.

3. The longitudinal stress in a flat-notched specimen was found to agree with that obtained by photoelastic methods.

4. The residual stress present in a structure welded from alloy steel SAE X-4130 cannot be measured in regions of the parent metal affected by the heat. Thus there is a rather effective restrictment on x-ray diffraction for determination of stress in weldments.

TN 991 PROPERTIES OF SOME EXPANDED PLASTICS AND OTHER LOW-DENSITY MATERIALS, Benjamin M. Axilrod and Evelyn Koenig, NACA, September 1945

Presentation of extensive data on properties of 7 low density, as thermal conductivity, density, weight and dimension changes due to heat and humidity, weathering, effects of organic solvents, water absorption, softness index before and after treatment by solvents, flexure and compressive properties.

TN 992 EFFECT OF FATIGUE-STRESSING SHORT OF FAILURE ON SOME TYPICAL AIRCRAFT METALS, J. A. Bennett, October 1945

Tests were made to determine the effect of service stresses on the impact resistance of 25S aluminum alloy. The average impact resistance was found to be unimpaired even in material cut from specimens broken by repeated stress-above or below the fatigue limit. The two alloys which were tested were 25S aluminum and X4130 chromium-molybdenum.

Prolonged fatigue stressing prior to the formation of cracks did not cause embrittlement. After cracks had formed the loss in impact resistance was a function of the size of the cracks.

The embrittling effect of fatigue cracks was greater at low temperatures than at room temperature.

When the micro-structure of 25S aluminum was studied by x-ray diffraction it was found to be inadequate to detect fatigue damage.

The best way to detect when the fatigue limit was reached was to note the decrease in endurance at stresses above the fatigue limit.

If the pre-stress was greater than the test stress, the damage occurred more rapidly during the first part of the test, then more slowly. The reverse was true if the pre-stress was less then the test stress. Thus in a machine which must endure overstress, it would be beneficial to avoid relatively high stress during the early part of its life.

TN 993 ANALYTICAL STUDY OF TRANSMISSION OF LOAD FROM SKIN TO STIFFENERS AND RINGS OF PRESSURIZED CABIN STRUCTURE, Theodore Hsueh-Huang Pian, M.I.T., October 1945

This report deals with pressurized cabins and may not be applicable to the design of light aircraft operating in areas where pressurized cabins are of little importance.

This paper is concerned with the problem of deformation and the stress analysis of a pressurized cabin structure, consisting of sheet metal skin, longitudinal stringers, and a finite number of rings which are equally spaced between two end bulkheads.

Three deformation parameters are considered and solved for:

1. Radial expansion of rings.
2. Quilting of stringers.
3. Transverse elongation of skin.

The structure is considered to be under internal pressure only and superposition is assumed to apply.

A method using strain energy is presented. The stresses determined once the three deformations have been found are:

1. Tensile stresses in rings and stringers.
2. Longitudinal and circumferential stresses in skin.

A sample problem is worked out completely and answers are compared with test results on a model by Lockheed and Consolidated-Vultee. The method developed is in good agreement with the test results and on the conservative side. An analysis of possible discrepences is made.

TN 994 COLUMN STRENGTH OF EXTRUDED MAGNESIUM ALLOYS, J. R. Leary and Marshall Holt, December 1945

The object was to provide a basis for establishing a general formula for the column strength of magnesium alloys AM-C58S and AM-C58S-T5 members that are not subject to local buckling or to torsional instability. The tensile tests were made on standard 1/2-inch wide tensile specimens - of the full thickness of the material.

Of all the tests run the only failure was for a specimen at which a shearing type of failure occurred at a strain of about 6.3 percent.

A relation that relates column strengths and slenderness ratio:

$$\frac{P}{A} = \frac{\pi^2 \bar{E}}{\left(\frac{KL}{r}\right)^2}$$

$\frac{P}{A}$ = column strength (psi)
$\bar{E}$ = effective modulus
L = length of member
r = least radius of gyration
K = coefficient describing the end of conditions of the specimen (for round ends K equals unity and for fixed ends K equals one-half)

For the alloys tested the maximum values of P/A are:

AM-C58S .... 21,300 psi
AM-C58S-T5 .... 30,000 psi

TN 998 NUMERICAL PROCEDURES FOR CALCULATION OF THE STRESSES IN MONOCOQUES, III-CALCULATION OF THE BENDING MOMENTS IN FUSELAGE FRAMES, J. N. Hoff, Paul A. Libby and Bertram Klein, April 1946

(a) In this report Southwell's method of systematic relaxation (TN 944) was used to calculate the bending moments and the distortions of fuselage rings upon which known concentrated and distributed loads are acting.
(b) The frames and rings are divided into beams of constant radius of curvature, the forces and moments caused in the ends of each section by a unit displacement in the ends of each section are calculated, the beams are then recombined to form the complete ring using three simultaneous equations at each joint.

(c) Examples of calculations include egg-shaped and circular rings with and without V-braces loaded symmetrically and anti-symmetrically. This report uses a large number of simultaneous equations and may be adaptable for use with a computer.

TN 999 NUMERICAL PROCEDURES FOR THE CALCULATIONS OF THE STRESSES IN MONOCOQUES IV - INFLUENCE COEFFICIENTS OF CURVED BARS FOR DISTORTIONS IN THEIR OWN PLANE, N. J. Hoff, Bertram Klein and Paul A. Libby, April 1946

(a) The purpose of this report was to formulate equations for the calculation of influence coefficient for use in TN 998.
(b) The report gives formulas for calculating six influence coefficients for fixed and moveable ends. 15 tables and 91 graphs give many influence coefficients as functions of B, angle subtended by circular median line of bar; γ, section length parameter (AL^2/I); ξ, ratio fo effective shear area to area of cross-section of the bar ($*A/A$).

TN 1002 STRESS ANALYSIS OF COLUMNS AND BEAM COLUMNS BY THE PHOTOELASTIC METHOD, B. F. Ruffner, March 1946, Oregon State College

This paper attempts to develop a simple, accurate and quick method of determining moments and critical loads in members loaded as beam columns by the use of methods of photoelastic analysis. Photoelastic techniques are applied to uniform and tapered beam columns, circular rings, and statically indeterminate frames. A discussion of the proper design of photoelastic models is also presented. Some approximate theoretical equations that prove helpful in analyzing photoelastic results are also presented.

For beam columns of constant EI and pin ends the accuracy of this method was good. Zero eccentricity of the end loads was not necessary and eccentricities had no effect upon critical load but may have a large effect upon bending moments at values of axial load less than the critical load.

For circular rings bending moments are a function of R^4/I and photoelastic tests indicate that formulas previously in use for the calculation of bending moments in circular rings give non-conservative values for high R^4/I, where R is any reaction for internal force of the member.

For a element of an indeterminate frame member where an axial load approaches the critical value this method is useful.

The photoelastic method can be used in the following areas where analytical methods are not readily available:

1. Beam columns of varying EI.

2. Structures such as flexible circular rings where deformations have a non-negligible effect upon stress distribution.

3. Statically indeterminate structures where internal forces and moments, etc. aren't linear functions of external loads.

TN 1004 THE COLUMN-STRENGTH OF ALUMINUM ALLOYS 75S-T EXTRUDED SHAPES, Marshall Holt and J. R. Leary, January 1946

The object was to determine the column strength of extruded aluminum alloy 75S-T. These values were as follows:

Tensile strength......................88,000 psi
Tensile yield strength................80,000 psi
Elongation ....10% in 2 inches

For column strength in the elastic stress range, the tests agree well with the Euler column curve as given below:

$$\frac{P}{A} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

$E = 10{,}500{,}000$ psi

$\frac{KL}{r}$ = slenderness ratio

$K = 0.50$

$\frac{P}{A}$ = column strength

For column stresses above the elastic stress range the tests agree with the tangent modulus curve which is the same form as Euler's equation except that the tangent modulus instead of the initial modulus is used.

TN 1005 CORRELATION BETWEEN STRENGTH PROPERTIES IN STANDARD TESTS SPECIMENS AND MOLDED PHENOLIC PARTS, P. S. Turner and R. H. Thomason, National Bureau of Standards, May 1945

Tensile, flexural, and impact properties of 10 selected types of phenolic molding materials.

This information is no longer applicable.

TN 1009 ANALYSIS OF DEEP RECTANGULAR SHEAR WEB ABOVE BUCKLING LOAD, Samuel Levy, Ruth M. Woolley and Josephine N. Corrick, March 1946

ABSTRACT: A solution of Von Kármán's equations for plates with large deflections is presented for the case of a rectangular shear web with height to width ratio 2.5 reinforced by vertical struts having one-fourth the weight of the shear web. Results were

compared to NACA TN NO. 962 for square shear web. The shear deformations for both webs were nearly the same.

CONCLUSIONS: The maximum principal stress at the center of the web continues to rise after buckling, while the minimum principal stress remains constant and then decreases slowly with increasing load. The direction of the maximum principal stress at the center forms an angle of 45° with the flanges at the buckling load; the angle decreases with increasing load; it is only about 32° at four times the buckling load.

In the corners of the web that are in line with the diagonal wrinkles, the minimum median fiber stress (compression) is about 30 percent larger in absolute value than the maximum median fiber stress (tension). The bending stress at the corner is about one-half as large as the median fiber stresses. The direction of the maximum median fiber stress in the corner changes from 45° relative to the flanges at buckling to about 43° at four times the buckling load.

The slope of the shear deformation-load curve shows an abrupt decrease in shear stiffness at the buckling load.

The effective width of the sheet drops off slowly as the buckling load is exceeded.

The compressive force in the strut is about three times as large at the middle as at the ends. This is a much larger variation than was found in reference 1 for a square shear web; it is probably caused by gusset action near the ends of the relatively longer struts reinforcing the rectangular web. The increase in strut force with load was roughly linear.

Comparison with the diagonal tension field theory as developed in reference 6 indicates that Kuhn's analysis is up to 37 percent more conservative than the present analysis except for strut force, for which the present analysis is more conservative.

Comparison with the diagonal tension field theory as developed in reference 7 indicates that Langhaar's analysis is much more conservative than the present analysis; the difference is of the order of 50 to 400 percent at the largest loads.

REFERENCES:

1. Levy, Samuel, Kenneth L. Fienup and Ruth M. Woolley: Analysis of Square Shear Web Above Buckling Load. NACA TN NO. 962, 1945.

2. Timoshenko, S.: Theory of Elastic Stability. McGraw-Hill Book Co., Inc., 1936.

3. Levy, Samuel: Bending of Rectangular Plates with Large Deflections. NACA Rep. No. 737, 1942.

4. Timoshenko, S.: Theory of Elasticity. McGraw-Hill Book Co., Inc. 1934.

5. Crout, Prescott, D.: A Short Method for Evaluating Determinants and Solving Systems of Linear Equations with Real or Complex Coefficients. Trans. A.I.E.E., vol. 60, 1941, pp. 1235-1241.

6. Kuhn, Paul: Investigations on the Incompletely Developed Plane Diagonal-Tension Field. NACA Rep. No. 697, 1940.

7. Langhaar, H. L.: Theoretical and Experimental Investigations of Thin-Webbed Plate-Girder Beams. Trans. A.S.M.E., vol. 65, October 1943, pp. 799-802.

TN 1010 STRESS-STRAIN AND ELONGATION GRAPHS FOR ALUMINUM ALLOY R301 SHEET, James A. Miller, February 1946

The following properties are determined from tests on duplicated longitudinal and transverse specimens from aluminum alloy R301 sheets with nominal thicknesses of 0.020, 0.032, and 0.064 inches.

1. Tensile and compressive stress-strain graphs and stress-deviation graphs sheets in T condition to a strain of 1%.

2. Graphs of tangent modulus and reduced modulus for a rectangular section versus strain in compression in T condition.

3. Tensile stress-strain graphs to failure in W and T condition.

4. Local elongation and elongation versus gage length for tensile specimens from sheet in W condition and T condition tested to fracture.

The W condition is quenched. The T condition is artifically aged.

Tensile tests were made on two longitudinal (in direction of rolling) specimens and two transverse (across direction of rolling) specimens for each thickness of sheet in T condition.

The stress strain graphs have coordinates of σ, ε where $\sigma = S/S_1$ and

$$\varepsilon = \frac{E_e}{S_1}$$

where S = stress corresponding to strain e.
S_1 = 0.7E secant yield strength.
E = Young's modulus.

The stress deviation graphs have coordinates of σ and δ where $\delta = \varepsilon - \sigma$. These were plotted on log-log paper to show where the stress-strain curve can be expressed by

$$e = S/E + K\left(\frac{S}{E}\right)^n$$

The graphs indicate that the relationship holds for the compressive specimens and for the longitudinal specimens for values of $S/S_1 > S_2/S_1$ where S_2 = 0.85E secant yield strength.

For the tangent-modulus-strain graphs, the ordinates are the ratios of tangent modulus E' to Young's modulus. The graphs show no evidence of a secondary modulus.

The reduced-modulus-strain graphs were derived from the corresponding tangent-modulus-strain curves using the formula

$$\frac{Er}{E} = \frac{4E'/E}{(1 + \sqrt{E'/E})^2}$$

Tensile tests to failure were made on two longitudinal and two transverse specimens from sheets of each thickness in both the W and T condition. The values of elongation usually corresponded to a strain of about 0.006 less than the maximum recorded strain under load.

The graphs of figures 37, 38, & 39 are useful for estimating values of stress, strain, tangent modulus, and reduced modulus, for R301-T sheet between 0.020 and 0.064 inches in thickness, for which Young's modulus and the secant yield strength in the desired direction are given.

TN 1013 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS, I - EXPERIMENTAL INVESTIGATION OF CYLINDERS WITH A SYMMETRIC CUTOUT SUBJECTED TO PURE BENDING, N. J. Hoff and Bruno A. Boley, June 1946

(a) Tests were run to find the effect on stress and strain of different size cutouts in monocoque cylinders subjected to pure bending.
(b) The strain was measured using strain rosettes and the stresses were calculated from:

$$\sigma_x = (E/(1 - u^2))(\varepsilon_x + u\ \varepsilon_c)$$

$$\sigma_c = (E/(1 - u^2))(\varepsilon_c + u\ \varepsilon_x)$$

$$\tau = G\gamma$$

E = Young's modulus
u = Poisson's ratio
τ = shear stress
σ_c = normal stress in sheet in circumferential direction
σ_x = normal stress in sheet covering in axial direction
ε = normal strain
γ = shear strain

(c) All 10 cylinders failed in general instability; two symmetric and one anti-symmetric pattern of buckling was observed. The buckling load of the cylinders having cutouts extending over 45°, 90°, and 135° was 66, 47, and 31%, respectively, of the buckling load of the cylinders without cutouts. Stress distribution is not linear in a cylinder with a cutout. Up to 1/2 the failing load the strain increases linearly in any one stringer with increasing applied moment, beyond this load the strain increases more rapidly than according to a straight line. In 7 out of 10 cases the maximum strain was reached in the stringer running along the edge of the cutout, in the remaining three cases the maximum strain was in the stringer adjacent to the edge stringer.

TN 1014 STRESSES IN AND GENERAL STABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS - II. CALCULATION OF THE STRESSES IN A CYLINDER WITH A SYMMETRIC CUTOUT, N. J. Hoff, Bruno A. Boley and Bertram Klein, June 1946

Presented in this report is a numerical procedure for the calculation of stresses in a monocoque cylinder with a cutout. In the procedure the structure is broken up into a great many units; the forces in these units corresponding to specified distortions of the units are calculated; a set of linear equations is established expressing the equilibrium conditions of the units in the distorted state; and the simultaneous linear equations are solved.

CONCLUSIONS:

1. A fully worked out numerical example is given.

2. The step by step numerical procedure is slowly convergent but its values correspond well to those obtained experimentally. (Problem was initially worked by hand.)

TN 1022 A FIXTURE FOR COMPRESSIVE TEST OF THIN SHEET METAL BETWEEN LUBRICATED STEEL GUIDES, James A. Miller, April 1946

(a) A fixture was designed to test thin sheets in compression; thin sheets must be supported against general instability.
(b) The fixture consisted of two steel guides and two clamps. The fixture held the single sheet while the load was applied.
(c) The report suggest that their fixture be used as a guide in making a fixture to hold sheets during compressive testing. The lubricant used was Texaco Marfak No. 3.

TN 1027 COLUMN STRENGTH OF ALUMINUM ALLOY 14S-T EXTRUDED SHAPES AND ROD, J. R. Leary and Marshall Holt, NACA, 1946

$$\frac{P}{A} = \frac{\pi^2 \overline{E}}{\left(\frac{KL}{r}\right)^2}$$

P = total load.

$\overline{E}$ = effective modulus, from Euler or Engesser. $\overline{E}$ = E in elastic range, decreases with stress in plastic range.

K = end fixity coefficient.

For elastic region (KL/r vs P/A plot straight line)

$$\frac{P}{A} = B - D\left(\frac{KL}{r}\right)$$

B = intersection of straight line on axis of zero slenderness ratio (plot of $\frac{KL}{r}$ vs P/A).

D = slope of plot.

TN 1030 THE FATIGUE CHARACTERISTICS OF BOLTED LAP JOINTS OF 24S-T ALCLAD SHEET MATERIALS, L. R. Jackson, W. M. Wilson, H. F. Moore and H. J. Grover, October 1946

(a) Fatigue tests were conducted to determine the effect of bolt fit on the fatigue strength of lap joints. Bolt fit varied from "press fit" to a "sloppy fit."

(b) Bolt Clearance (in)	Load (lb)	Life 180-in.-lb. torque (cycles)	Life of Similar Specimen with 108-in.lb. torque (cycles)
-0.001 to 0.000	2500	64,700	40,000 - 120,000
.002	2500	94,100	70,000 - 160,000
.002	1150	1,638,100	700,000 - 1,600,000
.010	2900	41,00	40,000 100,000
.025	2700	77,100	60,000 - 120,000
.025	950	1,057,400	1,000,000 4,000,000

(c) It was found that for unidirectional loading bolt fit is of little importance as far as the fatigue strength is concerned. Direct influence of bolt fit on fatigue strength under reversed loading is also small. However, loose-fitting bolts permit objectionable slip and joint deflection.
(d) All other useful information in this report, effect of number of bolts and sheet gage may be found in Bruhn.

TN 1031 A MULTIPLE BRIDGE FOR ELIMINATION OF CONTACT-RESISTANCE ERRORS IN RESISTANCE STRAIN-GAGE MEASUREMENTS, Isidore Warshawsky, March 1946

(a) A multiple-bridge circuit was developed to eliminate contact-resistance errors of the first order between the arms of the ordinary Wheatstone bridge.
(b) The methods are particularly applicable to rotating shafts or propeller blades.

TN 1036 COMPARISON OF STATIC STRENGTHS OF MACHINE COUNTERSUNK RIVETED JOINTS IN 24S-T, X75S-T, AND ALCLAD 75S-T SHEET, E. C. Hartmann and A. N. Zamboky, May 1946

The object was to compare the static strengths of machine-countersunk riveted joints to evaluate the differences in cutting action of the sharp edge of the sheet when the countersunk hole was the same depth as the thickness of the sheet.

The countersunk rivets are weaker than the protruding head rivets. This is due to the lack of cutting edge in the protruding rivet. This lack of a cutting edge increases the shear strength. This cutting action is more pronounced for the harder sheets than for the softer sheets. All of the countersunk holes were cut the entire thickness of the sheet to produce the greatest cutting effect and thus the greatest reduction in shear strength.

Thus it was indicated that if a sheet must be countersunk that it should not be countersunk the entire thickness of the sheet if it can be avoided. If it is done through the entire thickness it decreased the shear strength by a great amount.

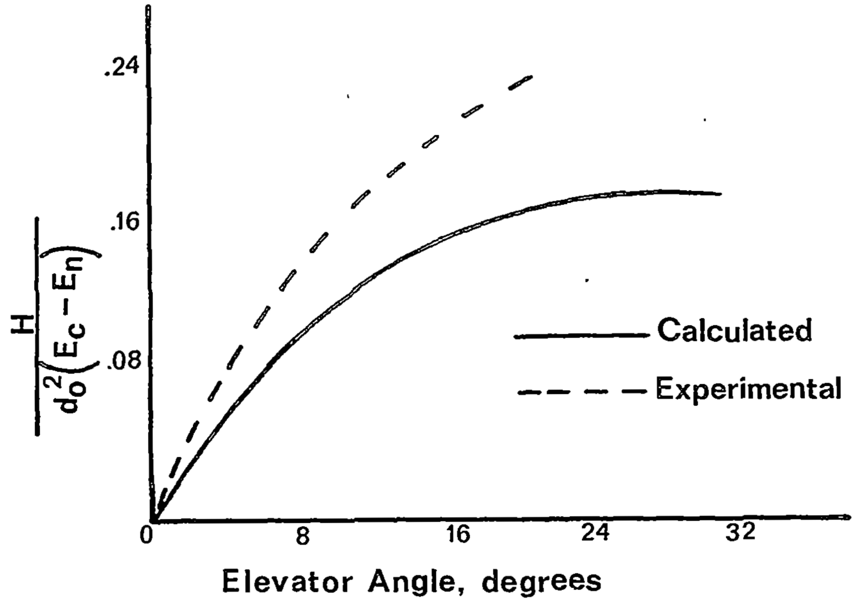
TN 1038 STRUCTURAL HINGE-MOMENT INCREMENTS CAUSED BY HINGE-AXIS DISTORTION, John V. Becker and Morton Cooper, April 1946

(a) This report studies the problem of structural hinge-moment increments caused by changing the elevator angle.
(b) When the elevator, rudder, or aileron is deflected the central hinge tends to rotate eccentrically. The hinge moment, H, is found to be:

$$\frac{H}{d_o^2\ (Ec-En)} = \frac{1}{2}\left(\frac{d}{d_o}\right)^2 \frac{\sin 2\ (\delta - \phi)}{\cos \phi}$$

H = hinge moment.
Ec = chordwise stiffness factor of elevator measured at central hinge relative to end hinges, pounds per inch.
En = normal-to-chord stiffness measured at central hinge relative to end hinges.
δ = angle of elevator chord to stabilizer chord (δ positive for trailing edge down).
d_o = perpendicular distance from central hinge to line joining a end hinges ($\delta \neq 0°$).
ϕ = angle of rotation of central hinge about line joining and hinges.

The structural stiffness factors are determined experimentally.
(c) For any control surface having three hinges the structural hinge-moment increments can be calculated if the normal-to-chord and chordwise stiffness factors and the elastic deflection curve are known. For a given misalignment of the hinges the structural hinge-moment increments increase indefinitely as the elevator chordwise stiffness factor. The structural hinge-moment increment varies as the square of the lift load on the tail. Structural hinge-moment increments increase the control forces required to produce a given elevator deflection.



TN 1039 QUANTITATIVE TREATMENT OF THE CREEP OF METALS BY DISLOCATION AND RATE PROCESS THEORIES, A. S. Nowick and E. S. Machlin, April 1946

Because of the development of the gas turbine focus was on heat resisting alloys. Creep resistance can be used to evaluate heat resistance alloy.

An equation for the steady state rate of creep as a function of applied stress and temperature is derived by applying Eyring's theory of rate processes and theory of dislocations to the problem.

This investigation is to evaluate the physical properties of heat resisting alloys in terms of physical constants in order to minimize the number of tests and new compositions and structure of better heat resisting alloys than those currently used.

The empirical equation that gives the dependence of steady state rate of creep on stress and absolute temperature can be taken as:

$$\log_e u = \log_e \left(\frac{d_1}{L} \frac{KT}{h}\right) - \frac{A + BT}{KT} \frac{\beta\sigma}{KT}$$

The theoretical treatment in this report has shown that parameters A, B, and β depend on physical constants of the material on following manner:

$A = VGof^2x^2$ $\beta = qVxf(1-2\ F(T))$

Where, $B = P' - V\ x^2f^2G\sigma\alpha = P' - A\alpha$

K = Boltzmann's constant.
T = absolute temperature.
h = Plank's constant.
d_1 = distance between atoms in slip direction.
f = fraction whose value is about 1/2.
G_o = modulus of rigidity at absolute zero.
V = volume associated with one atom.
x = ratio of d_1 to d_2.
q = stress concentration factor.
$F(T)$ = function of temperature and material.
P' = $- K \log_e P^5$.
α = temperature coefficient of modulus of rigidity.

The rate of creep was found to decrease with increase modulus of rigidity. National Defense Research Committee has shown that chrome base alloy have better resisting properties because of high tungsten of molybdenum content.

TN 1041 EFFECT OF NORMAL PRESSURE ON STRENGTH OF AXIALLY LOADED SHEET-STRINGER PANELS, A. E. McPherson, Samuel Levy and George Zibritosky, July 1946

ABSTRACT: Tests under combined axial load and normal pressure were made on 29 24S-T aluminum alloy sheet-stringer panels. The panels were reinforced by extruded Z stringers spaced 4 inches between centers. Empirical formulas were derived for predicting the effect of normal pressure on the strain for buckling of sheet between stringers. A simple formula was fitted to the data to describe the reduction of maximum axial load due to the presence of normal pressure. This report was done to provide additional experimental data and to derive empirical formulas for determining the buckling load, load carried after buckling, and ultimate load of sheet-stringer panels under combined axial load and normal pressure.

CONCLUSIONS: Normal pressure did not appreciably reduce the strain for buckling between rivets.

The critical buckling strain of the sheet was found to depend on the sheet thickness, the lateral pressure, and the restraint of the sheet at the stringer edge. The critical buckling strain for small lateral pressures depended principally on the flexural rigidity of the sheet and on the type of edge restraint; it was increased with an increase in sheet thickness and an increase in edge restraint. At large lateral pressures, on the other hand, the buckling strain depended principally on the amount of transverse curvature produced by the dishing under pressure; it was decreased with an increase in sheet thickness and an increase in edge restraint.

The sheet load per bay was unaffected by the panel width, panel length, or direction of application of the normal load. The sheet load for a given edge strain was decreased by lateral pressure, but was increased for strains somewhat greater than the buckling strain with no lateral pressure.

Lateral pressure caused a small reduction in the axial load at failure and this reduction increased as the panel thickness increased. The direction of the lateral pressure had no effect on the magnitude of this reduction.

The order of loading (pressure of axial load first) had a negligible effect on the buckling of the sheet and affected the sheet load by a very small percent.

Increasing sheet thickness caused a reduction in average stress at failure, corresponding to the smaller reinforcement ratio.

REFERENCE: Samuel Levy; Daniel Goldenberg; and George Zibritosky: Simply Supported Long Rectangular Plate Under Combined Axial Load and Normal Pressure. NACA TN NO. 949, 1944.

TN 1047 CLAMPED LONG RECTANGULAR PLATE UNDER COMBINED AXIAL LOAD AND NORMAL PRESSURE, Ruth M. Woolley, Josephine N. Corrick, and Samuel Levy, June 1946

ABSTRACT: A solution was presented for the buckling load and load carried after buckling of a clamped rectangular plate having a width-length ratio of 1:4 under combined normal pressure and axial load. Normal pressure causes a smaller increase in the buckling load of plates with clamped edges than of plates with simply supported edges. Neglecting the effect of lateral pressure on the sheet buckling load and on the load carried by the sheet after buckling is a conservative design in the elastic range. The sheet in airplane wings, fuselages, and hull bottoms constructed of sheet metal reinforced by stringers frequently is subjected to normal pressure as well as forces in the plane of the sheet.

CONCLUSIONS: 1. The initial general downward deflection of the sheet due to normal presssure, tends to disappear at high axial loads.

2. In the neighborhood of the buckling load, the load remained nearly constant while the deflection changed rapidly.

3. The deflection of the plate at the axial center line is a single long bulge for low axial force P and gradually builds up to a regular buckle pattern at larger values of P. The shifting of the buckle pattern is not accompanied by a drop in axial load.

4. Normal pressure causes a much greater proportionate increase in the buckling loads of plates with simply-supported edges than of plates with clamped edges.

5. The effect of normal pressure on the axial load for a given edge strain is negligible.

6. The buckling load at the highest normal pressure studies is 1.3 times the buckling load with no normal pressure.

Method used for solving for the amount of buckling was given in:

1. Levy, Samuel: Bending of Rectangular Plates with Large Deflections. NACA REP. NO. 737, 1942.

2. Levy, Samuel and Samuel Greenman: Bending with Large Deflection of Clamped Rectangular Plate with Length-Width Ratio of 1:5 under Normal Pressure. NACA TN NO. 853, 1942.

3. Crait, Prescott D.: A Short Method for Evaluating Determinants and Solving Systems of Linear Equations with Real or Complex Coefficients. Trans. A.I.E.E. vol. 60, 1941.

TN 1051 PRELIMINARY INVESTIGATION OF THE LOADS CARRIED BY INDIVIDUAL BOLTS IN BOLTED JOINTS, Manford B. Tate and Samuel J. Rosenfeld, May 1946

The present paper deals with the load distribution among the bolts of symmetrical butt joints. The test specimens were doubly symmetrical two and three butt joints made of 24-T aluminum alloy plates jointed by a single line of 1/4 inch alloy steel bolts. In the experimental tests the load which was distributed among the various bolts within and above the elastic range was determined.

The theoretical solution for the loads carried by bolts in symmetrical butt joints is based upon the following conditions:

1. The ratio of stress to strain is constant.

2. The stress is uniformly distributed over the cross sections of main plates and butt straps.

3. The effect of friction is negligible.

4. The bolts fit the holes initially, and the material of the plates in the immediate vicinity of the holes is not damaged or stressed in making the holes or by inserting the bolts.

The following conclusions are drawn from the results of this investigation:

1. From the tests of three bolt joints, there is about 10% difference between theoretical and experimental bolt loads within the elastic range. The bolt carried unequal loads in the elastic range.

2. A process of bolt load equalization took place beyond the limit of elastic action which for practical purposes caused the bolts to be loaded equally at joint failure. Because in the elastic range the bolts in the first rows carry far greater loads than interior bolts and joint failure may occur before complete equalization of bolt loads is realized.

3. Above the elastic range, the analytical curves can be extended in an empirical manner and this extension may be used to provide a basis for limit load design.

4. For joints in which the total load is imposed on two bolts, the distribution of load to the bolts at the ultimate joint load is less effected by fabrication inequalities and variability of materials than is the distribution in the elastic range.

TN 1054 IMPACT STRENGTH AND FLEXURAL PROPERTIES OF LAMINATED PLASTICS AT HIGH AND LOW TEMPERATURES, J. L. Lamb, Isabelle Albrecht and B. M. Axilrod, National Bureau of Standards, August 1946

A study of the effect of temperature on impact strength and flexural strength was made for several types of plastic laminates. The temperature range was from -70°F. to 200°F. Izod-impact tests were conducted to determine impact strengths. Data is presented in tabular form and several graphs showing the effect of temperatures on different properties are shown.

Results obtained by other investigators are reported in several sources including:

Field, Philip M.: Basic Physical Properties of Laminates. Modern Plastics, vol. 20, August 1943.

Oberg, T. T., R. T. Schwartz and Donald A. Shinn: Mechanical Properties of Plastic Materials at Normal and Subnormal Temperatures. Air Corps Tech. Rep. No. 4648, Modern Plastics, vol. 20

Norelli, P. and W. H. Gard: Temperature Effect on Strength of Laminates. Ind. Eng. Che., vol. 37, June 1945.

Some temperature effects on impact and flexural strengths can be seen in this table.

Type of Laminate	Change in Izod Impact Strength[a/] (-70°F(%)	200°F(%))	Change in Flexural Strength (-70°F(%)	200°F(%))
Grade C phenolic	-25 to -40[b/]	10 to 35	10 to 30	-30
Asbestos-fabric-phenolic	-15	-10	20	- 5
High strength paper phenolic	0 to -20	5 to -20	25	-40
Rayon fabric phenolic	0 to 35	0 to -10	30	-25
Glass fabric unsaturated polyester	45	-5 to -15	30	-30 to -35

a/ From value at 77°F.

b/ High pressure.

Test results showed:

1. Izod-impact strength temperature trend for the laminated plastics is different for the various types of material, but Izod-impact strength values for rayon fabric and glass fabric are greater than for the others.

2. Ratio of edgewise to flatwise impact strength for 1/2-inch thick phenolic laminates is constant.

3. An increase in flexural properties occurred for all laminates at low temperature and for all asbestos fabric at high temperatures. It stayed the same.

4. High strength paper and glass fabric laminates have outstanding flexural properties. Rayon fabric laminates have superior specific strength values.

5. Low pressure grade C phenolic compared favorably with high pressure.

Some work on humidity effects needs to be done.

TN 1058 STRAIN MEASUREMENTS AND STRENGTH TESTS OF 25-INCH DIAGONAL-TENSION BEAMS OF 75S-T ALUMINUM ALLOY, James P. Peterson, May 1946

A series of diagonal-tension beams were tested to determine the accuracy of previously published design charts and formulas. The tests were done on 75S-T aluminum alloy beams.

The results of stress and strain for this experimental test were in good agreement with published design charts and formulas for 24S-T aluminum alloy, differing by less than 10%; thus, design charts which have been available for more than 20 years are quite agreeable to actual conditions.

TN 1063 COMPARISON OF MEASURED AND CALCULATED STRESSES IN BUILT-UP BEAMS, L. Ross Levin and David H. Nelson, May 1946

A_T = area of beam.
A_F = area of flange.
A_{Fe} = effective area of flange.
F = vertical component of flange force.
I_T = moment of inertia of total effective area of beam.
I_F = moment of inertia of flange effective area.
L = length of beam.
M = bending moment

$N = \frac{2A_F}{ht} = 2\,A_F/A_T$

Q = moment about neutral axis of area between edge and point Y.
S = external shear force.
h = depth of beam between centroids of flanges.
t = thickness of shear web.
x = distance from tip of beam.
y = distance from neutral axis.
α = taper angle.
ε = tensile or compressive strain.
σ = normal stress in flange.
τ = shear stress in web.

<u>Beam Linearly Tapered in Depth</u>

$$\tau = \frac{S[\frac{A_F}{ht} + \frac{1}{4} - (\frac{y}{h})^2]}{A_F + ht/6} - \frac{M\tan\alpha[t/12 + \frac{2A_F{}^2}{h^2t} + \frac{2}{3}\frac{A_F}{h} - (y/h)^2(\frac{4A_F}{h} + t)]}{(A_F + \frac{ht}{6})^2}$$

$$F = \frac{M\ \tan\alpha}{h}\ \frac{I_F}{I_T} = \frac{M\ \tan\alpha}{h}\ \frac{A_F}{A_F + ht/6}$$

Ignoring moment of flanges about their own centroids.

Beam and Flanges Tapered at Same Rate

$$\tau = \frac{S[N + \frac{1}{2} - 2\ (y/h)^2]}{ht\ (N + 1/3)} - \frac{2M\ \tan\alpha[N + \frac{1}{2} - 6(y/h)^2]}{h^2t\ (N + \frac{1}{3})}$$

For Both Cases Above

$$\sigma = \frac{My}{I}\ \frac{1}{\cos^2\alpha}$$

Comparison of measured flange stresses with calculated flange stresses based on the net area and a fully effective web showed that the difference between the average measured stress and the average calculated stress in the central section of any of the beams did not exceed 6.1 percent.

TN 1066 STRESSES AROUND LARGE CUT-OUTS IN TORSION BOXES, Paul Kuhn and Edwin M. Moggio, May 1946

(a) For a large cut-out in a torsion box it is possible to calculate the primary stresses fairly easily.
(b)

$$\frac{\partial W}{\partial k} = \Sigma\ \frac{q}{G} - \frac{\partial q}{\partial K}\ \frac{s}{t} + \int \frac{\alpha}{E}\ \frac{\partial\alpha}{\partial k} \quad Adx = 0$$

k = fraction of total torque carried by shear webs in cut-out bay, (statically indeterminate and is calculated by applying the Principle of Least Work).
q = shear flow (running shear) lb/in.
t = thickness of wall, in.
A = cross-sectional area of member carrying direct stress, $in.^2$.
E = Young's modulus, kips/$in.^2$.
G = shear modulus, kips/$in.^2$.
S = surface area of one wall in one bay, $in.^2$.
W = internal work stored, kip-in.
α = direct stress, ksi.

gives the primary stresses. A load was applied to 5 torsion boxes with large cut-outs and the "primary" and "secondary" stresses were determined experimentally.
(c) It was concluded that the stress obtained from the theory are probably adequate for designing all components of the structure excepting the gross section of the cut-out cover, where the distribution of the shear stresses deviate so much from uniformity that

an additional theory of secondary stresses must be developed.

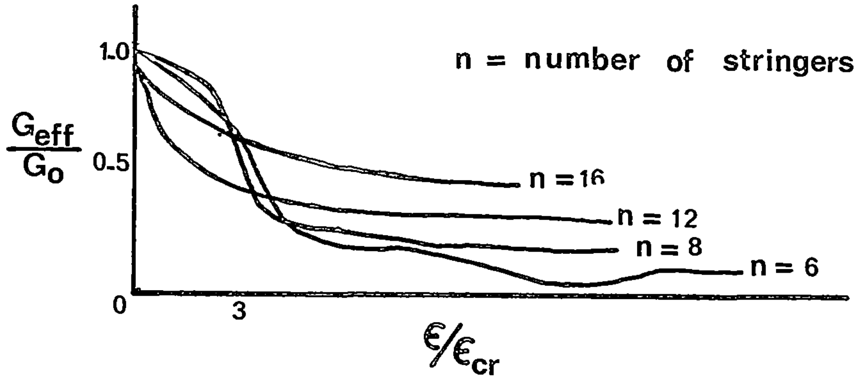
TN 1072 EFFECT OF BRAKE FORMING ON THE STRENGTH OF 24S-T ALUMINUM ALLOY SHEET, George J. Heimerl and Walter Woods, May 1946

(a) Tests were made to determine the effect of brake forming on the strength of 24S-T aluminum alloy sheet that had been formed to an inside bend radius of three times the sheet thickness.
(b) Forming appreciably raises both the tensile and the compressive yield stresses. The increase is greatest in the compressive yield stress for the with-grain direction. Forming only slightly raises the ultimate tensile strength and considerably decreases the percent elongation. A mark change is noted in the shape of the tensile and compressive stress-strain curves.

TN 1090 THE SHEARING RIGIDITY OF CURVED PANELS UNDER COMPRESSION, N. J. Hoff and Bruno A. Boley, August 1946

A detailed analysis is given in this report for the determination of the shearing rigidity of curved panels under compression, especially when the panels are in the buckled state. The testing was carried out on aluminum alloy (24S-T aluminum alloy) cylinders reinforced by stringers and rings. Performance of a given cylinder-stringer combination was determined by measuring the angle of twist of the cylinder caused by a known torque while the cylinder was subjected to uniform axial compression.

CONCLUSIONS: 1. It was found that the shearing rigidity decreases with increasing compression.



2. From the above figure the following equation was developed.

$$\frac{G_{EFF}}{G_o} = (1-N)e^{-N(\varepsilon/\varepsilon_{cr})} + N \text{ where } N = 0.0275[(2\pi r/d) + 1]$$

3. The above equation is useful $0 < \varepsilon/\varepsilon_{cr} < 12$
$1 < r/d < 2.5$

where:

G_o = shear modulus of cylinder at zero compressive load.
G_{EFF} = effective shear modulus.
ε = normal strain.
ε_{cr} = buckling strain of panel.
r = radius of cylinder.
d = width of panel measured along circumference.

REFERENCES: 1. NACA TN 1014
TN 1013
TN 968
TN 939
TN 938

2. Timoshenko, S.: Theory of Plates and Shells. 1st ed. McGraw-Hill Book Co., Inc., 1940.

TN 1095 MARINE EXPOSURE TESTS ON STAINLESS STEEL SHEET, Willard Mutchler, February 1947

This report deals with weathering tests on three types of metals.

1. aluminum rich alloys
2. magnesium rich alloys
3. stainless steels.

The purpose of this report was to study the effects of marine exposure on chromium-nickel alloys of the 18:8 type with and without small additions of columbiun, molybdenum and titanium as alloying elements. Also the effects of locality of exposure, of shot-welding, of various surface finishes and treatments, and of contact with dissimilar metals was studied in detail. The panels were exposed for 36 months.* This report is the last of a series of papers presented on the corrosion tests of stainless steels conducted from 1938 to 1945.

CONCLUSIONS: 1. Rust formation was greatest during the first six months of exposure.

2. Highly polished surfaces showed much less suceptibility to rust than dull finishes which were attacked vigorously.

3. Regular cleaning of the polished surfaces retarded rust greatly as did a good paint routine (primer and cover coat) on the other surfaces.

4. Molybdenum (2.5 → 3.5%) alloy steels showed superiority to rust formation in all cases; even when shot welded.

5. Fatigue tests showed the molybdenum alloy steels superior to other types, and equally as strong whether weathered or immersed.

6. Paint adhered only temporarily to stainless steel, offering only temporary protection.

7. Aluminum and magnesium alloys, when in contact with stainless steels, were highly anodic and were severely attacked when in contact with them.

8. Aluminum foil proved effective in reducing rust formation on the joints of stainless steel strips when used as an insulator between the strips.

TN 1097 OBSERVATIONS ON THE BEHAVIOR OF SOME NON-CIRCULAR ALUMINUM ALLOY SECTIONS LOADED TO FAILURE IN TORSION, R. L. Moore, NACA, February 1947

EQUATIONS: Specimen must be symmetrical about centerline. Ends restrained from warping.

1. Stress due to warping

$$\sigma = \frac{ET}{GJa} \frac{\sinh x/a}{\cosh L/2a} u$$

2. Stress due to large angle of twist

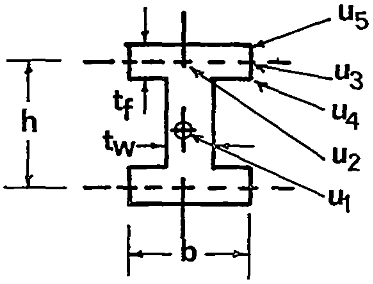
$$\sigma = E \frac{(\Theta r)^2}{2} - \varepsilon_o$$

3. $$\Psi = \frac{T}{JG}\left[x - a\frac{\sinh \frac{x}{a}}{\cosh \frac{L}{2a}}\right]$$

4. $$\theta = \frac{T}{JG}\left[1 - \frac{1}{\cosh \frac{L}{2a}}\right]$$

σ = longitudinal stress at section a-a.
x = distance of section a-a from center.
L = length of specimen between restrained ends.

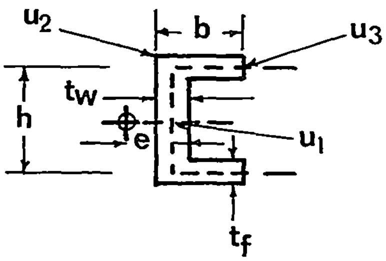
$a = \frac{\sqrt{EC_{BT}}}{JG}$ C_{BT} given in table.
u = warping factor given in table.
Θ = twist, radians per inch.
r = distance from center of twist.
ε_o = for machined I, $\varepsilon_o = 0.15\Theta^2$
extruded I, $\varepsilon_o = 0.63\Theta^2$
extruded channel and Z, $\varepsilon_o = 0.52\Theta^2$.
Ψ = twist of section a-a.
θ = twist of center of member.



$$u_1 = 0$$
$$u_2 = 0$$
$$u_3 = \pm \frac{hb}{4}$$
$$u_4 = \pm \frac{hb}{4} + \frac{bt}{4}$$
$$u_5 = \pm \frac{hb}{4} + \frac{bt}{4}$$

$$C_{BT} = \frac{I_f h^2}{2} + \underbrace{\frac{1}{72}\left[A_f^3 + \frac{Aw^3}{2}\right]}$$

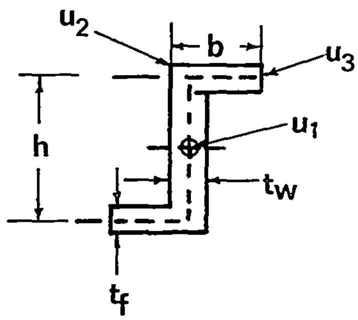
Omit this term for extruded I.



$$u_1 = 0$$
$$u_2 = \pm \frac{h}{2}\left(e + \frac{tw}{2}\right)$$
$$u_3 = \pm \frac{h}{2}(b-e)$$

$$C_{BT} = \frac{I_f h^2}{2}(4 - 6\, e/b)$$

$$e = \frac{3bA_f}{Aw + 6A_f}$$



$$u_1 = \pm \frac{hb}{2}\frac{A_f}{A}$$
$$u_2 = \pm \frac{hb}{2}\left(\frac{A_f b}{A} + \frac{tw}{2}\right)$$
$$u_3 = \pm \frac{hb}{2}\left(1 - \frac{A_f}{A}\right)$$
$$C_{BT} = \frac{I_f h^2}{2}\left[4 - 6\frac{A_f}{A}\right]$$

TN 1098 EFFECT OF CHANGE IN CROSS-SECTION UPON STRESS DISTRIBUTION IN CIRCULAR SHELL SUPPORTED FRAMES, David H. Nelson, NACA, July 1946

Report analyzes rings of constant cross-section and rings roughly proportional to local stress level, that is, beefed up with doublers.

NOMENCLATURE

M = local bending moment.

P_a = radial applied load.

R = radius of ring.

θ = station of change in cross-section, degrees; measured in clockwise direction from point 180° from point of applied load.

ϕ = station of bending moment and bending stress, radians; measured in same manner as θ.

η, ξ = bending factors determined by manner of reinforcement.

Radially Loaded Ring

$$M = \frac{P_a R}{\pi} \left(\frac{\phi}{2} \sin\phi + \frac{\cos\phi}{4} - \frac{1}{2} \right)$$ uniform cross section

$$M = \frac{P_a R}{\pi} \left(\frac{\phi}{2} \sin\phi + \xi \cos\phi - \eta \right)$$ reinforcement placed symmetrically about point of applied load

(Table 1)

Applied Moment (variable cross-section)

$$M = \frac{M_a}{2\pi} (\phi - \eta \sin\phi) \qquad 0 \leq \phi \leq \pi$$

$$M = \frac{M_a}{2\pi} (\phi - \eta \sin\phi - 2\pi) \qquad \pi < \phi < 2\pi$$

(Table 2)

Tangential Load (constant cross-section, but used for variable cross-section)

$$M = \frac{T_a R}{4\pi} [3 \sin\phi - 2\phi (\cos\phi + 1)] \qquad 0 < \phi < \pi$$

$$M = \frac{T_a R}{4\pi} [3 \sin\phi + (4 - 2\phi) (\cos\phi + 1)] \qquad \pi < \phi < 2\pi$$

Table 1. Value of bending factors for a single radial load

θ / r	90		120		135		150		165	
	η	ξ	η	ξ	η	ξ	η	ξ	η	ξ
1	.500	.250	.50	.25	.50	.25	.50	.25	.50	.25
2	.502	.297	.536	.325	.545	.336	.542	.331	.526	.302
3	.513	.327	.564	.376	.572	.387	.562	.370	.537	.323
4	.525	.351	.585	.414	.590	.421	.574	.393	.542	.334
5	.537	.372	.602	.444	.603	.444	.582	.409	.546	.341
6										
7	.559	.409	.626	.486	.620	.476	.592	.428	.550	.349
8	.569	.424	.635	.502	.626	.487	.595	.434	.552	.352
9										
10	.587	.452	.650	.527	.635	.503	.6	.443	.553	.356

Table 2.

θ / r	90°	120°
1	2.00	2.00
2	1.758	1.785
3	1.637	1.700
4	1.563	1.655
5	1.515	1.625
10	1.405	1.574

TN 1100 ELASTIC PROPERTIES IN TENSION AND SHEAR OF HIGH STRENGTH NON-FERROUS METALS AND STAINLESS STEEL-EFFECT OF PREVIOUS DEFORMATION AND HEAT TREATMENT, R. W. Mebs and D. J. McAdam, Jr., March 1947

(a) Experiments were run to investigate the influence of plastic deformation and annealing temperature on the tensile and shear elastic properties of nickel, monel, Inconel, copper, 13:2 Cr-Ni steel, and 18:8 Cr-Ni steel, and aluminum-monel.
(b) This report has 41 pages of tables and graphs giving:
Tables:
- Chemical composition
- Thermal treatment
- Work-hardening rate
- Mechanical treatment
- Hystersis

Graphs:
- Hystersis loops
- Stress-strain
- Stress-set
- Stress-modulus of elasticity
- Stress-prior extension
- Proof stress-prior deformation
- Proof stress-prior extension
- Proof stress-annealing temperature
- Modulus of elasticity-prior temperature
- Modulus of elasticity-Poisson's ratio
- Poisson's ratio-annealing temperature

TN 1102 THE CRYSTAL STRUCTURE AT ROOM TEMPERATURE OF EIGHT FORGED HEAT-RESISTING ALLOYS, J. Howard Kittel, July 1946

(a) In order to determine the crystal structure of eight leading forges alloys-S816, S590, Gamma Columbium, Hastelloy B, 16-25-6, 19-9DL, Nimonic 80, and N155 an investigation was conducted by x-ray diffraction.
(b) It was found that the predominant phase occurring in each alloy was a solid solution of the alloying elements present in relatively large amounts. The crystal structure of the solid solution was the face-centered cubic type. Alloys S816, S590, and Gamma Columbium, which contain the largest percentages of columbium, showed diffraction lines from a second phase that is believed to be columbium carbide, CbC.

TN 1103 THE LAGRANGIAN MULTIPLIER METHOD OF FINDING UPPER AND LOWER LIMITS TO CRITICAL STRESSES OF CLAMPED PLATES, Bernard Budiansky and Pai C. Hu, July 1946

ABSTRACT: The theory of Lagrangian multipliers is applied to the problem of finding upper and lower limits to the true compressive buckling stress of a clamped rectangular plate. The paper presents the details of application as well as the fundamentals and principles of the Lagrangian multiplier method by demonstrating the use of the method to obtain both upper and lower limits to the true compressive buckling stress of a rectangular plate clamped along all edges.

CONCLUSIONS: 1. The Lagrangian multiplier method can be used to compute accurate upper and lower limits to the compressive buckling stress of a clamped rectangular plate, thereby bracketing the true results.

2. From a consideration of rapidity of convergence toward the exact solution in clamped plate problems, it is preferable to use an expansion that satisfied the zero-slope boundary conditions term by term rather than the zero-deflection boundary conditions.

3. Because of the fact that the Lagrangian multiplier method permits the effects of infinite subsets of expansion terms to enter into the solution, it is believed that a particular stability determinant derived by the Lagrangian multiplier method will, in general, yield a closer upper limit than that obtained from a determinant of equal order in the Rayleigh - Ritz method.

4. It is expected that the method of Lagrangian multipliers may be useful in the analysis of other stability and vibration problems. In particular, the method may be immediately applied to the determination of vibration frequencies of clamped plates, and to the determination of buckling stresses of clamped plates under compression in two directions.

TN 1105 STATIC AND DYNAMIC CREEP PROPERTIES OF LAMINATED PLASTICS FOR VARIOUS TYPES OF STRESS, Joseph Marin, Pennsylvania State College, February 1947

Creep tests were conducted so that the creep-stress relations could be studied for the following types of loadings:

1. Simple tension
2. Static torsion
3. Static bending
4. Static tension with fluctuating axial stress.

Five laminated plastics were tested. They were:

1. Glass fabric laminate with polymerizing type resin
2. High strength paper base plastic
3. High strength rayon laminate with phenolic resin
4. Grade C phenolic resin laminate
5. Cotton fabric laminate as used in Grade C but molded with low pressure.

Three types of tests were conducted:

1. Static tests
2. Repeated stress tests
3. Creep tests

The data is presented in tabular form giving mechanical properties under various loads and creep test data. Load-strain, load-deflection, torque twist, stress-strain hystersis loops, and creep with time diagrams are presented.

It was found that:

1. Relative values of mechanical properties were not in the same order for different types of loads.

2. Effects of repeated stressing varied, for most tests ductility and stiffness decreased and yield strength increased.

3. Creep resistance varied with ultimate tensile strength except for torsion creep tests on square specimens.

In general the type of job should determine the plastic used.

TN 1119 INCREASING THE COMPRESSIVE STRENGTH OF 24S-T ALUMINUM ALLOY SHEET BY FLEXURE ROLLING, George J. Heimerl and Walter Woods, August 1946

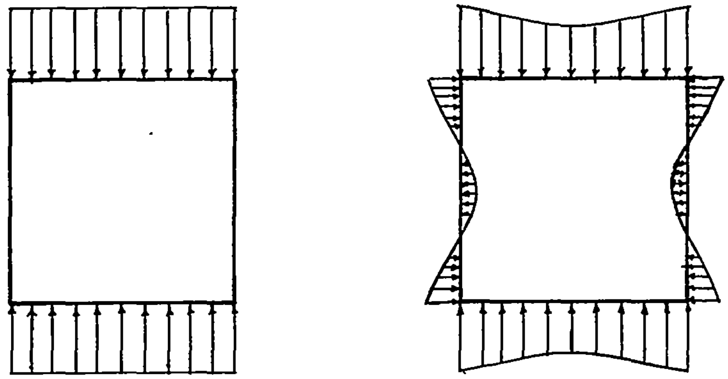
A method was devised to increase the compressive strength of 24S-T aluminum alloy. The sheet was alternately bent and then straightened by rolling. The tests showed that the greatest increase was in compressive yield stress in the with-grain direction regardless of the direction of rolling. The increase was greater as the radius of flexure became smaller and as the number of steps was increased. The tensile properties were little affected.

TN 1124 EFFECT OF SMALL DEVIATIONS FROM FLATNESS ON EFFECTIVE WIDTH AND BUCKLING OF PLATES IN COMPRESSION, Pai C. Hu, Eugene E. Lundquist and S. B. Batdorf, Langley, September 1946

An analysis of simulated test data calculated by large-deflection theory and applying to the elastic behavior of simply supported square plates under compression is presented. The effects of initial deviation from flatness (a realistic condition) on buckling properties as predicted theoretically for perfectly flat plates is investigated. The following properties associated with buckling are discussed as to the effects of deviation from initial flatness.

1. Growth of buckles with increase in load.
2. Effective width of plate.
3. Experimentally determined buckling or critical stress.
4. Applicability of the Southwell plot method of predicting theoretical critical stresses for perfectly flat plates from experimental observations on actual plates.

The plates considered in this analysis are loaded in the following manner:



Loading Before Buckling **Loading After Buckling**

The solutions of the Von Kārmān large-deflection equations by method of Samuel Levy (reference 1). Levy, Samuel: Bending of Rectangular Plates with Large Deflections. NACA TN 846, 1942 are required in this method. These solutions are outlined in an appendix along with an appendix extending this method to square plates.

The types of initial deviations considered in this numerical analysis are those components of the buckle pattern that first become predominate after the assumed flat square plates buckles. For perfectly flat plates under a compressive load such as the one mentioned in this paper buckling does not progress to any degree until the critical buckling stress is reached. For a plate with original deviation from flatness, however, the buckling starts at very low stress values but does not progress very much until the range of the theoretical buckling stress is reached. It was found that initial deviations from flatness produce the greatest effect near the theoretical flat-plate critical stress. In spite of some uncertainity expressed in the report it is clear that initial deviations reduce the experimentally determined buckling stress. For all values of stress the effective width of load carrying capacity of a plate with an initial deviation from flatness is reduced while the effective width for stiffness against further compression is less than that of a flat plate at stresses below the theoretical critical stress but greater at stresses above.

At stresses well above or below the critical stress, initial deviations are of little importance. The Southwell plot method presented in Timoshenko, S.: Theory of Elastic Stability, McGraw-Hill Book Co., Inc., 1936, does not give satisfactory results for actual plates with deviations since the stress-deflection curves for these plates do not approximate rectangular hyperbolas as the method requires.

Graphs are presented showing variation of different properties with and without initial deviations.

The most marked effect of small deviations in plates was the fact that the buckle growth is high in the region around the critical stress, in the other regions, high and low stress, the plate acts much the same as an initially perfectly flat plate.

TN 1125 EFFECT OF RATIO OF RIVET PITCH TO RIVET DIAMETER ON THE FATIGUE STRENGTH OF RIVETED JOINTS OF 24S-T ALUMINUM ALLOY SHEET, Harold Crate, David W. Ochiltree and Walter T. Graves, NACA, 1946

P_f = load per rivet required to produce failure in a given number of cycles.
P_u = ultimate load per rivet to produce failure.
P = rivet pitch (distance between rivets).
d = rivet diameter.

CONCLUSIONS: 1. For each sheet thickness, there is an optimum value of P/d which yields maximum value of P_f/P_u.

2. Optimum value of P/d independent of cycles.

TN 1126 STRESS RUPTURE OF HEAT-RESISTING ALLOYS AS A RATE PROCESS, E. S. Machlin and A. S. Nowick, NACA, 1946

Recommends presenting stress-rupture data on semi-log plot, instead of log-log. Presents stress-rupture equation to space experiments (to get accurate results from fewest data points).

$$\log t_r = \frac{A + BT - D\sigma}{T}$$

A,B,D = constants of structure, composition.
T = temperature (°R).
t_r = time for rupture.

TN 1130 EVALUATION OF TWO HIGH-CARBON PRECISION-CAST ALLOYS AT 1700° AND 1800°F. BY THE RUPTURE TEST, E. E. Reynolds, J. W. Freeman and A. E. White, September 1946

This report was to investigate the strengths of the NT-2 alloy and the VT2-2 alloy under high temperatures. The results of the tests are as follows:

1. The high carbon NT-2 alloy has a higher rupture strength than the higher carbon VT2-2 alloy at 1700° and 1800°F.

2. For time periods up to 500 hours the NT-2 alloy had better rupture strength than the best alloy X-40 tested at this time.

The VT2-2 was also stronger over this time period than the X-40 alloy.

3. For periods over 1000 hours the lower carbon alloys seem to be stronger than either the NT-2 or VT2-2 alloys.

4. The ductility of the X-40 alloy was higher than that of either the NT-2 or VT2-2 alloys at 1700° and 1800°F.

TN 1136 BEARING STRENGTH OF SOME SAND-CAST MAGNESIUM ALLOYS, R. L. Moore, NACA, 1947

Tests made on AM403, AM260, AM265, which met specifications on these alloys.

	Edge Distance		
Ratio	1 D	1.5 D	2 D or Greater
Bearing Yield / Tensile Yield	1.5	2.0	2.5
Bearing Ultimate / Tensile Ultimate	0.8	1.2	2.6

TN 1137 DEVICE FOR MEASURING PRINCIPLE CURVATURES AND PRINCIPLE STRAINS ON A NEARLY PLANE SURFACE, A. E. McPherson, NACA, 1947

Development of device as described in title to measure principle strains on a panel to within $\pm$ 2%. Equations and description given.

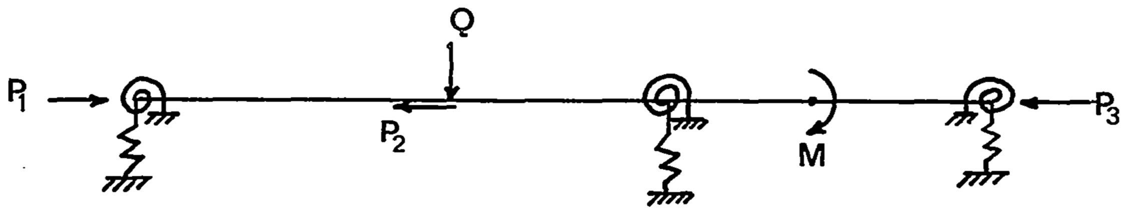
TN 1150 A RELAXATION PROCEDURE FOR THE STRESS ANALYSIS OF A CONTINUOUS BEAM COLUMN ELASTICALLY RESTRAINED AGAINST DEFLECTION AND ROTATION AT THE SUPPORTS, Pai C. Hu and Charles Libove, Langley, October 1946

A practicable procedure for the stress analysis of an elastically supported continuous beam-column having supports represented by deflectional and rotational springs. This method uses a relaxation process to determine deflections and rotations of supports and the deflection curve, shears, and bending moments using simple equations and graphs. This method is applicable below the proportional limit. Tables and graphs presented to facilitate the use of this method have been prepared for axial compression and spans with uniform flexural stiffness. The following reference is useful in this connection:

Niles, Alfred S., and Joseph S. Newell: Airplane Structures. Vol. II, Third ed., John Wiley and Sons, Inc., 1943, pp. 62-155.

Three appendicies are given. One is on the derivation of the balancing, induced-shear, and induced-moment equations, another presents the deflection equations used in this method, and the last gives the preliminary computations of an illustrative example presented in the test of the report.

This method is applicable to systems such as the one represented by this figure:



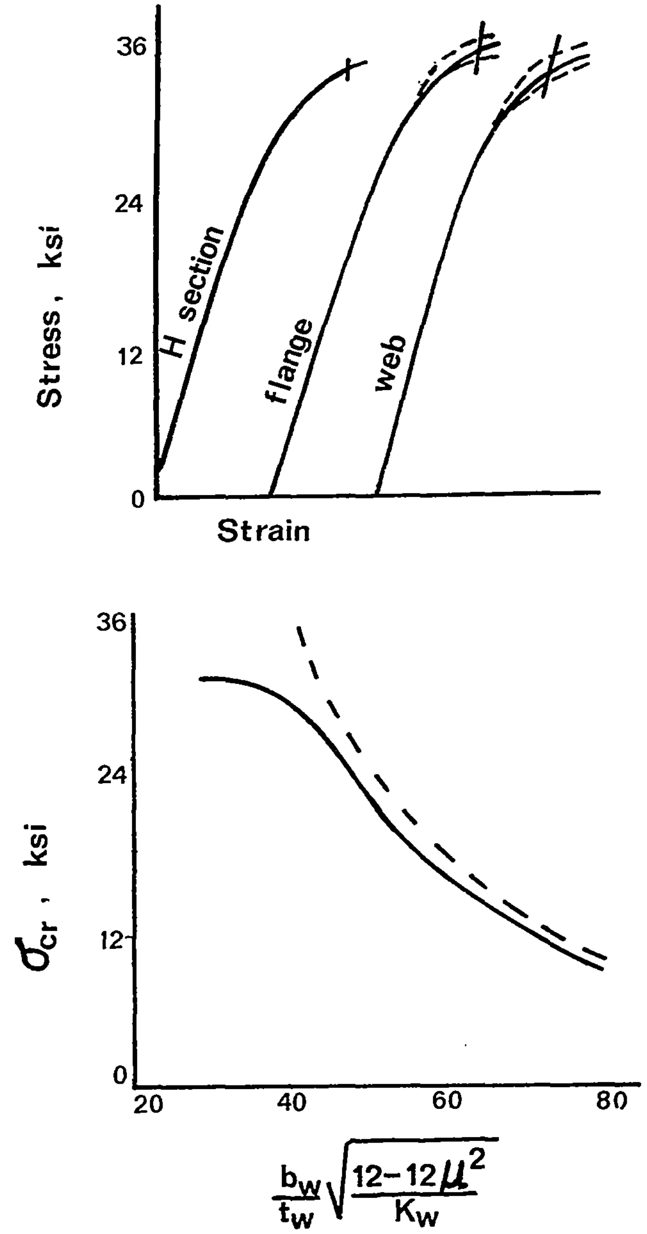
In general this method entails the following procedure:

1. All joints are frozen (prohibited from movement).
2. Fixed end shears and moments are calculated.
3. Locking force is calculated as the algebraic sum of fixed end shears at the joint and locking moment as the algebraic sum of fixed end moments at the joint (locking force is the force required to lock the joint, etc.).
4. Balancing force and moment are then equal and opposite to locking force and moment.
5. Equilibrium is then obtained and a vertical deflection δ and rotation θ result. This deflection and rotation can then be calculated using the deflection equations.

TN 1156 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS, EXTRUDED O-1HTA MAGNESIUM ALLOY, George J. Heimerl and Donald E. Niles, January 1947

(a) Tests were run to find the column and plate compressive strengths of extruded O-1HTA magnesium alloy within and beyond the elastic range.

(b)



bw, tw = width and thickness of web.

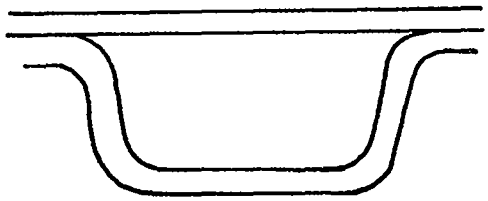
k_w = nondimensional coefficient used with bw and tw in plate buckling formula from (Kroll, W. D., Fisher, Gordon P., and Heimerl, George J.: Charts for Calculation of the Critical Stress for Local Instability of Columns with I-, Z-, Channel, and Rectangular-Tube Section. NACA ARR No. 3K04, 1943.

μ = Poisson's ratio, taken as 0.3 for extruded 0-1HTA magnesium.

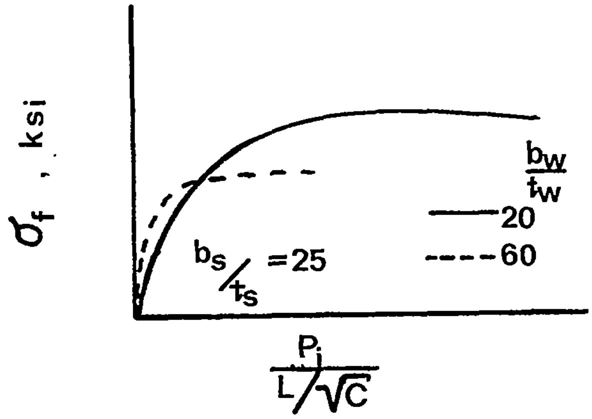
TN 1157 COMPRESSIVE STRENGTH OF 24S-T ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL FORMED HAT-SECTION STIFFENERS, Evan H. Schuette, Saul Barab, and Howard L. McCracken, December 1946

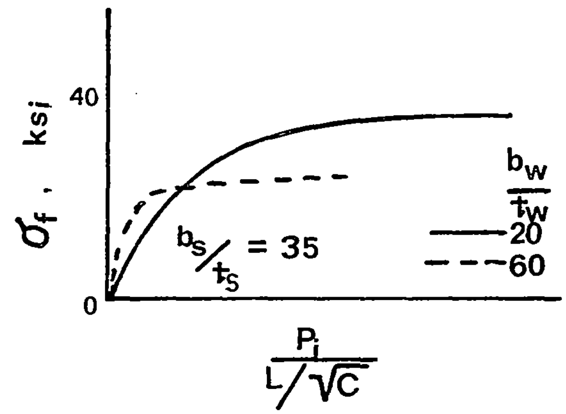
(a) Tests were run on sheets of 24S-T aluminum reinforced with hat-shaped stiffeners. The thickness of the stiffener material was 0.625 times the skin thickness. Comparative envelope curves are presented for hat-stiffened and Z-stiffened panels.

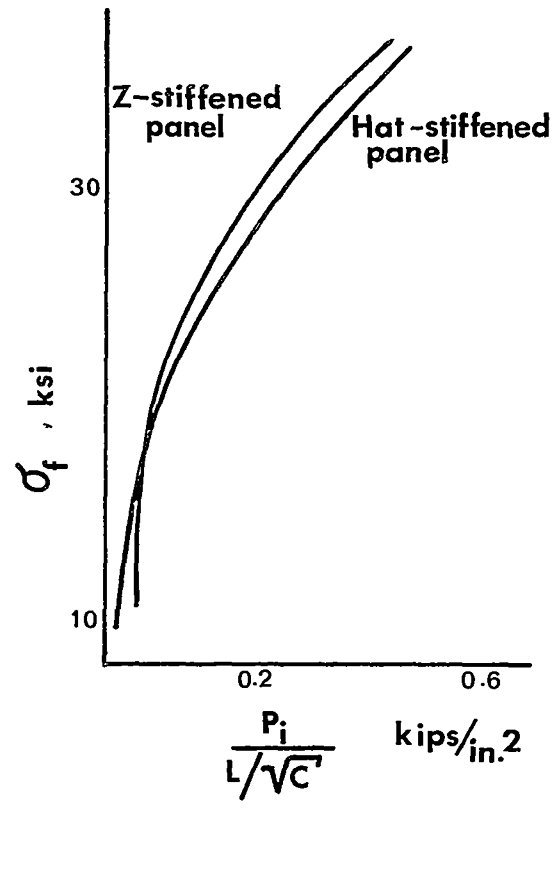
(b)



Hat - Stiffener




40
0
σ_f, ksi
b_w/t_w
20
60
$b_s/t_s = 35$
$\frac{P_i}{L/\sqrt{C}}$


Z-stiffened panel
Hat-stiffened panel
30
10
σ_f, ksi
0.2
0.6
$\frac{P_i}{L/\sqrt{C}}$ kips/in.^{2}

TN 1162 EFFECT OF BRAKE FORMING IN VARIOUS TEMPERS ON THE STRENGTH OF ALCLAD 75S-T ALUMINUM ALLOY SHEET, Walter Woods and George J. Heimerly - Langley Mem. Aero. Lab., January 1947

CONCLUSIONS:

1. When Alclad 75S sheet was formed (r = 3t) in the 0 and W tempers and subsequently heat treated to the T temper, the tensile and compressive strengths were either increased or little affected as compared with those of similarly treated unformed material.

2. When Alclad 75S-T sheet "as received" was formed (r = 6t), the tensile yield stress was reduced about 7 percent for the with-grain direction and about 1 percent for the cross-grain direction, whereas the ultimate and compressive yield stresses were increased somewhat.

3. In all cases, the percent elongation in 2 inches was reduced from about 14 or 15 percent for the flat material to about 10 or 12 percent for the formed material.

TN 1172 COMPARATIVE TESTS ON EXTRUDED 14S-T AND EXTRUDED 24S-T HAT-SHAPED STIFFENER SECTIONS, Marshall Holt and G. W. Feil, March 1947

From the edge-compression tests of panels of 24S-T sheet with extruded 14S-T and 24S-T stiffeners, the following conclusions can be drawn:

1. The extruded 14S-T stiffeners have compressive yield strength, based on full-section tests, 20% higher than those of the 24S-T stiffeners.

2. The panels using 14S-T stiffeners are stronger than those using 24S-T stiffeners by 5% when the 24S-T sheet thickness is 25% greater than that of the stiffeners and by 12% when the 34S-T sheet thickness is 25% less than that of the stiffeners.

3. The percent of extra strength gained by using higher strength stiffeners diminishes rapidly as the ratio of sheet area to stiffener area increases.

4. The average stress at which buckling occurred was higher for panels using higher strength stiffeners. In both cases the load at first buckling of the sheet was about 75% of ultimate.

5. Permanent buckling occurred almost simultaneously with elastic buckling.

6. Secondary failure (fractured stiffeners or rivets) occurred after the ultimate load was reached.

TN 1176 STRESSES AROUND RECTANGULAR CUT-OUTS WITH REINFORCED COAMING STRINGERS, Paul Kuhn, Norman Rafal and George E. Griffith, January 1947

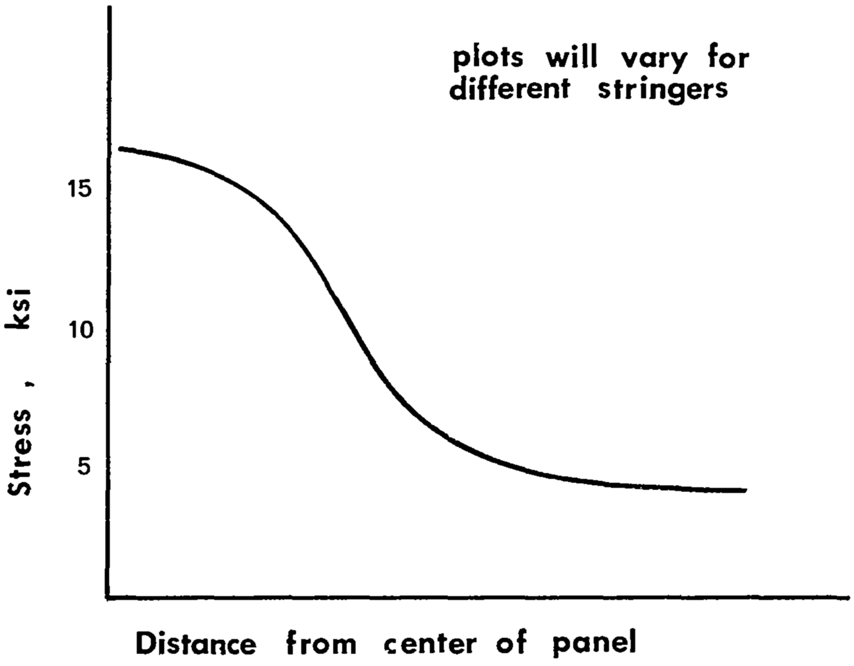
Strain measurements and strength tests were made on six skin-stringer panels under axial loads. Six panels were tested--three with rectangular cut-outs and three with long cut-outs.

The stresses were calculated by the method given in:

Kuhn, Paul, John E. Duberg, and Simon H. Diskin: Stresses Around Rectangular Cut-Outs in Skin-Stringer Panels Under Axial Loads - II. NACA ARR. No. 3J02, 1943.

This method assumes that all stringers are of constant cross section.

A plot of the results of span-wise stress resulting from a load of 20 kips applied at the end of the stringer panel is shown below. These results obtained from Tucker optical strain gage measurements agreed well with the calculated values.



TN 1177 EFFECT OF RIVET OR BOLT HOLES ON THE ULTIMATE STRENGTH DEVELOPED BY 24S-T AND ALCLAD 75S-T SHEET IN INCOMPLETE DIAGONAL TENSION, L. Ross Levin and David H. Nelson, Langley Mem. Aero. Lab., January 1947

Strength tests made on shear webs of 24S-T and Alclad 75S-T aluminum alloy to determine the effect of rivet or bolt holes on the allowable shear stress of the materials. In order to obtain data on specimens that failed at different stages of incomplete diagonal tension, one type of specimen--a flat sheet with closely spaced stiffeners--approached a condition of pure shear stress; the other - a flat sheet without stiffeners - gave well-developed diagonal tension. The rivet factor C_r, (pitch minus diameter) divided by pitch, was varied from about 0.81 to about 0.62 by using a constant pitch and changing the size of the holes. These shear web tests indicated:

1. The shear stresses on the gross section at failure were almost constant for all values of C_r investigated if the other properties of the web were not changed.

2. For webs with the edges clamped between two heavy plates and stiff washers, the average shear stress on the gross section at failure was 36.9 ksi for the stiffened Alclad 75S-T webs, 31.9 ksi for the unstiffened Alclad 75S-T webs, 30.3 ksi for the stiffened 24S-T webs, and 25.8 ksi for the unstiffened 24S-T webs.

3. When the webs were fastened with a heavy plate along one side with the heads of the rivets or bolts bearing directly on the sheet on the opposite side, the shear strength of the webs was about 11 percent less than when the edges were well supported on both sides.

TN 1187 FORMULAS FOR ADDITIONAL MASS CORRECTIONS TO THE MOMENTS OF INERTIA OF AIRPLANES, Frank S. Malvestuto and Lawrence J. Gale, February 1947

Formulas are presented for additional mass and moments of inertia of airplanes that are swung as a part of the pendulum.

SYMBOLS

b = span of surface
S = area of surface
A = aspect ratio of surface $(b^2/5)$
C_r = root chord of surface
C_t = tip chord of surface $(\frac{2S}{b} - C_r)$
$\bar{C}$ = mean chord of surface (s/b)
λ = plan form taper of surface (C_r/C_t)
Γ = dihedral of wing or horizontal tail

L_f = length of fuselage
W = geometric average width of fuselage
d = geometric average depth of fuselage
ℓ = component in plane of surface of perpendicular distance between axis of rotation and centroid of area of surface
ℓ_{fx} = distance from centroid of side area of fuselage to axis of rotation parallel to and in the plane of the X-axis
ℓ_{fy} = component of distance in the X-Y principal plane of fuselage of the perpendicular distance between the centroid of the plan area of fuselage, and the axis rotation parallel to and in the plane of the Y-axis
ℓ_{fz} = distance from centroid of side area of fuselage to axis of rotation parallel to and in the plane of the Z-axis
ℓ_{tx} = distance from centroid of vertical-tail area to axis of rotation parallel to and in the plane of the X-axis
ℓ_{ty} = component of distance in the X-Y plane of fuselage of the perpendicular distance between the centroid of horizontal tail area and the axis of rotation parallel to and in the plane of the Y-axis
ℓ_{tz} = distance from centroid of vertical tail area to axis of rotation for Z-swinging
K = coefficient of additional mass of a flat rectangular plate
K' = coefficient of additional moment of inertia of a flat rectangular plate
D_λ = taper-ratio correction factor
$D_{\Gamma\Gamma}$ = dihedral correction factor
K_{fx}, K_{fy}, K_{fz} = coefficients of additional mass of equivalent ellipsoids for motion along the X-, Y-, and Z-axes
K'_{fx}, K'_{fy}, K'_{fz} = coefficients of additional moments of inertia of equivalent ellipsoids about the X-, Y-, and Z-axes
M_a = additional mass of both
I_a = additional moment of inertia
I_x, I_y, I_z = moments of inertia about the X-, Y-, and Z-body axes
I_{xa}, I_{ya}, I_{za} = total additional moments of inertia about X-, Y-, and Z-body axes
I'_{xa}, I'_{ya}, I'_{za} = total additional moments of inertia about X-, Y-, and Z-swinging axes
ρ = density

SUBSCRIPTS

w = wing
fus = fuselage
ht = horizontal tail
vt = vertical tail

EQUATIONS:

Wing and Tail Surfaces:

In translation $M_a = \frac{\pi\rho}{4} K'\bar{C}^2 b$

Rotating about chord $I_a = \frac{\pi\rho}{48} K'\bar{C}^2 b^3 = \frac{\pi\rho}{48} D_\lambda D_\Gamma K'\bar{C}^2 b^3$

Rotating about span $I_a = \frac{\pi\rho}{48} K'\bar{C}^3 b^2$

Rotating about non-centroidal axis $I'_a = I_a + M_a \ell^2$

Rotating about axis parallel to chord $I'_a = \frac{\pi\rho}{48} K'\bar{C}^2 b^3 + \frac{\pi\rho}{48} K'\bar{C}^2 b \ell^2$

Fuselage:

Motion along Y-axis $M_a = \rho K_{fy} L_f W d$

Motion along Z-axis $M_a = \rho K_{fz} L_f W d$

Rotations about Z and Y axes

Y-axis $I_{ya} = \frac{\rho}{5} K'_{fy} L_f W d\left(\frac{L_f^2}{4} + \frac{3d^2}{2\pi}\right)$

X-axis $I_{za} = \frac{\rho}{5} K'_{fz} L_f W d\left(\frac{L_f^2}{4} + \frac{3W^2}{2\pi}\right)$

Rotations about non-principal axes $I'_a = I_a + M_a \ell^2$

EXAMPLES:

$$I'_{ya} = \frac{\rho}{5} K'_{fy} L_f W d\left(\frac{L_f^2}{4} + \frac{3d^2}{2\pi}\right) + \rho\left(K_{fz} L_f W d \, \ell_{fy}{}^2\right)$$

$$I'_{za} = \frac{\rho}{5} K'_{fz} L_f W d\left(\frac{L_f^2}{4} + \frac{3W^2}{2\pi}\right) + \rho\left(K_{fy} L_f W d \, \ell_{fz}{}^2\right)$$

NOTE: NO CORRECTION REQUIRED FOR X-AXIS.

Complete Plane:

$$I'_{xa} = \frac{\pi\rho}{48}(K'D_\lambda D_\Gamma S^2 b)_w + \rho(K_{fy}L_f Wd\,\ell_{fx}^{\;2})_{fus}$$

$$I'_{ya} = [\frac{\rho}{5}K'_{fy}L_f Wd(\frac{L_f^{\;2}}{4} + \frac{3d^2}{2\pi})]_{fus} + \rho(K_{fz}L_f Wd\,\ell_{fy}^{\;2})_{fus}$$

$$+ \frac{\pi\rho}{4}(\frac{KS^2}{b}\,\ell_{ty}^{\;2})_{ht}$$

$$I'_{za} = [\frac{\rho}{5}K'_{fz}L_f Wd(\frac{L_f^{\;2}}{4} + \frac{3W^2}{2\pi})]_{fus} + \rho(K_{fy}L_f Wd\,\ell_{fz}^{\;2})_{fus}$$

$$+ \frac{\pi\rho}{4}(KS^2/b\;\ell_{tz}^{\;2})_{vt}$$

TN 1204 EFFECT OF CENTRIFUGAL FORCE ON THE ELASTIC CURVE OF A VIBRATING CANTILEVER BEAM, Scott H. Simpkimson, Laurel J. Eatherton and Morton B. Millenson, 1947

Purpose of investigation to discover stress level of aircraft prop in flight, to determine effect of centrifugal load on stress level of prop.

CONCLUSIONS:

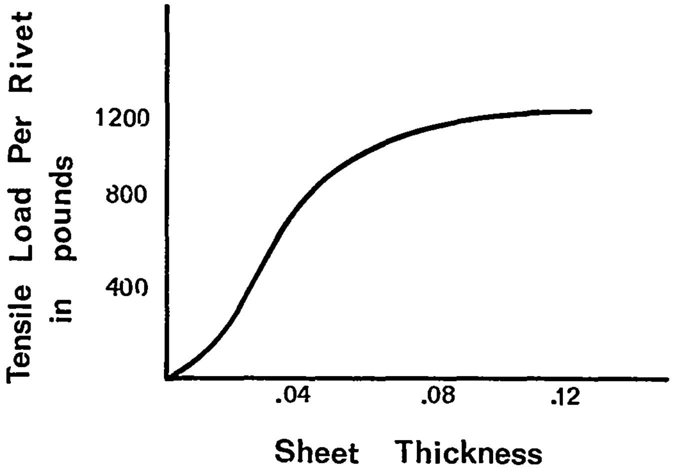
Node and maximum vibratory stress level locations are not affected by centrifugal force, within range of experiment. Static-vibration surveys of prop blades and rotating parts may be utilized to locate areas of maximum stress. Tests went to 100% above normal operating velocities.

TN 1205 DATA ON OPTIMUM LENGTH, SHEAR STRENGTH, AND TENSILE STRENGTH OF AGE-HARDENED 17S-T MACHINE-COUNTERSUNK RIVETS IN 75S-T SHEET, Evan H. Schuette and Donald E. Niles, March 1947

A series of tensile-strength and shear-strength tests were made on age-hardened 17S-T rivets machine-countersunk in 75S-T sheet. The angle of countersink was 60° and the depth of countersink was half the rivet diameter or 1.25 times the sheet thickness.

The results of the tests indicated that such joints can be made satisfactory in regard to both flushness and strength if the ratio of buck (the length of rivet protruding beyond the surface of the countersunk sheet before driving) to diameter of the rivet is kept between 0.9 and 1.5.

A graph of sheet thickness versus tensile load per rivet is shown below.



TN 1207 REACTIONS WITH STEEL OF COMPOUNDS CONTAINING CHEMICAL GROUPS USED IN LUBRICANT ADDITIVES, Allen S. Powell, February 1947

The chemical reactions between steel of a type used in aircraft engine cylinder barrels and compounds containing reactive groups found in lubricants were investigated. It was found that the compounds used in lubricants reacted with steel surfaces at temperatures from 400° to 650° F to give identifiable products. Oxygen and water dissolved in the reagents tended to corrode steel more readily than the reactive group. The principal corrosive action found was caused by oxygen carried to the reactant as dissolved air.

The products that were formed were analyzed by reflection electron diffraction.

TN 1219 STRESS ANALYSIS BY RECURRENCE FORMULA OF REINFORCED CIRCULAR CYLINDERS UNDER LATERAL LOADS, John E. Duberg and Joseph Kempner, March 1947

Develops recurrence equation for stress analysis of reinforced circular cylinders loaded at the ribs. Cylinders may be composed of bays of different cross-section and length with different size reinforcing rings. May be restrained at both or either end. However, if many bays are used, computations become prohibitively long. Simplified difference - equation solution may be used, assuming an infinitely long circular cylinder. Assumption is valid when more than 2 bays from restraint.

TN 1222 BUCKLING STRESSES OF SIMPLY SUPPORTED RECTANGULAR FLAT PLATES IN SHEAR, Manuel Stein and John Neff, March 1947

The present paper evaluates the shear buckling stresses of rectangular flat plates with simple supported edge more accurately than previous work on this problem.

The critical shear stress for a rectangular flat plate with simply supported edges is given by the equation:

Critical shear stress $\tau = \frac{K_S \pi^2 D}{b^2 t}$

where K_S = shear stress coefficient.

There are two values of K_S for each value of length-width ratio. These two values of K_S correspond to buckling into an odd number of buckles (symmetric buckling) and into an even number of buckles (antisymmetric buckling). A curve is presented from which the critical stresses may be obtained when the dimensions of the plate are known.

Through the use of the matrix iteration method and by a proper choice of the terms in the series representing the deflection, more accurate results were obtained.

TN 1223 CRITICAL COMBINATIONS OF SHEAR AND DIRECT STRESS FOR SIMPLY SUPPORTED RECTANGULAR FLAT PLATES, S. S. Batdorf and Manuel Stein, March 1947

The buckling of a simply supported rectangular flat plate under combination of shear and direct stress was investigated by means of an energy method. The critical combinations of stress for several length width ratios were determined to an accuracy of about 1% by use of tenth order determinants in conjunction with a modified matrix iteration method.

The purpose of the present paper is to investigate this transition and to determine whether any appreciable change in the form of the interaction curve for shear and longitudinal stress occur as the length-width ratio of the plate increases from 1 to ∞.

The results for the critical combinations of direct stress and shear of simply supported rectangular flat plates show that:

1. For shear and longitudinal direct stress the interaction curve of all length-width ratios is a parabola for which the equation in terms of stress ratios is

$$R_S^2 + R_X = 1$$

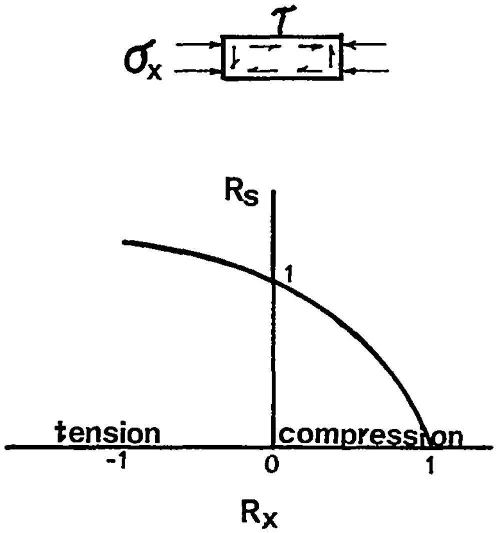
where:

R_S = the ratio of shear stress present to the critical stress in pure shear

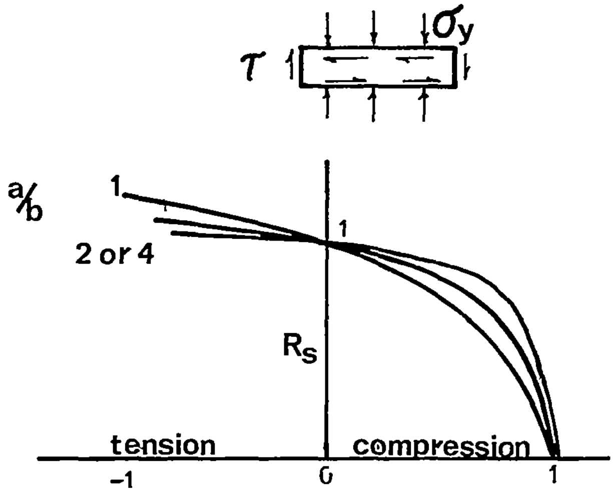
R_X = the ratio of longitudinal direct stress present to the critical stress in pure longitudinal compression

2. For shear and transverse direct stress, the shape of the interaction curve depends on the length-width ratio of the plate.

When the length-width ratio of the plate equals 1 or 2, the interaction curve is very near a parabola. When the length-width ratio of the plate equals 2 or 4, the parabolic equation does not hold in compression. When the length-width ratio of the plate is greater than 4, the interaction curve approximates the interaction curve for a length-width ratio of ∞.



Interaction curve for an infinitely long flat plate under combined shear and longitudinal direct stress in terms of stress ratios R_S and R_X.



Transition in the form of interaction curve for shear and transverse direct stress for a simply supported rectangular flat plate as the length-width ratio change from 1 to ∞ in terms of R_S and R_Y.

$$R_S = \frac{\tau}{\tau_{cr}} \; ; \qquad R_Y = \frac{\sigma y}{\delta y_{cr}}$$

TN 1230 A METALLURGICAL INVESTIGATION OF LARGE FORCED DISCS OF LOW-CARBON N-155 ALLOY, Howard C. Cross and J. W. Freeman, April 1947

This is a report which gives 37 pages of charts and tables presenting data on N-155 alloy, giving the physical characteristics such as the stress-strain curves and the effects of heat. This alloy was under investigation for use in gas-turbines.

TN 1241 EXPERIMENTAL INVESTIGATION OF THE STRESS DISTRIBUTION AROUND REINFORCED CIRCULAR CUT-OUTS IN SKIN STRINGER PANELS UNDER AXIAL LOADS, Daniel Farb, Langley Mem. Aero. Lab., March 1947

Results are presented of strain surveys around four reinforced circular cut-outs successively made in an axially loaded skin stringer tension panel. Surveys made in the elastic range. Test specimen was a 16 stringer 24S-T aluminum alloy panel 144 inches long and approximately 48 inches wide. Circular cut-outs were progressively 10, 22, 34, and 46 inches in diameter. For the smaller diameter, only 2 stringers were cut. For the largest diameter, only the two outside stringers remained.

CONCLUSIONS:

1. The maximum stringer stress occurred at a transverse station which intersected the median line of the reinforcing rings at approximately 45° from the transverse center line of the cut-out. The maximum stringer stress occurred in either the continuous stringer bounding the cut-out or in the cut-out stringer adjacent to this continuous stringer.

2. In estimating the bending stresses in the reinforcing rings, the practice of assuming the stringer loads at a large distance from the cut-out applied directly to the rings was found to be unduly conservative.

3. Empirical relationships were determined for evaluating the maximum stringer stress in the panel and for approximating the longitudinal stresses in the stringers and rings at the transverse center line of the cut-out.

$$\alpha_s = \frac{P}{A_s + 0.58 A_r}$$

where: α_s = average stringer stress
P = external load on the panel
A_r = cross sectional area of rings
A_s = cross sectional area of skin and stringers

TN 1251 ANALYSIS OF THE COMPRESSIVE STRENGTH OF HONEYCOMB CORES FOR SANDWICH CONSTRUCTIONS, Charles B. Norris, April 1947

(a) This report developed an equation for comparing honeycombs of the same shape but various materials, sizes, and wall thicknesses.

(b)

$$Ps = \frac{s}{g} E^{1/3} \cdot \left(\frac{P_p\, g_a}{rg - g_a}\right)^{2/3}$$

Ps = specific compressive strength of a honeycomb
E = Young's modulus
g = specific gravity of the material
g_a = apparent specific gravity of core construction
P_p = proportional limit of material
r = ratio of original length of corrugated sheet to sheet after corrugation

$$s = (K/n^2)^{1/3}$$

K = constant depending upon the type of edge support, must take into account the narrow walls of double thickness at the junctions of corrugations and the wider walls of single thickness that may be curved

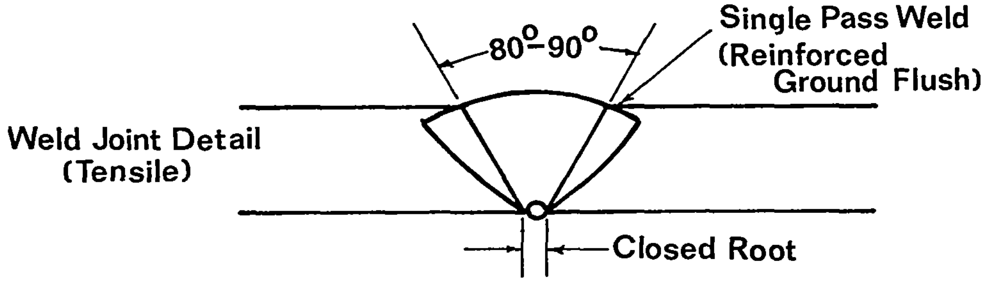
$$a = n\alpha$$

a = width of plate
α = height of corrugation
n = proportional constant

(c) This equation was tested for plywood and sheets of corrugated resin-impregnated paper. It is believed that the formula will work for other materials, but it is suggested that tests be run on materials that are greatly different from plywood and resin-impregnated paper.

TN 1261 EFFECT OF VARIABLES IN WELDING TECHNIQUE ON THE STRENGTH OF DIRECT-CURRENT METAL-ARC-WELDED JOINTS IN AIRCRAFT STEEL I - STATIC TENSION AND BENDING FATIGUE TESTS OF JOINTS IN SAE 4130 STEEL SHEET, C. B. Voldrich and E. T. Armstrong, Battelle Memorial Institute, July 1947

Arc-welded butt joints in 1/8 inch SAE 4130 steel sheet of aircraft quality, which were made under various conditions of welding and heat treatments, were tested to evaluate the effects of specific welding-technique factors on the strength of the joints. Tests were conducted to determine the behavior of the welds in tension and for fatigue due to bending. The materials and procedures used in welding the specimens were chosen so as to conform with typical industrial practice. Radiographs of the individual specimens are also given along with the report showing the characteristics of the particular welds. The welds examined were of two types, one with a continuous weld all across the specimen and the other type with interruptions in the weld. Some of the defects present in the interrupted welds were crater blow holes, transverse crater cracking, and incomplete fusion. A cross section of the tensile weld is shown below:



The tensile tests showed that:

Continuous welds are better than interrupted ones since interruptions reduce tensile strength. The position of the weld had little effect upon tensile strength and preheating had no discernable effect upon the strength of welded joints for 1/8 inch thick metal. The effects of heat treatment are listed below:

Welds With Plain Carbon Electrodes	Continuous Weld = 30% tensile gain Interrupted Weld = 30% tensile gain
Welds Made With Alloy Steel Electrodes	Continuous Weld = 50% tensile gain Interrupted Weld = 40% tensile gain

When the welds were tested for failure due to fatigue due to bending two basic types of welds were used:

1. The joints either had the natural weld reinforcement or were machined flush with the surfaces of the plates.

2. The joints either had a sound weld (continuous bead) or a weld with internal crater defects (interrupted bead).

The greatest influence on the plate-bending fatigue strength of the welded specimens was the external stress-raiser at the toe of welds in the reinforced specimens. Internal stress raisers caused by crater blowholes or cracks never became as critical as the external stress-raisers. Surface decarburization while not due to welding technique is important since it reduces fatigue strength at the surface which is the critical area as far as the weld is concerned. More detailed discussion in conjunction with the radiographs is presented in the test of the report.

TN 1262 EFFECT OF VARIABLES IN WELDING TECHNIQUE ON THE STRENGTH OF DIRECT-CURRENT METAL-ARC-WELDED JOINTS IN AIRCRAFT STEEL II - REPEATED STRESS TESTS OF JOINTS IN SAE 4130 SEAMLESS STEEL TUBING, C. B. Voldrich and E. T. Armstrong, Battelle Memorial Institute, April 1948

This report is a continuation of the work reported in NACA TN 1261. In NACA TN 1261 static-tension and bending-fatigue tests of metal-arc-welded plate joints were conducted to investigate some effects of variations of welding techniques. It was believed that more information could be obtained from fatigue tests of welded joints in aircraft tubing. The object of these tests was not to evaluate the fatigue strength and endurance limit of arc-welded joints in aircraft tubing, but to make use of repeated stress tests to compare welds with different contours, more or less penetration, and greater or lesser heat effect on the parent metal, and this to determine the degree in which these factors are governed by the type of electrode, speed of welding, current, position, preheat, and other related conditions. Eight separate groups of test specimens were tested. The characteristics of the specimens are listed in the test of the report.

The basic conclusion of TN 1261, that the external stress concentrations caused by the geometry of the weld were by far the most critical, even exceeding the poor qualities of the poorest acceptable weld, was reaffirmed in this report. The most significant result of this investigation was that the stress concentrations caused by normal flat and convex fillets in tubular sections are higher, and exert a greater influence on the strength of welded thin-wall sections, than is generally expected. It was found that tension-prestressing did not improve weld fatigue strength but shot-peening did due to the induced compressive stress.

TN 1263 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS III - CALCULATION OF THE BUCKLING LOAD OF CYLINDERS WITH SYMMETRIC CUTOUTS SUBJECTED TO PURE BENDING, N. J. Hoff, Bruno A. Boley and Bertram Klein, May 1947

(a) A strain energy theory was developed for calculating the buckling load of a monocoque cylinder in pure bending. Radial and tangential bending as well as torsion of the stringers; bending of the rings in their plane; and shear in the sheets were all considered in strain-energy quantities. The deflection shape at buckling was considered to be a full sine wave extending over the length of the cutout in the axial directions. The shape was represented by the first seven terms of a Fourier series. A linear force distribution was used instead of a linear strain distribution.

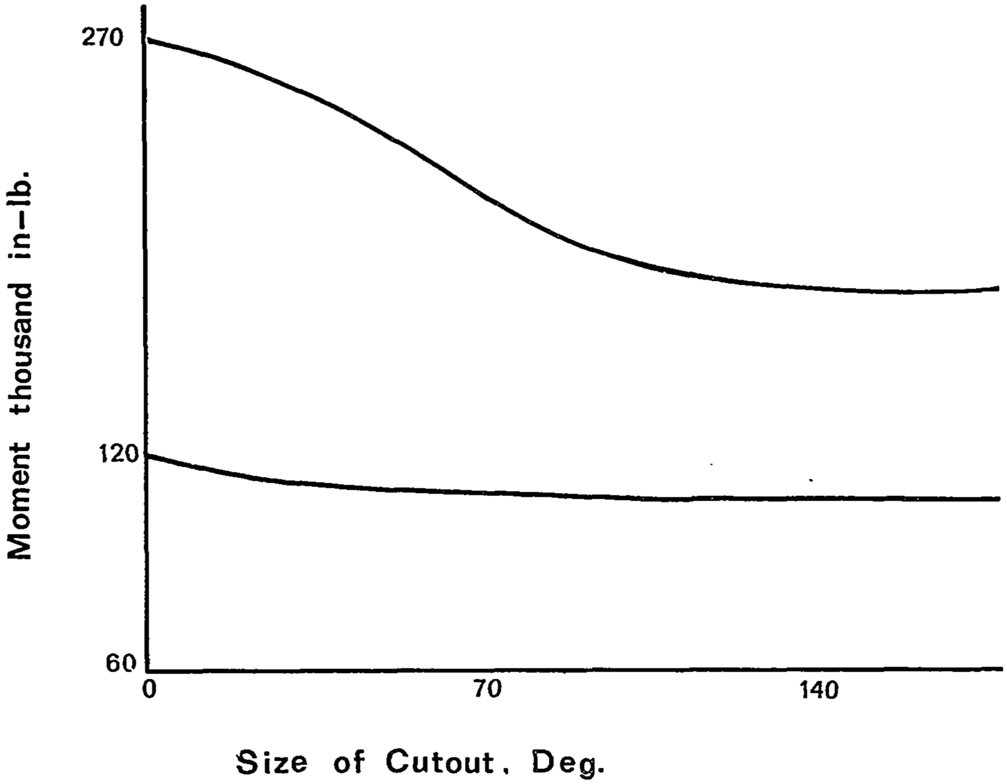
(b) The best agreement between experimental and theory was 13%; the worst was 39%, in every case theory predicted a higher value of buckling load than experiment.

TN 1264 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS IV - PURE BENDING TESTS OF CYLINDERS WITH SIDE CUTOUT, N. J. Hoff, Bruno A. Boley and Louis R. Viggiano, February 1948

(a) Nine 24-ST Alclad cylinders 20 inches in diameter and 39 to 90 inches long, with a wall thickness of 0.012 inches, and with rings and stringers of 24-ST were tested in pure bending. The cutouts were symmetrically with respect to the horizontal plane, they were 12.9 or 19.3 inches long, and cut the circumference by angles of 45°, 90°, or 135°.

(b) All cylinders failed in general instability. The main bulge was located at the edge stringer on the compression side and secondary bulges appeared near the lowest stringer in the cylinders.

(c) On the complete side of the cylinder the stress distribution is linear; on the cutout side the stress is very low in the cut stringer and is a maximum in the edge stringers. The buckling load decreases when the cutout increases in size. The cylinders can still carry large loads even after buckling.



TN 1274 COMPRESSIVE-STRENGTH COMPARISONS OF PANELS HAVING ALUMINUM-ALLOY SHEET AND STIFFENERS WITH PANELS HAVING A MAGNESIUM-ALLOY SHEET AND ALUMINUM-ALLOY STIFFENERS, Norris F. Dow, William A. Hickman and Howard L. McCracken, April 1947

Report examines two types of panels, Mg-Al, and 24S-T. Shows that for given panel weight, Mg-Al panel had higher buckling loads and higher efficiencies except for highest loads tested, where stiffeners were closest. For panels of "ideal" proportions, 24S-T panels were moreefficient. In specific minimum weight designs, Mg-Al panels again were best. It is concluded that Mg-Al construction which permits wider stiffener spacing and higher buckling loads should permit construction of smoother wings because of having fewer rivets and less buckling under loads.

TN 1297 BENDING STRESSES DUE TO TORSION IN A TAPERED BOX BEAM, Edwin T. Kruszewski, Langley Mem. Aero. Lab., May 1947

A method is presented for the calculation of bending stresses due to torsion in a tapered box beam. A special taper was assumed in which all flanges, if extended, would meet at a point. The general procedure of analysis given is similar to the procedure for a non-tapered beam presented by Paul Kuhn in his paper "A Method of Calculating Bending Stresses Due to Torsion", NACA ARR, December 1942. Recurrence formulas developed for use in this calculation are included.

Theory and experimental data agree.

For boxes with very small taper the flange stresses in the out-board half of the box are very small. In these boxes a first approximation of the bending stresses due to torsion can be made by using the properties of the tapered box at the root, by con-sidering the box non-tapered, and then using the method of analysis described by Kuhn in his paper on bending. For more accurate calculations, the method of this paper can be used.

TN 1310 CHARTS FOR STRESS ANALYSIS OF REINFORCED CIRCULAR CYLINDERS UNDER LATERAL LOADS, Joseph Kempner and John E. Duberg, Langley Mem. Lab., May 1947

REFERENCES:

Duberg, John E., and Kempner, Joseph: Stress Analysis by Recur-rence Formula of Reinforced Circular Cylinders Under Lateral Loads, NACA TN 1219, 1947.

Wignot, J. E., Combs, Henry, and Ensrud, A. F.: Analysis of Circular Shell-Supported Frames, NACA TN 929, 1944.

Kuhn, Paul, Duberg, John E., and Griffith, George E.: The Effect of Concentrated Loads on Flexible Rings in Circular Shells, NACA ARR No. L5H23, 1945.

Charts are given for 3 basic types of loadings: concentrated radial load, concentrated tangential loading, and concentrated bending moment.

TN 1314 AN INVESTIGATION OF THE HIGH TEMPERATURE PROPERTIES OF CHROMIUM BASE ALLOYS AT 1350° F, J. W. Freeman, E. E. Reynolds, and A. E. White, May 1947

One of the objectives in the metallurgical research on heat resis-tance metals for gas turbines has been the development of alloys which could operate at high temperatures under stresses similar to those permissible at room temperature.

The 55Cr-25Fe-20Mo and the 60Cr-25Fe-15Mo alloys had rupture strengths as high as 73,000 psi in 100 hours. At the present time the most promising chromium base alloy at 1350° F for buckets for gas turbines appears to be 60Cr-25Fe-15Mo with less than 0.05% carbon and from 0.5 to 0.7% silicon. This alloy can be machined and fabricated, in the normal manner, and techniques have been worked out for casting buckets.

The most serious are brittleness at room temperature and the necessity for melting and casting under high vacuum to avoid the determental effects from the oxygen and nitrogen in air. The further improvement seems quite possible. The chromium base alloys have very low shock-resistance and sensitivity to stress concentrations at room temperature.

TN 1322 THE SPOT WELDING OF DISSIMILAR ALUMINUM ALLOYS IN THE 0.040 INCHES THICKNESS, W. F. Hess, R. A. Wyant and F. J. Winsor, 1947

Report shows that the following combinations can be welded:

Alclad 24S-T	to	bare 24S-T
Alclad 24S-T	to	52S-1/2H
Alclad 24S-T	to	3S-1/2H
Alclad 24S-T	to	61S-T
Alclad 24S-T	to	R-301-T
Alclad 24S-T	to	Alclad 75S-T
R-301-T	to	Alclad 75S-T
Alclad 75S-T	to	bare 75S-T

Chemical surface treatments are as follows:

1. Degrease in trichloroethylene or alkaline degreaser.

2. Treat with (a) 1.5% $H_2S_iF_6$ (for Alclad 24S-T, 52S-1/2H, 75S-T, Alclad 75S-T, R-301-T, 3S-1/2H)
   or (b) 2% HNO_3 (for 24S-T, 61S-T, 14S-T).

Tests showed sound welds resulted with forge force = 2.5 times weld force, weld force from 800 to 1200 lbs; current rise of 3000 amperes per millisecond; forge time of 38 milliseconds.

TN 1323 CHARTS FOR THE MINIMUM WEIGHT DESIGN OF MULTIWEB WINGS IN BENDING, Evan H. Schuette and James C. McCulloch, June 1947

The present report considers a multiweb wing in which the buckling of the webs and compression skin under bending loads is of primary significance in the design. A method for calculating the buckling stress and design charts is presented.

Charts are presented for 24S-T aluminum alloy sheet, extruded 75S-T aluminum alloy, and extruded 0-1HTA magnesium alloy. A second chart for 0-1HTA which makes direct comparison with the other two materials is also presented. These charts make possible for designer to choose a minimum weight design of multiweb wings. An example of the use of the charts is given. The methods by which the various charts were prepared are discussed in Appendix A (preparation of chart for calculation of buckling stress) and B (design charts). Appendix C gives a discussion of the effects of shear in the webs on the buckling stress of multiwebs wings.

TN 1324 INTERACTION BETWEEN THE SPARS OF SEMIMONOCOQUE WINGS WITH CUTOUTS, N. J. Hoff, Harry Kase, and Harold Liebowitz, July 1947

The stresses in the two spars of a model of a wing having three rectangular cutouts were calculated by the FIBAL method which is a modification of Southwell's method of systematic relaxations. By comparing the theoretical results with those taken from the use of the SR-4 strain gage, it was found that in the four different conditions of loading and end fixation (one spar loaded and then the other and alternately having the end fixed) that satisfactory results were obtained.

11 references.

TN 1335 THE LOCAL BUCKLING STRENGTH OF LIPPED Z-COLUMNS WITH SMALL LIP WIDTH, Pai C. Hu and James C. McCulloch, June 1947

This report presents a method for calculating the buckling strength of lipped Z-columns.

$$\frac{\sigma_{cr}}{\eta} = k_w \frac{\pi^2 D}{b_w^2 t}$$

A lower limit for the major part of C_B can be calculated by assuming the lip-flange combination free to slide along the web from the formula:

$$C_B = \frac{1}{12} b_L^3 b_F^2 t_L \left(\frac{4 + \frac{b_L}{b_F} \frac{t_L}{t_F}}{1 + \frac{b_L}{b_F} \frac{t_L}{t_F}} \right)$$

The upper limit for C_B may be calculated by assuming the lip-flange combination fixed in the longitudinal direction at the intersection with the web from the formula:

$$C_B = 1/3\ b_L^3\ b_F^2\ t_L$$

The stiffness against lateral deflections of the lips can be calculated from:

$$S^V_{flange} = - \frac{\pi^2 I_p}{4\lambda^2} \left(\sigma_{cr} - \frac{\eta GJ}{I_p} - \frac{\tau}{I_p} \frac{\pi^2 EC_{BT}}{\lambda^2} \right)$$

C_B = important part of C_{BT} the torsion bending constant
E = modulus of elasticity
G = shear modulus of elasticity
I_p = polar moment of inertia of lip-flange cross section about axis of rotation
J = torsion constant for lip-flange section
S^V = stiffness in moment distribution analysis for far edge not supported but elastically restrained against rotation and deflection
k_w = nondimensional coefficient used in plate-buckling formula
b_L = width of lip
b_F = width of flange
b_W = width of web
t = thickness of plate
σ_{cr} = critical compressive stress
λ = half wave length of buckles in longitudinal direction
η = nondimensional coefficient for plates which accounts for decrease of modulus beyond elastic range; it also is influenced by slight discrepancies between actual specimen tested and idealized specimen for which calculated strength is made
τ = nondimensional coefficient for columns corresponding to for plates

TN 1341 A SIMPLIFIED METHOD OF ELASTIC-STABILITY ANALYSIS FOR THIN CYLINDRICAL SHELLS. II - MODIFIED EQUILIBRIIM EQUATION, S. B. Batdorf, (superseded by report 874), June 1947

Treated in CR-912. See page 528 for discussion.

TN 1342 A SIMPLIFIED METHOD OF ELASTIC STABILITY ANALYSIS FOR THIN CYLINDRICAL SHELLS. II - MODIFIED EQUILIBRIUM EQUATION, S. B. Batdorf, (superseded by report 874), June 1947

Treated in CR-912. See page 528 for discussion.

TN 1343 CRITICAL STRESS OF THIN-WALLED CYLINDERS IN AXIAL COMPRESSION, S. B. Batdorf, Murry Schildcrout, and Manuel Stein, (superseded by report 887), June 1947

Similar material in CR-912, page 528.

TN 1344 CRITICAL STRESS OF THIN WALLED CYLINDERS IN TORSION, S. B. Batdorf, Manuel Stein, and Murry Schildcrout, June 1947

(a) A theoretical solution is given for the critical stress of thin-walled cylinders loaded in torsion.

(b) Critical shear stresses for cylinders:

$$\tau_{cr} = k_s \frac{\pi^2 D}{L^2 t}$$

k_s = critical shear-stress coefficient

For short cylinders:

k_s = 5.34 edges simply supported and 8.98 when the edges are clamped

For simply supported cylinders:

$k_s = 0.85 Z^{.75}$

For cylinders with clamped edges:

$k_s = 0.93Z^{.75}$

Z = curvature parameter $= \frac{L^2}{rt}\sqrt{1 - \mu^2}$

L = length of cylinder
r = radius of cylinder
t = thickness of cylinder wall

TN 1345 CRITICAL COMBINATIONS OF TORSION AND DIRECT AXIAL STRESS FOR THIN-WALLED CYLINDERS, S. A. Batdorf, Manuel Stein, and Murry Schildcrout, June 1947

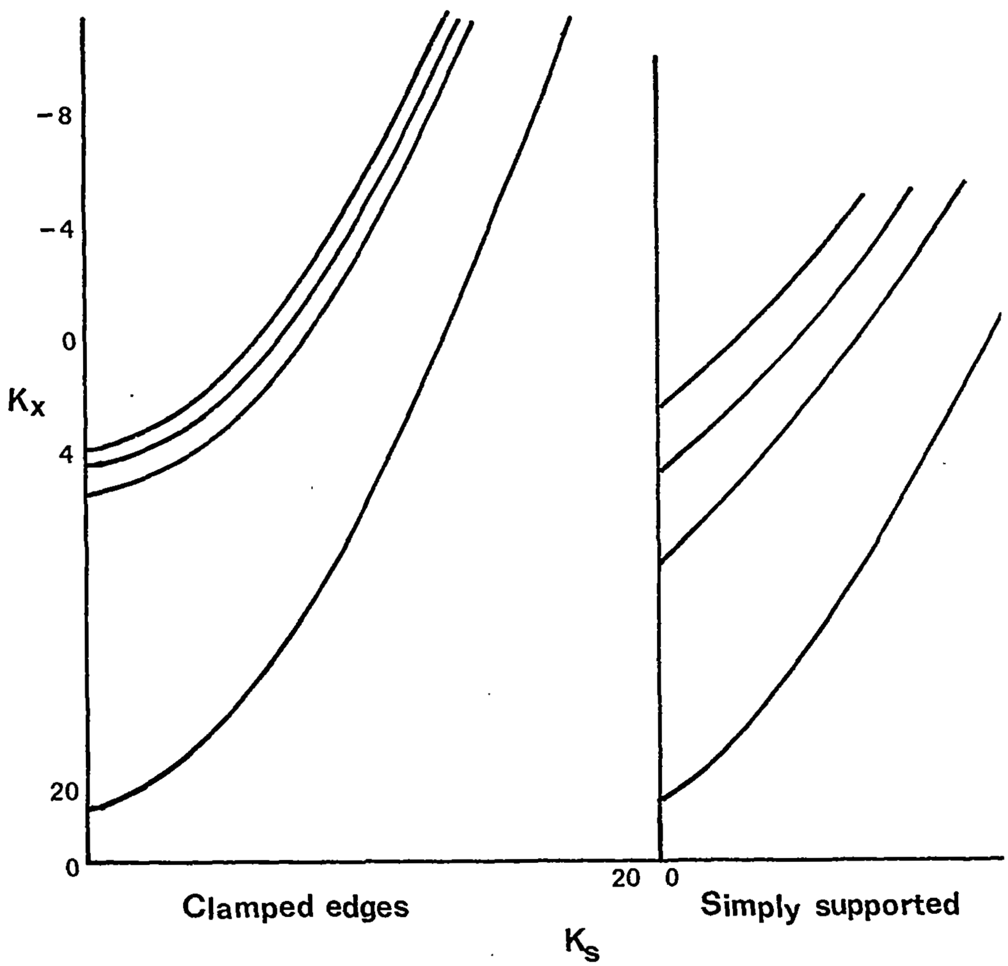
(a) A theoretical solution was found for the determination of the combinations of direct axial stress and torsion which cause thin-walled cylinders with either simply supported or clamped edges to buckle.

(b) The combinations of shear and axial stress which cause cylinders to buckle come from:

$$\tau = \frac{K_s \pi^2 D}{L^2 t} \qquad \text{(see TN 1344)}$$

$$\sigma_x = \frac{K_x \pi^2 D}{L^2 t} \qquad \text{(see TN 1343)}$$

(c) Their combination for failure is given by: Figure 1 where k_s is the shear-stress coefficient (TN 1344) and k_x (TN 1343) is the direct-axial-stress coefficient.



TN 1346 CRITICAL SHEAR STRESS OF LONG PLATES WITH TRANSVERSE CURVATURE

TN 1347 CRITICAL COMBINATIONS OF SHEAR AND LONGITUDINAL DIRECT STRESS FOR LONG PLATES WITH TRANSVERSE CURVATURE, S. B. Batdorf, Murry Schildcrout, and Manuel Stein, Langley Mem. Aero. Lab., June 1947

Theoretical solutions presented.

TN 1348 CRITICAL SHEAR STRESS OF CURVED RECTANGULAR PANELS, S. B. Batdorf, Manuel Stein, and Murry Schildcrout

A solution based on small-deflection theory was presented for the critical shear stress of curved rectangular panels with simply supported edges. For panels having simply supported edges this problem is solved theoretically in the Appendix.

For cylindrically curved panels the critical shear stress τ_{cr} is:

$$\tau_{cr} = K_s \frac{\pi^2 D}{b^2 t}$$

where:

K_s = critical shear stress coefficient

D = flexural stiffness of panel-unit length $\left(\frac{Et^3}{12 - 12\mu^2}\right)$

μ = Poisson's ratio

b = axial or circumferential dimension of panel whichever is smaller

t = panel thickness

The curvature parameter used is $Z = \frac{b^2}{rt}\sqrt{1 - \mu^2}$ where r → radius of curvature of panel.

RESULTS:

1. The buckling curves for panels of fixed length-width ratio approach the curves for a complete cylinder at high values of Z.

2. Panels having a large ratio of circumferential length to axial length approach a cylinder at lower values of Z than panels having a small ratio of circumferential length to axial length.

3. With any appreciable initial eccentricities, deflections tend to increase gradually with load and no snap buckle occurs. The three specimens in which snap buckling did not occur fell in the range of $6 < Z < 12$. Here experimental buckling stresses are only slightly affected by initial eccentricities.

4. There were also some results in which experimental buckling stresses were considerably affected by initial eccentricities.

5. The critical shear stresses given by a theoretical solution based on small-deflection theory for simply supported curved rectangular panels were found to be in good agreement with experimental critical stresses defined in such a way as to be rather intensive to local imperfections.

13 references used.

TN 1361 DEFORMATION ANALYSIS OF WING STRUCTURES, Paul Kuhn, July 1947

Bending as well as torsional deflections are discussed for wings with or without cut-outs. The formulas are given in such a form that they yield corrections to be added to the deflections calculated by means of the elementary theory.

Numerical examples are given to illustrate the use of the equations.

Similar material may be found in Analysis and Design of Aircraft Structures, E. B. Bruhn, 1949 Revised Edition.

TN 1364 STRENGTH ANALYSIS OF STIFFENED BEAM WEBS, Paul Kuhn and James P. Peterson, Langley Mem. Aero. Lab., July 1947

Supersedes: NACA Rep. No. 697, 1940. Investigations on the Incompletely Developed Plane Diagonal-Tension Field. Paul Kuhn.

NACA ARR, August 1942. The Strength of Plane Web Systems in Incomplete Diagonal Tension. Paul Kuhn and Patrick T. Chiartito.

This information is included in Kuhn's Stresses in Aircraft and Shell Structures. McGraw Hill Book Co., Inc., 1956.

Superseded by TN 1756.

TN 1375 LIMITS OF PRECISION IN THE DETERMINATION OF LATTICE PARAMETERS AND STRESSES BY THE DEBYE-SCHERRER METHOD, Hans Ekstein and Stanley Siegel, October 1947

(a) This report was done as an attempt to improve the precision of x-ray diffraction. Experiments were performed with copper radiation on zinc samples. The Bragg angle was 87.53° so that the geometric-line width could be made small in comparison with the spectral-line width.

(b) The sharpness of the diffraction line is limited by the spectral breadth of the primary characteristic radiation; crystal orientation and photographic film also limit the precision in determination of lattice parameters. The relative error in lattice spacing is approximately 2 x 10^{-5}; this value determines the accuracy with which stress measurements may be made.

TN 1380 THE 1350° F STRESS-RUPTURE PROPERTIES OF 2 WROUGHT ALLOYS AND 3 CAST IRONS, E. E. Reynolds, J. W. Freeman and A. E. White, 1947

Wrought alloys: NR82 (6059 modified-low carbon)
NR84 (N-155 modified-low carbon)

Cast alloys: NR71 (X-40)
NR87 (Co-CrtNi, base 9 Mo)
NR90 (Co-Cr-Ni base 5 Mo, 5W)

Stress for rupture tabulated against time in table, also giving elongation and treatment. Such data should be available from manufacturer for alloys designed for high temperature uses.

TN 1385 STRESS-STRAIN AND ELONGATION GRAPHS FOR ALCLAD ALUMINUM ALLOY 75S-T SHEET, James A. Miller, 1947

Report includes plots of:

Tensile and compressive stress-strain and stress deviation
Tangent modulus and reduced modulus in compression
Tensile stress-strain to failure
Local elongation and elongation against gage length for tensile specimens loaded to failure

TN 1389 DESIGN CHARTS FOR FLAT COMPRESSION PANELS HAVING LONGITUDINAL EXTRUDED Y-SECTION STIFFENERS AND COMPARISON WITH PANELS HAVING FORMED Z-SECTION STIFFENERS, Norris F. Dow and William A. Hickman

Design charts.

TN 1410 AN IMPROVED PHOTOELASTIC METHOD FOR DETERMINING PLANE STRESSES, C. B. Norris and A. W. Voss, January 1948

(a) An improved photoelastic method has been developed for determining stress concentrations. The method used was a double-oblique method of photoelastic analysis. A stress coat was also used to give values of θ.

(b) The following equations were used to find the principal stresses:

$$\frac{n_x}{n_n} = \frac{n_1^2 - n_2^2}{n_n^2} \frac{\cos^2\phi}{(1 + \cos^2\phi)\sin^2\phi\cos^2\theta}$$

$$n_x = n_p + n_q$$

$$n_n = n_p - n_q$$

For $\phi = \frac{\pi}{2}$

$$\sigma_u = a\left[1 - \frac{4d^4}{(d^2 + 4x^2)^2}\right] \qquad \sigma_v = a\left[1 - \frac{d^2x^2}{(\frac{d^2}{4} + z^2)^2}\right]$$

For $\phi = 0$

$$\sigma_u = a(1 - \frac{d}{\frac{d}{2} - x} - \frac{d}{\frac{d}{2} + x}) \qquad \sigma_v = a$$

n_p = fringe order for the algebraically larger of the principal stresses p
n_q = fringe order for the other principal stress q
n_n = fringe order from photograph with light normal to surface of model
n_o = fringe order from photograph with light oblique to surface of model
ϕ = angle between direction of light inside model and a normal to its surface
θ = orientation of p measured counterclockwise from x-axis principal stresses to a point
x = radial distance from center of disk to point
d = diameter of disk
a = 2P/d
P = load

(c) The method above was considered the best at the time the report was written.

TN 1411 THE SPOT WELDING OF ALCLAD 24S-T IN THICKNESSES OF 0.064, 0.081 AND 0.102 INCH, W. F. Hess, R. A. Wysnt, and F. J. Winsor, Rensselaer Polytechnic Inst., November 1947

As a result of this investigation it may be concluded in general that welding machines equipped with dual-pressure systems are even more important for the production of spot welds of high quality in the heavier gages of Alclad 24S-T than has been reported in the previous investigations with lighter gages of this alloy. The results of this investigation were subject to the following machine limitations: a forge force of 5000 pounds and a peak current of 74 kiloamperes, obtained with a condenser capacitance of 2640 microfarads, and a condenser voltage of 3000, and a transformer-turns ratio of 400:1. A welding machine with much higher electrode force and current capacity is required in order to obtain maximum benefits in spot-welding Alclad 24S-T in thicknesses of 0.081 inch or greater.

Electrodes of 4 inch radius are suitable for all gages of Alclad 24S-T from 0.020 to 0.064 inch. When forging is to be applied, the optimum electrode force during welding, in pounds, should be about 25 times the single sheet thickness, in mils, using this tip contour. For gages heavier than 0.064 inches, it is desirable to use larger radius electrodes. With these tips, somewhat higher electrode forces during welding are preferable.

In welding Alclad 24S-T up to 0.081 inch in thickness, it has been observed that, when the optimum value of weld force is employed for a particular thickness of material and tip contour, a forge of 2.5 times the weld force is adequate to eliminate cracks in the welds up to the point on the strength current characteristic at which expulsion starts. This ratio of forge-to-weld force will probably also be found adequate for the heavier gages when sufficient machine capacity permits their welding under optimum conditions.

TN 1415 THE EFFECT OF PREHEATING AND POSTHEATING ON THE QUALITY OF SPOT WELDS IN ALUMINUM ALLOYS, W. F. Hess, B. A. Wyant, and F. J. Winsor, November 1947

(a) The purpose of this report was to determine the effect of preheating and postheating on spot welds in aluminum alloys.

(b) While a slight reduction in the tendency for expulsion in Alclad 24S-T was obtained using a slowly rising preheat current there was no change in hard alloys, 24S-T or 61S-T. Steep-current wave forms increased the tendency toward expulsion in aluminum alloys. Postheating had no effect on the shear strength of welds until the magnitude of the current was large enough to cause remelting of the welds, which increased the weld diameter and shear strength.

TN 1421 EFFECT OF VARIATION IN DIAMETER AND PITCH AND RIVETS ON COMPRESSIVE STRENGTH OF PANELS WITH Z-SECTION STIFFENERS. PANELS OF VARIOUS LENGTHS WITH CLOSE STIFFENER SPACING, Norris F. Dow and William A. Hickman, September 1947

It was found in this report that the effect of rivit diameter and rivit pitch on the compressive strength depended on the type of panel. Short panels that failed by local buckling showed an increase in strength with either a decrease in pitch or an increase in diameter. Panels which failed by a combination of column bending and local buckling showed less increase, but did increase in strength with an increase in diameter, while long panels which failed by column bending showed a decrease in strength with either an increase in diameter or a decrease in pitch; however, the decrease may be due to the greater initial curvature induced in the panel by the greater number or size of rivets.

TN 1425 NON-LINEAR LARGE-DEFLECTION BOUNDARY-VALUE PROBLEMS OF RECTANGULAR PLATES, Chi-Teh Wang, March 1948

Covered in:

Theory of Plates and Shells, Ed. by S. M. Durgar'yan.

TN 1432 CHANGES FOUND ON RUN-IN AND SCUFFED SURFACES OF STEEL CHROME PLATE AND CASE IRON, J. N. Good and Douglas Godfrey, October 1947

(a) A study was made of run-in and scuffed steel, chrome-plate, and cast-iron surfaces. X-ray and electron diffraction, microhardness determinations, and microscopy were used.

(b) The principal chemical reactions were oxidation and carburization. The hardness of the surface varied while the crystallite size was on the order of 10^{-7} centimeters.

TN 1433 INSTABILITY OF OUTSTANDING FLANGES SIMPLY SUPPORTED AT ONE EDGE AND REINFORCED BY BULBS AT OTHER EDGE, Stanley Goodman and Evelyn Boyd, December 1947

(a) The compressive buckling of outstanding flanges reinforced by bulbs was determined by the torsion-bending theory for flanges having 54 shapes and a range of lengths. The edge of the flange opposite the bulb and the loaded ends were considered simply supported. The results were analyzed to determine the shape of flange that gave the greatest support to the structure to which it was attached.

(b) It was found that the flanges capable of giving the most support without torsional buckling had overall flange widths from 1.9 A_F to 2.6 A_F, where A_F is the cross-sectional area of the flange.

TN 1435 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS. VI - CALCULATION OF THE BUCKLING LOAD OF CYLINDERS WITH SIDE CUTOUT SUBJECTED TO PURE BENDING, N. J. Hoff, Bertram Klein, and Bruno A. Boley, January 1948

(a) A strain-energy theory was developed for the calculation of buckling load in general instability of circular reinforced monocoque cylinders having a side cutout and subjected to pure bending.

(b) The average deviation between theoretical and experimental buckling load was 27.1 and 34.4 percent for the first and second set of experiments respectively.

TN 1439 COMPRESSIVE STRENGTH OF 24S-T ALUMINUM ALLOY FLAT PANELS WITH LONGITUDINAL FORMED HAT-SECTION STIFFENERS HAVING A RATIO OF STIFFENER THICKNESS TO SKIN THICKNESS EQUAL TO ONE, William A. Hickman and Norris F. Dow, September 1947

Tests were done on 24S-T aluminum alloy flat compression panels with longitudinal formed hat section stiffeners in which the thickness of the stiffeners is equal to the thickness of the skin.

NOMENCLATURE:

P_i = compressive load per inch of panel width

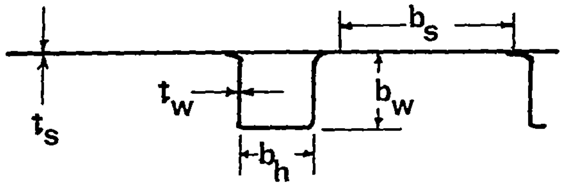
L = length of panel

C = coefficient of and fixity in Euler column formula

σ_f = average stress at failure

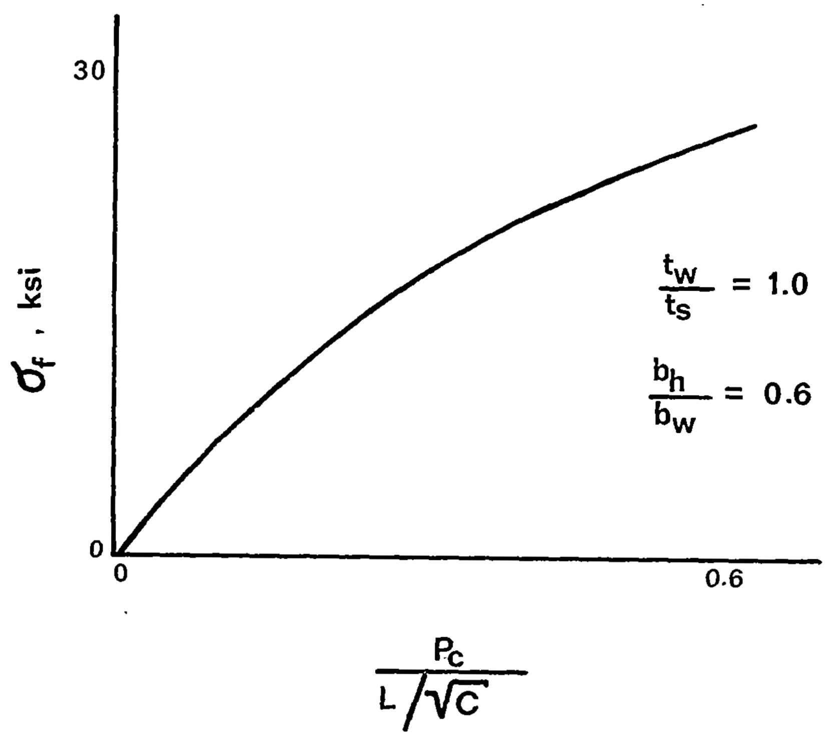
The following results were noted:

1. When $P_i/L/\sqrt{C}$ has a low value (long panels that fail by column bending). The stress developed by the panels increases with an increase in b_W/t_W.



2. At very high values of $\frac{P_i}{L/\sqrt{C}}$ (short panels that fail by local buckling). An increase in the ratio b_H/b_W tends to decrease the stress.

3. Except at very low values of $\frac{P_i}{L/\sqrt{C}}$, the stress developed by the test panels increases as b_S/t_S is decreased.



TN 1440 FURTHER INVESTIGATION OF PREHEATING AND POSTHEATING IN SPOT WELDING 0.040 INCH ALCLAD 24S-T, W. F. Hess and F. J. Windsor, Rensselaer Poly. Inst., December 1947

CONCLUSIONS:

1. In alternating current spot welding of aluminum alloys the weld times is very important with regard to the quality of weld produced.

2. For a given weld size, too short a weld time, in conjunction with a low electrode force, resulted in the occurrence of internal cracks in the welds. Increasing the weld time eliminated these cracks. The minimum weld time required for complete elimination of internal cracks probably is a function of the weld size.

3. With properly prepared surfaces, preheating produced some improvements in the weld quality when the preheat current was sufficiently high in magnitude and of long duration. The employment of intermediate values of preheat current was definitely dangerous. This was believed to be due to a lowering of the sheet to sheet resistance which rendered the welding current ineffective in producing welds of adequate size.

4. High values of preheat current tended to eliminate expulsion and surface flashing usually associated with spot welding untreated Alclad 24S-T. The application of preheating for improving spot weldability, however, may be quite critical. Too low a value of preheat current may either fail to eliminate expulsion or seriously reduce the weld strength. Too high a value of preheat current may, of itself, cause expulsion rather than eliminate it.

5. Postheating currents of lower magnitude than the welding current had no effect on the weld size or quality.

6. Postheating currents higher in magnitude than the welding current and of long duration improved both weld shear strength and quality, in cases for which the welds exhibited internal cracking without postheating.

7. Improvement in weld strength and quality effected by postheating was no greater than that which could be brought by increasing weld time and current.

8. For excellent quality, the weld time is one of the most important variables in the alternating current spot welding process.

TN 1443 SHEAR LAG IN A PLYWOOD SHEET-STRINGER COMBINATION USED FOR THE CHORD MEMBER OF A BOX BEAM, Palamede Borsari and Ai-ting Yu, M.I.T., March 1948

This report is interesting but probably no longer applicable.

TN 1444 DEVELOPMENT OF CASE ALUMINUM ALLOYS FOR ELEVATED-TEMPERATURE SERVICE, Webster Hodge, L. W. Eastwood, C. H. Lorig, and H. C. Cross, January 1948

An investigation was undertaken to develop an aluminum alloy for service at elevated temperatures. One such alloy was developed with the composition below:

Magnesium	6%
Manganese	1%
Copper	1.5%
Vanadium	0.1%
Zirconium	0.25%
Titanium	0.08%
Beryllium	0.005%
Aluminum	95%

The experimental alloy is compared below with alcoa 142-HTA and alcoa 254-T2.

Property	Alcoa 142-HTA	Alcoa 254-T2	Exp.
Tensile strength at room temperature (psi)	26,000	26,000	35,000
Yield strength at room temperature	15,600	25,000	25,000
Brinell hardness number	62	84	86
Tensile strength at 600° F (psi)	8,900	12,750	12,750

As can been seen from the data the experimental alloy was as good when not better than the other two alloys. Other properties not listed also show improvement over those of the two alcoa alloys.

TN 1458 ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF BOLTED JOINTS, Samuel J. Rosenfield, 1947

Analysis in

ANALYSIS AND DESIGN OF FLIGHT VEHICLE STRUCTURES, E. F. Bruhn, Tristate Offset Co. 1965 covers this adequately and is in general use.

TN 1462 BENDING OF RECTANGULAR PLATES WITH LARGE DEFLECTIONS, Chi-Teh Wang, April 1948

This report solves Von Karman's equations for thin plates with large deflections for length to width ratios of 1.5 and 2.

Median fiber stresses:

$$\sigma'_x = \frac{\partial^2 F}{\partial y^2} \qquad \sigma'_y = \frac{\partial^2 F}{\partial x^2} \qquad \tau'_{xy} = -\frac{\partial^2 F}{\partial x \partial y}$$

Median fiber strains:

$$\epsilon'_x = \frac{1}{E}\left(\frac{\partial^2 F}{\partial y^2} - \mu \frac{\partial^2 F}{\partial x^2}\right) \qquad \epsilon'_y = \frac{1}{E}\left(\frac{\partial^2 F}{\partial x^2} - \mu \frac{\partial^2 F}{\partial y^2}\right)$$

$$\gamma'_{xy} = -\frac{2(1+\mu)}{E} \frac{\partial^2 F}{\partial x \partial y}$$

Extreme fiber bending and shearing stresses:

$$\sigma''_x = - \frac{Eh}{2(1 - \mu^2)} \left(\frac{\partial^2 w}{\partial x^2} + \mu \frac{\partial^2 w}{\partial y^2}\right)$$

$$\sigma''_y = - \frac{Eh}{2(1 - \mu^2)} \left(\frac{\partial^2 w}{\partial y^2} + \mu \frac{\partial^2 w}{\partial x^2}\right)$$

$$\tau''_{xy} = - \frac{Eh}{2(1 + \mu)} \frac{\partial^2 w}{\partial x \partial y}$$

w = deflection of middle surface
μ = Poisson's ratio
F = stress function
h = thickness of plate

TN 1464 EFFECTS OF SURFACE FINISH, OF CERTAIN DEFECTS, AND OF REPAIR OF DEFECTS BY WELDING ON FATIGUE STRENGTH OF 355-T6 SAND CASTINGS AND EFFECTS OF PRIOR FATIGUE STRESSING ON TENSILE PROPERTIES, F. M. Howell, G. W. Stickley and J. O. Lyst, 1948

Composition and tensile properties of casting complied with A.S.T.M. and government specifications. Fatigue strength of sound castings was 6900 lbs at 25,000,000 cycles. Shot-blasting and grit-blasting increased fatigue strength 35%. Porosity up to 2.4% had no effect on fatigue strength. Machining lowered fatigue strength of 2.4% porous specimens 15%, based on 25,000,000 cycles. Sand holes decreased fatigue strength, especially when near edge of specimen. Fatigue resistance of castings having defects improved by welding and reheat treatment. Dross inclusions have harmful effect, except ribbon-shaped masses parallel to load. Previous fatigue stressing without failure had no effect on tensile properties. Grit-blasting did not harm tensile properties. Shot-blasting lowered tensile strength 9% but increased yield strength slightly. Specimens with welds had tensile strength about 4% less than unwelded specimens.

TN 1465 THE RUPTURE TEST CHARACTERISTICS OF HEAT RESISTANT ALLOYS AT 1700° F AND 1800° F, J. W. Freeman, E. E. Reynolds and A. E. White, February 1948

Tests on sheet alloys indicate:

1. Superiority over standard chrome nickel iron alloys decreases with time over 1000 hours. At 1800° F, time is much less.

2. Sheet vitallium, S590, low-carbon N-155, and J-838 alloys gave highest strengths. 310S was best of standard alloys.

3. Different lots of 310S and inconel had widely varying properties, indicating heat treatment to be highly influential on properties.

4. Oxidation decreased rupture characteristics; indicating weakening in corrosive service conditions.

5. Tendency toward equalization of rupture properties agglomeration, solution, or lack of precipitation of excess constituent believed to control strength at lower temperatures.

TN 1466 RECURRENCE FORMULAS AND DIFFERENTIAL EQUATIONS FOR STRESS ANALYSIS OF CAMBERED BOX BEAMS, Joseph Kempner, Langley Mem. Aero. Lab., October 1947

This information is included in Kuhn's 1956 publication.

TN 1467 EFFECT OF VARIATION IN DIAMETER AND PITCH OF RIVETS ON COMPRESSIVE STRENGTH OF PANELS WITH Z-SECTION STIFFENERS - PANELS OF VARIOUS STIFFENER SPACINGS THAT FAIL BY LOCAL BUCKLING, Norris F. Dow and William A. Hickman, October 1947

In the test run in this TN to determine the effect of rivet diameter and pitch on the compression strength, the diameter was varied from 1/16 to 1/4 and the pitch from 3/16 to 1-3/4. In all cases no matter what the stringer spacing increasing the diameter or decreasing the pitch increases the compressive strength.

Report presents 14 pages of data to show that, regardless of stiffener spacing, compressive strengths of stiffened panels increased appreciably with either an increase in diameter of rivets or decrease in pitch.

TN 1469 TENSILE, FATIGUE AND CREEP PROPERTIES OF FORGED ALUMINUM ALLOYS AT TEMPERATURES UP TO 800° F, L. R. Jackson, H. C. Cross and J. M. Berry, March 1948

Data on fatigue strength, tensile strength, creep properties, and thermal expansion of forged aluminum alloys XB18S, 18S, 24S and 32S from 70° F to 800° F.

TN 1480 DETERMINATION OF PLATE COMPRESSIVE STRENGTHS, George J. Heimerl, December 1947

Results of local instability tests of H-, Z- and C-section plate assemblies for four extruded aluminum alloys and two magnesium alloys were listed to determine plate compressive strengths of aircraft structural materials.

The experimental critical compressive stress is given by:

$$\frac{\sigma_{cr}}{\eta} = \frac{K_w \pi^2 E t_w^2}{12(1 - \mu^2) b_w^2}$$

K_w = nondimensional coefficient dependent on plate properties and edge conditions

t_w and b_w = thickness and width of the web of the H-, Z- or C-sections

η = coefficient which measures the reduced plate modulus ηE (for stresses in the elastic range $\eta = 1$, above the elastic range, $\eta < 1$)

E = Young's modulus

μ = Poisson's ratio

The following conclusion was drawn:

1. For Z- and C-sections the results for σ_{cr} above the elastic range generally tend to be somewhat lower than those for the corresponding H-section. Thus σ_{max} is slightly greater for the H-section than for the Z- or C-section.

TN 1481 DIAGONAL TENSION IN CURVED WEBS, Paul Kuhn and George E. Griffith, November 1947

The engineering theory of incomplete diagonal tension in plane webs as presented in TN 1364 is generalized in order to make it applicable to curved webs.

When a stiffened cylinder is subjected to torque loads applied at the ends the stress at which the sheet buckles is given by (if h is smaller than d)

$$\tau_{cr} = \frac{K_s \pi^2 D}{th^2}$$

h = spacing of stringers

d = spacing of rings

If d is smaller than h, then d replaces h in the previous formula. The results of experiment agree well with this formula.

$$D = \left(\frac{Et^3}{12(1 - \mu^2)}\right)$$

μ = Poisson's ratio

t = thickness of web

After the torque increase beyond the point where the stress is above the critical value, the sheet buckles and begins to carry part of the shear as diagonal tension.

The tension can then be broken down into a diagonal tension and a shear tension. They are given by:

$$q_{DS} = Kq \qquad \text{where } q \text{ is the total shear flow}$$

$$q_S = (1-K)\,q$$

where:

$$K = \tan h\left[\left(0.5 + 300\,\frac{td}{Rh}\right)\log_{10}\frac{\tau}{\tau_{cr}}\right]$$

The stress in a stringer is given by:

$$\sigma_{ST} = -\frac{K\tau\cot\alpha}{\frac{A_{st}}{ht} + 0.5(1-K)}$$

τ = shear stress
α = angle of diagonal tension
A = cross sectional area
h = spacing of stringers

The stress in a ring by:

$$\sigma_{RG} = -\frac{K\tau\tan\alpha}{\frac{A_{RG}}{dt} + 0.5(1-K)}$$

The results of these formulas agree with the experimental results to the same accuracy as that obtained in TN 1364 on plane webs.

TN 1482 A METHOD OF CALCULATING THE COMPRESSIVE STRENGTH OF Z-STIFFENED PANELS THAT DEVELOP LOCAL INSTABILITY, George L. Gallaher and Rolla B. Boughan, November 1947

(a) A method for calculating the compressive strength of Z-stiffened panels that develop local instability was formulated from the elastic theory for plate buckling and test results. This method can be used above as well as within the elastic range.

(b) The critical compressive stress for local instability:

$$\sigma_{CR} = \frac{K_s\pi^2 E_{sec} t_s^2}{12(1-\mu^2)b_s^2}$$

K_s = is the buckling stress coefficient

t_s = is the thickness of the skin

b_s = is the width of the skin

μ = is Poisson's ratio

E_s = is the secant modulus

(c) The values of the average stress at maximum load above three-fourths the yield stress are just slightly greater than the buckling stresses, thus an approximation of the average compressive stress at maximum load can be calculated from the above formula. The results obtained from the formula for values of the critical compressive stress are reasonably accurate within the elastic range but tend to be 6% unconservative above the elastic range.

TN 1485 FATIGUE STRENGTH AND RELATED CHARACTERISTICS OF AIRCRAFT JOINTS
H. W. Russell, L. R. Jackson, H. J. Grover, and W. W. Beaver, Battelle Memorial Institute, February 1948

Direct stress fatigue tests of 0.040 inch specimens of several aluminum alloy sheet materials and of various riveted joints.

1. At long lifetimes, the bare materials, both with and without a stress-raiser, had considerably higher fatigue strengths than corresponding clad materials.

2. At short lifetimes, the difference in fatigue strengths of bare and clad materials was less.

3. Although the static strengths of 75S-T Alclad and R303-T275 clad were higher than that 24S-T Alclad, the long life fatigue strengths were generally lower.

4. Shallow scratches did not seem detrimental to the fatigue strength of alclad sheet materials. Scratches deeper than the minimum depth of cladding may, however, cause quite large reduction in fatigue strength.

5. The clad materials, both with and without a stress raiser, appeared to have almost the same fatigue strength at 375° F as at room temperature.

6. Results of the tests for fatigue damage of 24S-T Alclad and of 75S-T Alclad were compatible with the simple approximation that damage due to any alternating stress is proportional to the ratio of the number of cycles at such stress to the endurance lifetime at that stress.

In regard to fatigue properties of riveted joints:

1. Single row riveted lap joints of the various sheet materials showed long life fatigue strengths decreasing in the following

order: 24S-T bare, 24S-T Alclad, R303-T275 clad, 75S-T Alclad, and R303-T275 bare.

2. Comparison of specimens dimpled by different operators showed fatigue strengths varying as much as ± 10%.

3. Lap joints with several rows of rivets were stronger in fatigue than joints with single rows, but the strength in pounds per rivet decreased as the number of rows increased.

4. Butt joints and stiffened lap joints were generally considerably stronger in fatigue than simple lap joints, although there was relatively little difference in static strength.

5. Equally loaded sheets, joined by rivets which carried little shear load, were about 30% weaker in fatigue strength than plain sheets.

6. Riveted joints had not much lower fatigue strengths at 375° F than at room temperature.

7. Cumulative damage of riveted joints appeared to be approximately predictable in terms of the percent of endurance life times run at each stress level.

TN 1489 DISLOCATION THEORY OF THE FATIGUE OF METALS, E. S. Machlin (superseded by Report 929), January 1948

This report advances the theory that metals fail in fatigue because of the growth of a dislocation among the atoms of the metal. It is assumed that the amount of crack growth per crack source (M) required for failure is a constant.

$$\log N = \log\left(\frac{2\pi w h M}{KT}\right) + \frac{\Delta Fg}{2.3KT} - \frac{0.422q' \, Vxf^{\sigma}m}{2.3KT}$$

σ_m = maximum tensile or compressive stress of cycle
N = number of cycles to failure
f = fraction experimental value = 0.374
w = frequency of cycle of stress application
h = Planck's constant
T = absolute temperature
K = Boltzmann's constant
ΔFg = free energy of activation involved in generation of dislocations
q' = proportionality constant relating a to m/2 times the stress-concentration factor
V = atomic volume
x = ratio of distance between atom in slip direction to interplanar spacing of slip planes ($\sqrt{3/2}$ for face and body centered cubic lattices)

τ_a = average resolved shear stress in polycrystalline specimen operating for failure

Equation should not be used for strain or precipitate-hardened materials, furthermore this equation has not been verified completely.

TN 1492 AN INVESTIGATION OF FRETTING CORROSION UNDER SEVERAL CONDITIONS OF OXIDATION, B. W. Sakmann and B. G. Righmire, June 1948

(a) Tests were made on various materials to gain more information on fretting corrosion. The materials were tested in air, vacuum, oxygen, and helium. Results showed chemical action was of primary importance. There was more corrosion in air than in vacuum and more corrosion in oxygen than in helium. In most cases it was found that wear was of such a severe nature that protective oxide films are abraded. It was found that if one of the metals is soft the hard oxide fragments may be embedded in the softer metal thus reducing the rate of wear. However, most metals form such hard oxides that the oxides actually increase the rate of wear.

TN 1499 THE INWARD BULGE TYPE BUCKLING OF MONOCOQUE CYLINDERS. IV - EXPERIMENTAL INVESTIGATION OF CYLINDERS SUBJECTED TO PURE BENDING, N. J. Hoff, Bruno A. Boley and S. V. Nardo, September 1948

This report gives the experimental data obtained from buckling tests on 18 monocoque cylinders. One of the purposes of the report was to establish the critical value of the parameter Λ, that is, a value above which failure would occur by general instability and below which panel instability would take place.

On the basis of two series, each consisting of six cylinders and the theoretical (TN 938 and TM 838) the likelihood of failure by panel or general instability may be decided from the following table.

r/d	General Instability Zone	Transition Zone	Panel Instability Zone
2.58	$\Lambda > 40$	$20 < \Lambda < 40$	$\Lambda < 20$
4.46	$\Lambda > 74$	$16 < \Lambda < 74$	$\Lambda < 16$

In this table:

$$\Lambda = (r^4/L_1^3 d)\ (E_{str} I_{str}/E_r I_r)$$

Moreover:

$$I_{str} = I_{str_r} + (5/8)(1/n^2) I_{str_t}$$

r	=	radius of cylinder
d	=	stringer spacing measured along circumference
L_1	=	distance between adjacent rings
E_{str}	=	Young's modulus for stringer
E_r	=	Young's modulus for ring
I_r	=	moment of inertia of ring plus effective width of sheet
n	=	parameter required in calculations of buckling strain[1]
I_{str_r}	=	string moment of inertia for radial bending
I_{str_t}	=	stringer moment of inertia for tangential bending

Some caution should be exercised in using these recommendations since they are based on model tests and theory and no full-scale tests had been carried out to substantiate them. It was suggested that the cylinders be designed so that Λ fall in the transition zone.

[1]From: Hoff, N. J., General Instability of Monocoque Cylinders. Jour. Aero. Sci., vol. 10, no. 4, April 1943, pp. 105-114, 130.

TN 1502 BEARING TESTS OF 14S SHEET AND PLATE, R. L. Moore, Alcoa, August 1948

It was concluded from tests of bare and Alclad 14S-W and 14S-T sheet and plate, in thicknesses of 0.064 inch, 0.250 inch and 0.75 inch, that the ratios of bearing to tensile properties for the with-grain direction were essentially the same as previously proposed in NACA TN 901, 920, 974, and 981 for other high-strength, aluminum alloy sheet and plate, namely:

Ratios for With-Grain Tests	Edge Distance 1.5 x Pin Diameter	Edge Distance 2.0 x Pin Diameter
Bearing ultimate / Tensile ultimate	1.5	1.9
Bearing yield / Tensile yield	1.4	1.6

All of the above named reports are on file with our structures summaries.

TN 1503 BEARING STRENGTHS OF SOME ALUMINUM-ALLOY ROLLED AND EXTRUDED SECTIONS, R. L. Moore, September 1948

(a) Bearing tests were made on rolled and extruded 14S-T4, 14S-T6, 24S-T4, and 75S-T6.

(b) Ratios of bearing to tensile properties:

For rolled bar of 24S-T4, 14S-T4, 14S-T6 up to 2 inches thick and 14S-T4 and 14S-T6 up to 1 inch thick:

Ratios	1.5 x Pin Diameter	2.0 x Pin Diameter
Bearing ultimate / Tensile ultimate	1.5	1.9
Bearing yield / Tensile yield	1.4	1.6

For rolled 75S-T bar up to 2 inches thick, and extruded 14S-T4 and 14S-T6 from 1 to 2 inches thick:

Ratios	1.5 x Pin Diameter	2.0 x Pin Diameter
Bearing ultimate / Tensile ultimate	1.3	1.6
Bearing yield / Tensile yield	1.3	1.4

TN 1505 THE INWARD BULGE TYPE BUCKLING OF MONOCOQUE CYLINDERS. V - REVISED STRAIN ENERGY THEORY WHICH ASSUMES A MORE GENERAL DEFLECTED SHAPE AT BUCKLING, N. J. Hoff, Bertram Klein, and Bruno A. Boley, September 1948

(a) A strain energy theory is developed for the calculation of the critical load for the inward bulge type of general instability of reinforced monocoque cylinders subjected to pure bending. The deflected shape at buckling is assumed to be represented by an expression containing eight free parameters in addition to the two characterizing the wave lengths in the circumferential and axial directions.

(b) The numerical procedure used in this report is considered too long to use in structural design; it was suggested that the method in TN 1499 be used for practical work. The method in TN 1505 gave errors of 8 to 23%.

TN 1512 STRESS-STRAIN AND ELONGATION GRAPHS FOR ALCLAD ALUMINUM 24S-T SHEET, James A. Miller, 1948

Tested Alclad aluminum 24S-T sheets with thicknesses of 0.032, 0.064 and 0.125 inch.

Plots of:
- Tensile and compressive stress-strain and stress deviation
- Tangent and reduced modulus versus strain
- Stress-strain tension to failure
- Local elongation and elongation against gage length to fracture

TN 1513 STRESS-STRAIN AND ELONGATION GRAPHS FOR ALCLAD ALUMINUM-ALLOY 24S-T81 SHEET, James A. Miller, May 1948

Results of tests on duplicate longitudinal and transverse specimens of Alclad aluminum-alloy 24S-T81 sheet of thickness of 0.032, 0.064 and 0.125 inches are presented.

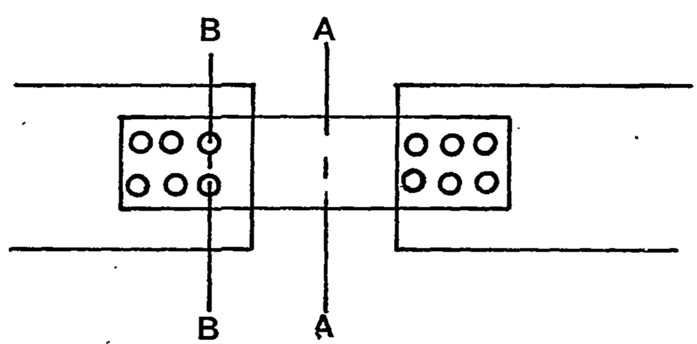
Examples of some of the parameters plotted in this report were:

1. Tensile and compressive tests to 1% strain.
2. Graphs of tangent modulus for a rectangular section A.
3. Stress-strain graphs for tensile specimens tested to failure.

The graphs were quite numerous, too much so to copy or summarize.

TN 1514 FATIGUE OF GUSSETED JOINTS, Howard L. Langdon and Bernard Fried, September 1948

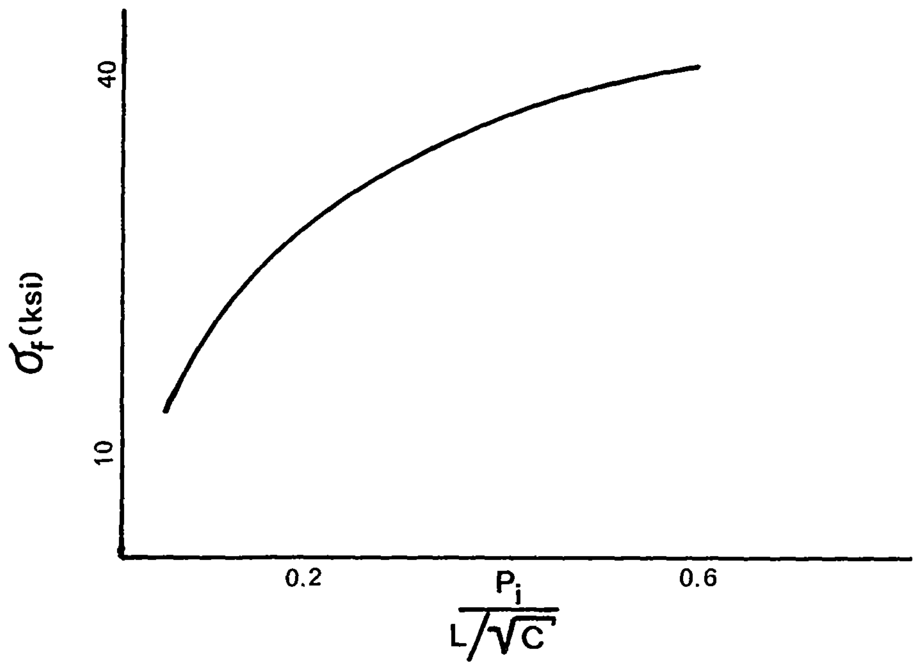
For simple type tested, edge finish of gusset (whether stamped or saw-cut) had no effect on fatigue life. For a given cross-sectional area, narrow and thick gusset plates had longer fatigue lives than wide thin plates. Observed of riveted gussets, were 2 types of failure: (1) where stress across gross (A-A) section was less than 23,000 psi, failure occurred in gross section, (2) where stress was higher, failure was at net (B-B) section. Among spot-welded gussets, fatigue life was dependent on stress concentrations at welds. Riveted gussets thus had longer fatigue lives.



TN 1518 STRUCTURAL EVALUATION OF AN EXTRUDED MAGNESIUM-ALLOY T-STIFFENED PANEL, Norris F. Dow and William A. Hickman, February 1948

Compressive tests were made of six different lengths of a ZK60A magnesium-alloy flat panel having skin and longitudinal T-section stiffeners. The results indicated that the extruded panel had structural characteristics somewhere between those for 24S-T and those for 75S-T aluminum alloy Y-stiffened panels, but because of the nature of the extruded construction, required fewer rivets by far to assemble than either the 24S-T or 75S-T panels. The height of the stiffeners was also less for the extruded panel.

Following is a graph of stress vs $\frac{P_i}{L/\sqrt{C}}$ (see TN 1439).



TN 1519 THE BUCKLING OF A COLUMN ON EQUALLY SPACED DEFLECTIONAL AND ROTATIONAL SPRINGS, Bernard Busransky, Paul Seide, and Robert A. Weinberger, March 1948

Solution is presented for buckling of column supported by equally spaced springs (rotational and directional) which all have equal spring constants. Too specific to be of value. Charts in report necessary.

TN 1522 CALCULATION OF UNCOUPLED MODES AND FREQUENCIES IN BENDING OR TORSION OF NONUNIFORM BEAMS, John C. Houbolt and Roger A. Anderson, February 1948

This report presents a method for calculating the frequency and modes of nonuniform beams.

For free harmonic bending vibration:

$$\frac{d^2}{dx^2}\left(EI\,\frac{d^2 Yn(x)}{dx^2}\right) = w_n^2\, m\, Yn(x)$$

For torsional vibration:

$$-\frac{d}{dx}\left(GJ\,\frac{d\phi n(x)}{dx}\right) = w_n^2\, Ip\, \phi n(x)$$

$Yn(x)$ = deflection at the n-th node
$\phi n(x)$ = rotation at the n-th node
w_n = 2 fn circular frequency at the n-th node
m = mass of beam per unit length
I_p = mass polar moment of inertia per unit length about the axis of rotation

The above equations were solved by numerical integration. Modes higher than the fundamental are calculated by using the orthogonal relation between normal modes. Since the equations do not include the effect of structural damping, rotary inertia, and shear, engineering judgement must be used to interpret the solutions.

TN 1523 BEARING STRENGTHS OF SOME ALUMINUM-ALLOY SAND CASTING, R. L. Moore, August 1948

(a) Bearing tests were made of aluminum-alloy sand castings of 195-T4, 195-T6, 220-T4, 356-T6 to evaluate the bearing strengths of these alloys.

(b) Ratios of average bearing to tensile strengths:

	Ratios for Edge Distances of					
Alloy	1.5 x pin dia.		2.0 x pin dia.		4.0 x dia.	
	BS/TS	BYS/TYS	BS/TS	BYS/TYS	BS/TS	BYS/TYS
Bearing tests on 1/2-in.-diameter steel pin 1/4-in.-thick by 2-1/4 in. wide castings						
195-T4	1.62	1.73	2.20	2.04	3.00	2.12
195-T6	1.60	1.77	2.21	2.13	3.02	2.19
356-T6	1.60	1.75	2.12	2.06	2.62	2.17
220-T4	1.96	1.82	2.39	2.05	2.89	2.13

Bearing tests on 1/4-in. diameter pin in 1/8 in. thick by 2-1/4 in. wide casting

195-T4	1.92	1.77	2.52	2.14	4.21	2.24
195-T6	1.81	1.77	2.52	2.13	4.03	2.21
356-T6	1.69	1.89	2.11	2.06	3.56	2.30
220-T4	2.36	1.79	2.81	1.97	4.21	2.16

(c) The only significant difference between the bearing and bearing-tensile ratios for aluminum castings and common wrought-aluminum was that the castings showed a 20% increase in the ratios of bearing yield to tensile yield over the same ratio for common wrought-aluminum.

TN 1525 STRESS AND DISTORTION MEASUREMENTS IN A 45° SWEPT BOX BEAM SUBJECTED TO BENDING AND TO TORSION, George Zender and Charles Libove, March 1948

An untapered aluminum-alloy box beam, representing the main structural component of a full-span, two spar, 45° swept wing with a carry-through bay, was subjected to tip bending and twisting loads and its stresses and distortions were measured. Only symmetrical loads were considered and stresses were kept below the proportional limit.

For bending the important effect of sweep was to cause a considerable build-up of normal stress and vertical shear stress in the rear spar near the fuselage. No such effect was found in torsion. The stresses in the outer portions of the box, both in bending and in torsion, appeared to be unaffected by sweep and agreed fairly well with stresses given by elementary beam formulas.

The spar deflections of the swept box beam could be estimated approximately by analyzing the outer portions of the box beam as ordinary cantilevers and making adjustments for the flexibility of the inboard portion.

TN 1526 A GENERAL SMALL-DEFLECTION THEORY FOR FLAT SANDWICH PLATES, Charles Libove and S. B. Batdorf (superseded by Report 889), April 1948

TN 1529 AN INVESTIGATION OF MECHANICAL PROPERTIES OF HONEYCOMB STRUCTURES MADE OF RESIN-IMPREGNATED PAPER, C. B. Norris and G. E. Mackin, May 1948

(a) An investigation was made to determine the order of magnitude of the important mechanical properties of honeycomb-like structures. The modulus of rigidity, shear stress at proportional limit, and shear strength of resin-impregnated paper honeycomb compares favorably with those of balsa wood. The modulus of elasticity, compressive strength at proportional limit, compressive strength, and tensile strength are lower than those of balsa wood, but higher than those of cellular cellulose acetate and cellular hard rubber.

(b) Ratio of strength of two materials in honeycomb structure.

$$\frac{P_s 1}{P_s 2} = \left(\frac{J_o 1}{g_a 2}\right)^{2/3}$$

P_s = specific strength (compressive strength divided by apparent specific gravity)
g = specific gravity

TN 1530 PLASTIC BUCKLING OF A RECTANGULAR PLATE UNDER EDGE THRUSTS, G. H. Handelman and W. Prager (superseded by Report 946), August 1948

This report develops a new theory on the stress-strain relations for the behavior of a metal in the plastic range. The new theory is based on the idea that for a fiber compressed beyond the elastic limit, the tangent modulus assumes different values depending on whether the variation of stress relieves or reinforces the existing compressive stress.

The stress-strain relation developed in this report for plastic and elastic regions:

$$E_o d\epsilon_x = \lambda d\sigma_x - \left(\nu + \frac{\lambda-1}{2}\right) d\sigma_y$$

$$E_o d\epsilon_y = -\left(\nu + \frac{\lambda-1}{2}\right) d\sigma_x + \frac{\lambda+3}{4} d\sigma_y$$

$$E_o d\gamma_{xy} = 2(1 + \nu)\ d\tau_{xy}$$

E_o = Young's modulus
$d\epsilon_x, d\epsilon_y$ = infinitesimal strain increment present in buckling
$d\gamma_{xy}$ = infinitesimal strain increment present in buckling
$d\tau_{xy}$ = infinitesimal stress increments present in buckling
$d\sigma_{xy}$ = infinitesimal strain increment present in buckling
λ = ratio of Young's modulus to tangent modulus
γ = Poisson's ratio

TN 1536 BIAXIAL PLASTIC STRESS-STRAIN RELATIONS FOR 24S-T ALUMINUM ALLOY, Joseph Marin, J. H. Faupel, V. L. Dutton, and M. W. Brossman, Penn. State, May 1948

1. The yield strengths for biaxial tension may be predicted approximately by the distortion energy theory.

2. The values of the nominal biaxial ultimate stresses for biaxial tension agree well with values based on the maximum stress theory.

3. The values of the true biaxial fracture stresses for biaxial tension agree well with values based on the maximum stress theory.

4. There is a decrease in nominal and true ductility for biaxial tension compared with uniaxial tension. However, the test values do not agree with the theoretical values based on the generalized St. Venant Theory.

5. The generalized St. Venant Theory can be used to predict approximately biaxial stress-strain relations in the plastic range by using the stress-strain relations in simple tension.

TN 1544 STRENGTH OF THIN WEB BEAMS WITH TRANSVERSE LOAD APPLIED AT AN INTERMEDIATE UPRIGHT, L. Ross Levin, Langley Mem. Aero. Lab., February 1948

Tests made and a method of computing stresses and predicting failures in these directly loaded uprights developed.

1. The stresses in the uprights were predicted with about the same accuracy in the beams with a load applied at one of the intermediate uprights as in the beams which had all the load applied at the end uprights.

2. The ultimate loads on the beams which had a load applied at an intermediate upright were predicted with about the same accuracy as the ultimate loads on the beams which had all the load applied on the end upright.

TN 1551 FRACTURE STRENGTH OF 75S-T ALUMINUM ALLOY UNDER COMBINED STRESSES, E. G. Thomsen, I. Lotze and J. E. Dorn, July 1948

The effect of combined stresses on the fracture strength of 75S-T aluminum alloy was determined by applying axial loads and internal pressure to thin-wall drawn tubes. It was found that:

1. The metal fractures when the maximum principal stress exceeds a critical value.

2. Increasing the mean hydrostatic tension appears to decrease the critical shear stress.

3. Values of the shear stresses for fracture are greater when the macroscopic plane of fracture cuts the lines of fibering

than they are when the plane of fracture is parallel to the directions of maximum principal extensions during fabrication.

TN 1552 INVESTIGATION ON THE VALIDITY OF AN IDEAL THEORY OF ELASTO-PLASTICITY FOR WROUGHT ALUMINUM ALLOYS, E. G. Thomsen, I. Cornet, I. Lotze, and H. E. Dorn, University of California, July 1948

1. The idealized theory for plastic deformation of work hardenable materials is fairly valid for some applications. For example, tension, compression, and torsion curves for initially isotropic R magnesium alloys and for 2S-0, 52S-0, and 61S-W alloys are suitably correlated by this theory for strains up to about 0.06.

2. The idealized theory for plastic deformation of work hardenability metals does not provide an accurate basis for analysis of wrought aluminum alloys. Tension, compression, and torsion data obtained for 13 alloys do not correlate well with analyses based upon the theory.

3. Anisotropy of plastic deformation, discontinuity of the structure, and density variations with deformation and type of loading probably contribute to failure to the theory.

4. Other factors such as the assumption of linearity between stress and infinitesimal strain may also contribute to failure of the theory.

5. Correlation is obtained between torsion and compression data for a few of the aluminum alloys tests, if the maximum shear stress is plotted as a function of the effective strain. Theoretical justification for this method of correlation, however, has not been established.

6. No general theory is available (at the time of this report) to correlate the plastic flow of metals.

TN 1553 COMPRESSIVE STRENGTH OF 24S-T ALUMINUM ALLOY FLAT PANELS WITH LONGITUDINAL FORMED HAT SECTION STIFFENERS HAVING FOUR RATIOS OF STIFFENER THICKNESS TO SKIN THICKNESS, William A. Hickman and Norris F. Dow, March 1948

This report contains the same conclusions that were obtained by the same authors in TN 1439. The only difference in the reports is that in this one 4 ratios of stiffener thickness to skin thickness were tested to substantiate his results. The same results hold.

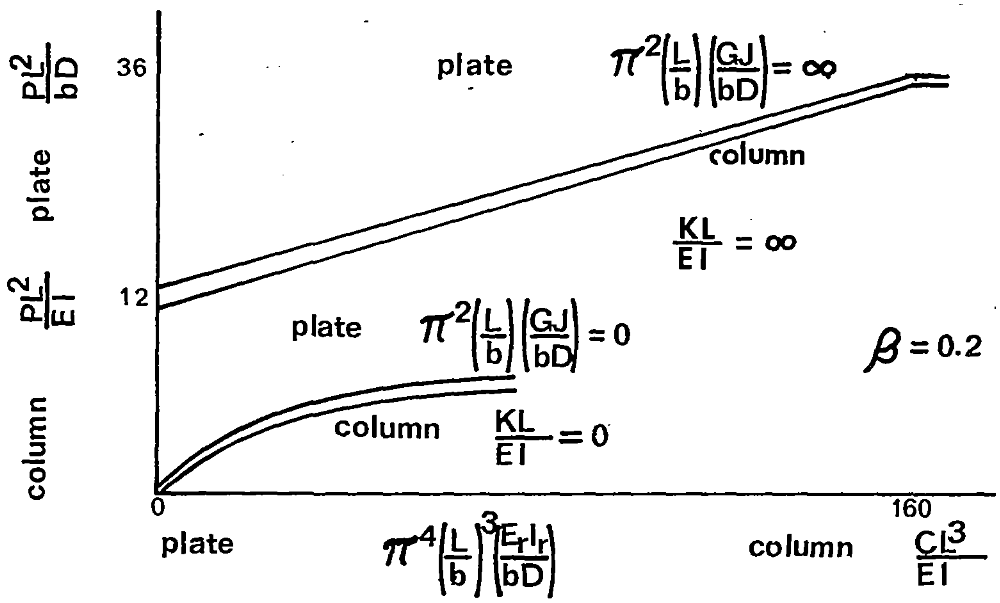
TN 1556 A UNIFIED THEORY OF PLASTIC BUCKLING OF COLUMNS AND PLATES, Elbridge A. Stowell (superseded by Report 898), April 1948

This report was made to present more information on plastic buckling of column or beams. For column buckling it was found that the tangent modulus was used in place of the modulus of elasticity in the formulas used in calculating the buckling in the elastic region. If a plate buckles in the plastic region then the secant modulus is used in the formulas.

TN 1557 COMPRESSIVE BUCKLING OF SIMPLY SUPPORTED PLATES WITH TRANSVERSE STIFFENERS, Bernard Budiansky and Paul Seide, April 1948

(a) Charts are presented for the analysis of the stability under longitudinal compression of simply supported rectangular plates with several equally spaced transverse stiffeners that have both torsional and flexural rigidity.

(b)



(c) There are other graphs for β equal to 0.50, 0.35, and less than 0.20.

TN 1558 NOTES ON THE LAGRANGIAN MULTIPLIER METHOD IN ELASTIC-STABILITY ANALYSIS, Bernard Budiansky, Pai C. Hu, and Robert W. Conner, Langley Mem. Aero. Lab., May 1948

Elementary examples given to demonstrate the application of the Lagrangian multiplier method to the elastic stability analysis of (a) flat rectangular clamped plates in shear and (b) plate stiffener combinations. Exact solutions were obtained for the examples considered; for other problems, such as the shear buckling of a finite clamped plate, approximate solutions may be obtained in two different ways providing upper and lower limits to the true value of the buckling stresses.

TN 1559 BUCKLING STRESSES OF CLAMPED RECTANGULAR FLAT PLATES IN SHEAR, Bernard Budiansky and Robert W. Conner, May 1948

(a) By consideration of antisymmetrical, as well as symmetrical buckling configurations, the theoretical shear buckling stresses of clamped rectangular flat plates were evaluated.

(b) The critical shear stress for a rectangular flat plate:

$$\tau = k_s \frac{\pi^2 D}{b^2 t} \quad \text{for } \beta \text{ from 1 to 3.}$$

a = length of plate
b = width of plate
β = plate aspect ratio (a/b)
t = thickness of plate
E = Young's modulus for material
u = Poisson's ratio for material
D = flexural stiffness of plate $(Et^3/(12(1-u^2)))$
τ = critical shear stress
k_s = critical shear stress coefficient in the formula

(c) Using buckling-stress coefficients from TN 1558 values were obtained within 1-1/4 percent of the true buckling stresses.

TN 1565 BUCKLING IN SHEAR OF CONTINUOUS FLAT PLATES, Bernard Budiansky, Robert W. Connor, and Manuel Stein, 1948

Theory developed to determine critical shear stresses in beam web. Especially applicable to thin-web spars, where web is thin, with heavy flanges and supports running from flange to flange to stiffen web. Beam is assumed infinitely long with square bays.

Infinitely Long Clamped Plate With Square Bays

$$\tau = k_s \left(\frac{\pi^2 D}{b^2 t} \right)$$

	k_s
Two opposite edges clamped two simply supported	12.6 (max.)
Two opposite edges clamped two continuous	13.14
All edges clamped	14.71

Doubly Infinite Array of Square Panels

	k_s
All edges simply supported	9.35
All edges continuous	11.10
All edges clamped	14.71

Spar webs with reinforcements like stringers are the second case, where k_s = 13.14, not first case, where k_s = 12.6 at a maximum. k_s decreases with increasing width-length ratio.

TN 1583 EFFECT OF SHEAR LAG ON BENDING VIBRATION OF BOX BEAM, Roger A. Anderson and John C. Houbolt, May 1948

The investigation has shown that, even though the shear lag in a given box beam had a relatively insignificant effect on the static deflection of the beam under a tip load and on the fundamental frequency of vibration, it caused an appreciable reduction in the higher frequencies. This increasing effect of shear lag on the high modes can be explained by the fact that the relatively greater rates of change of the bending moment over the span in these modes of vibration are accompanied by increased shear deformation of the cover sheets and result in a reduced flexural stiffness of the beam. It has been pointed out that shearing deformations in the thin cover sheets effectively change the stiffness, and hence the vibration characteristics, of the beam.

Shear deformation of the cover also takes place around discontinuities and abrupt changes in cross sections, such as cut-outs, and around points of load concentration. In an actual wing, shear-lag effects due to these disturbances may be of more importance than the simple effect treated in this paper and should therefore be investigated when a determination of the modes and frequencies is being made. The analytical procedure for introducing shear-lag corrections for more complicated structures differs little from the procedure presented in this report.

TN 1589 EFFECT OF LONGITUDINAL STIFFENERS ON THE BUCKLING LOAD OF LONG FLAT PLATES UNDER SHEAR, Harold Crate and Hsu Lo, June 1948

The theoretical shear buckling coefficient for a long flat plate reinforced with any number of longitudinal stiffeners, of equal stiffness and equally spaced across the plate, can be obtained from a single curve for each of the edge conditions - simply supported or clamped. The test results were found to be in "fair" agreement with the theoretical studies.

TN 1594 EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF CONCENTRATED WEIGHTS ON FLUTTER CHARACTERISTICS OF A STRAIGHT CANTILEVER WING, Harry L. Runyan and John L. Sewall, June 1948

Results are presented for almost 100 flutter tests in which concentrated weights were mounted rigidly to a straight cantilever wing. The moments of inertia and mass of the weights were varied and the weight position was varied chordwise and spanwise. During the entire series of flutter tests the elastic properties of the wing did not materially change. The results are presented in the form of curves that show the effects of varying concentrated weights on the various flutter parameters.

At the time of this report (June 1948) there existed several analytical methods of approaching flutter problems. This data is presented to aid in someone making a comparison.

TN 1611 AXIAL FATIGUE TESTS AT ZERO MEAN STRESS OF 24S-T AND 75S-T ALUMINUM ALLOY STRIPS WITH A CENTRAL CIRCULAR HOLE, W. C. Brueggeman and M. Mayer, Jr., August 1948

Axial fatigue tests at zero mean stress have been made on 0.032 and 0.064 inch 24S-T and 0.032 inch 75S-T sheet metal specimens 1/4, 1/2, 1, and 2 inches wide without a hole and with central holes giving a range of hole diameter d to specimen width w from 0.01 to 0.95. No systematic difference was noted between the results for the 0.032 inch and the 0.064 inch specimens although the latter seemed the more consistent. In general the fatigue strength based on the minimum section dropped sharply as the ratio d/w was increased from zero to about 0.25. The plane specimens showed quite a pronounced decrease in fatigue strength with increasing width. The holed specimens showed only slight and rather inconclusive evidence of this size effect. The fatigue stress concentration factor was higher for 75S-T than for 24S-T alloy. Evidence was found that a very small hole would not cause any reduction in fatigue strength.

TN 1625 OBSERVATIONS ON THE MAXIMUM AVERAGE STRESS OF FLAT PLATES BUCKLED IN EDGE COMPRESSION, E. H. Schuette, February 1949

This report is a graphical study of the maximum average stress of a buckled flat plate in edge compression. The following formula was found that fits the data.

$$\bar{\sigma}_{max} = K(\sigma_{cr})^{0.25} (\sigma_{cy})^{0.75}$$

K = constant
σ_{cr} = critical or budkling stress
σ_{cy} = compressive yield stress
σ_{max} = maximum average stress (average stress at maximum load)

K, in this report that produced the best curve (when compared to the data), was 0.80. Data indicated that the constant 'varied in some inverse fashion with the width-thickness ratio. Good fits to all data for extrusions with flat-plate elements (with width-thickness ratios up to about 25) were obtained with the constant equal to 0.80. The report notes that care should be taken when applying the above method to unformed sheets.

TN 1629 THE EXPERIMENTAL DETERMINATION OF THE MOMENTS OF INERTIA OF AIRPLANES BY A SIMPLIFIED COMPOUND-PENDULUM METHOD, William Gracey, June 1948

The method for finding the moments on inertia of an airplane presented in this report is an improved version of the method presented in TN 265, 351, 1187. This new method takes into account not only the effects of ambient air, but also uses a simplified method to find the center of gravity of the airplane.

The new method of finding the center of gravity consists mainly of suspending the plane by suspension arms of different lengths determine the period of oscillation for the two lengths and solve the two equations, for the moment of inertia, for one of the two suspension lengths. Then plugging this value back into the equation the moment of inertia can be solved for. The test uses a bifiar torsional pendulum for finding the moment of inertia about the z axis and uses a compound pendulum for finding the moment of inertia about the x and y axis. The new method presents very good results and permits a reduction in experimental technique, test apparatus, and time; another result of the test is the fact that the airplane always remains in an upright position.

TN 1635 STRENGTH TESTS OF SHEAR WEBS WITH UPRIGHTS NOT CONNECTED TO THE FLANGES, Charles W. Sandlin, Jr., June 1948

The purpose of this report was to run tests and to develop a method for calculating the ultimate shear stress of curved and plane shear webs where the uprights are not connected to the flanges. This condition exists in detachable wing skin panels. The method that was developed leads to two equations:

$$\tau_{ult} = \frac{T_{ult}}{2AT}$$

$$\tau_{ult} = \frac{P_{ult}}{h_e t}$$

τ_{ult} = ultimate shear stress
T = torque
P = force
h_e = depth of beam measured between centroids of flanges
A = area enclosed by median line of cross section of torsion box
t = thickness of web

A reduced "effective" column length was used (formula 12 NACA TN 1364) in determining the reduced allowable stresses that must be used since the uprights are not attached to the flanges. It was found that this method gives good results; it was also found that the ultimate strength of a curved web was about the same as a plane web, most of the webs failed when the upright came through the skin.

TN 1640 DIRECT-READING DESIGN CHARTS FOR 75S-T ALUMINUM ALLOY FLAT COMPRESSION PANELS HAVING LONGITUDINAL STRAIGHT WEB Y-SECTION STIFFENERS, Norris F. Dow and William A. Hickman, Langley Aero. Lab., August 1948

Direct reading design charts are presented. These charts make possible the direct determination of the stress and all the panels proportions required to carry a given intensity of loading with a given skin thickness and effective length of panel.

TN 1661 CRITICAL AXIAL COMPRESSIVE STRESS OF A CURVED RECTANGULAR PANEL WITH A CENTRAL CHORDWISE STIFFENER, S. B. Batdorf and Murry Schildcrout, Langley Aero. Lab., July 1948

Information is contained in Kuhn's book.

TN 1681 CRITICAL STRESS OF AN INFINITELY LONG PLATE IN THE PLASTIC REGION, Elbridge Z. Stowell, August 1948

(a) In this report the critical shear stress for an infinitely long plate under uniform shear was calculated from:

$$\tau = \frac{\pi^2 k_s E t^2}{12(1-\mu^2)b^2}\eta$$

τ = critical shear stress
k_s = coefficient depending upon conditions of edge restraint and shape of plate
t = thickness of plate
b = width of plate
E = Young's modulus
μ = Poisson's ratio
η = coefficient which allows for reduction in shear stress in plastic range

$$\eta = \frac{E_s \sin 2\phi_o 2\sqrt{f_1(\epsilon)}\sqrt{1 - \frac{1-C_3}{2}\sin^2 2\phi} + 2[1+2\sin^2\phi-(1-C_3)\cos^2\phi]f_2(\epsilon)}{E \sin 2\phi\ 2\sqrt{f_1(\epsilon)} + 2(1+2\sin^2\phi_o)f_2(\epsilon)}$$

E_s = secant modulus of material
$f_1(\epsilon)$ = functions of elastic restraint
$f_2(\epsilon)$ = functions of elastic restraint
C_3 = plasticity coefficient
ϕ_o = wave angle in elastic range

$$\phi = 1/2 \cos^{-1} \frac{(3 - C_3)\ f_2(\epsilon)}{\dfrac{2\sqrt{f_1(\epsilon)}}{\sqrt{1 - \frac{1-C_3}{2}\sin^2 2\phi}} + (3 + C_3)\ f_2(\epsilon)}$$

The angle of the waves ϕ is that angle which will make the critical shear stress a minimum. As soon as the magnitude of the elastic restraint is selected, the angle of the waves, and therefore, may be computed for any stress.

For the case of simply supported edges:

$$f_1(\epsilon) = f_2(\epsilon) = 1$$

For the case of clamped edges:

$$\epsilon = \infty$$
$$f_1(\epsilon) = 5.14$$
$$f_2(\epsilon) = 1.24$$

TN 1692 DETERMINATION OF BENDING MOMENTS IN PRESSURE LOADED RINGS OF ARBITRARY SHAPE WHEN DEFLECTIONS ARE CONSIDERED, F. R. Steinbacher and Hsu Lo, University of Michigan, September 1948

An analytical method has been desired for determining bending-moment distribution in rings of arbitrary shape under internal pressure loads, with the change of geometric shapes caused by the load being considered.

Charts are provided for two specific families of rings of various proportions and flexibilities.

On comparing the results with the results of solutions in which deflections have been neglected, it is seen that the bending moments previously computed have always been much too conservative.

For rings not included in the charts, an average of 20 hours is necessary for the complete solution of the problem.

The process is thoroughly outlined in the report (about 30 pages).

CONCLUSIONS:

1. Results obtained by the present method showed good agreement with test data and proved that results obtained when change of geometric shape was not considered are inadequate for flexible rings.

2. Although only rings with double symmetry under internal pressure loads are discussed in the present work, the method can be extended to include rings of any shape under any system of external loads.

TN 1705 EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF THE PLASTIC FLOW IN A TENSION PANEL WITH A CIRCULAR HOLE, George E. Griffith, September 1948

Seven uniformly dimensioned 24S-T tension panels with a central circular hole were subjected to various loads.

The results show that, as the amount of plastic flow increases, the stress concentration factor is appreciably reduced and the strain concentration factor is appreciably increased.

Subjecting the panels to 100 repeated loading cycles caused no change to occur in the maximum values of the stress and strain concentration factors.

TN 1710 MINIMUM-WEIGHT DESIGN OF SIMPLY SUPPORTED TRANSVERSELY STIFFENED PLATES UNDER COMPRESSION, Alexander Gomza and Paul Seide, September 1948

Weight of a simply supported transversely stiffened compression panel subjected to a given buckling load is investigated as a function of the stiffener spacing, plate thickness, and the geometry of the stiffener cross section.

It is shown that there are particular combinations of stiffener spacing and plate thickness, dependent upon the geometrical properties of the stiffener cross section, for which the panel weight if a minimum. Charts are presented to facilitate the determination of these optimum values of stiffener spacing and plate thickness.

TN 1714 PLATE COMPRESSIVE STRENGTH OF FS-1h MAGNESIUM-ALLOY SHEET AND A MAXIMUM-STRENGTH FORMULA FOR MAGNESIUM-ALLOY AND ALUMINUM-ALLOY FORMED SECTIONS, George L. Gallaher, October 1948

The plate compressive strength of FS-1h magnesium-alloy sheet was determined from local-stability tests of formed Z-section columns. The critical compressive stress was found to correlate well with the compressive stress-strain curve for the material. The curves of average stress at maximum load plotted against calculated elastic critical strain resulted in a family of curves similar to previous results for aluminum-alloy sheet.

TN 1728 SHEAR LAG IN AXIALLY LOADED PANELS, Paul Kuhn and James P. Peterson, October 1948

The method of calculating shear-lag effects in axially loaded panels by means of the previously developed concept of the "substitute single-stringer panels" is simplified by an empirical expression for the width of the substitute panel which eliminates the need for successive approximations. For simple types of single-stringer panels, a theory not dependent on the assumption of infinite transverse stiffness is developed that can be used to estimate the effect of transverse stiffness on the stresses in practical panels. Strain measurements on five panels indicate that the theory should be adequate for design purposes and that the effect of transverse stiffness may be appreciable.

TN 1730 EFFECTS OF TEMPORAL TANGENTIAL BEARING ACCELERATION OF PERFORMANCE CHARACTERISTICS OF SLIDER AND JOURNAL BEARINGS, Dezso J. Ladanyi, October 1948

A theoretical analysis of the effects of temporal tangential bearing acceleration on several performance characteristics of slider and journal bearings is presented. The derivations of the mathematical expressions for these effects begin with the laws of classical hydrodynamics and conclude with modified versions of the usual performance equations in lubrication. Equations are presented that establish fundamental relations and show the effects of this type of acceleration on pressure distribution and load capacity.

The equations show that the factor which is most important in establishing the effect of acceleration on bearing performance characteristics is the ratio of acceleration to speed. When this ratio is high, the effect of acceleration is large; when it is low, the effect is small. It was found that acceleration acts to decrease load capacity of the bearing.

TN 1737 EFFECT OF VARIATION ON DIAMETER AND PITCH OF RIVETS ON COMPRESSIVE STRENGTH OF PANELS WITH Z-SECTION STIFFENERS - PANELS THAT FAIL BY LOCAL BUCKLING AND HAVE VARIOUS VALUES OF WIDTH-TO-THICKNESS RATIO FOR THE WEBS OF THE STIFFENERS, Norris F. Dow and William A. Hickman, November 1948

An experimental investigation is being conducted to determine the effect of varying the rivet diameter and pitch on the compressive strength of flat 24S-T aluminum alloy Z-stiffened panels of the type for which design charts are available. The present part of the investigation is concerned with panels which have various values of width-to-thickness ratio of the webs of the stiffeners and have such length that failure is by local buckling. The results show that for these panels, regardless of their stiffener widths, the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets.

TN 1747 DETERMINATION OF COUPLED AND UNCOUPLED MODES AND FREQUENCIES OF NATURAL VIBRATION OF SWEPT AND UNSWEPT WINGS FROM UNIFORM CANTILEVER MODES, Roger A. Anderson and John C. Houbolt, Langley Mem. Lab., November 1948

Except for certain idealized cases, the natural vibration modes and frequencies of airplane wings cannot be found by exact analysis, and thus approximate methods must be used. Such a method is presented. The energy method is used to derive two sets of linear characteristic equations, one for symmetrical modes and the other for antisymmetrical modes. These same equations also lead to solutions for the coupled and uncoupled modes and frequencies of the unswept wing and fuselage.

The important feature of the method presented herein is the simplification that results from the use of the natural modes of a uniform cantilever beam as expansions for the deflection and twist of the vibrating nonuniform free-free wing. With the addition of appropriate rigid-body-displacement terms, these expressions may be made to satisfy all the geometrical boundary conditions for both symmetrical and antisymmetrical wing vibration. Analyzing idealized structures for which exact solutions could be made shows that only a few terms are needed in the expansions to obtain good accuracy.

TN 1749 SHEAR FLOWS IN MULTICELL SANDWICH SECTIONS, Stanley U. Benscoter, Langley Aero. Lab., November 1948

Formulas developed in explicit form for the shear flows in multicell sandwich beams in bending and torsion. Formulas also developed for the shear flows corresponding to various functional chordwise distributions of the cell twist and, in scalar or matrix form, for the shear flows corresponding to an arbitrary chordwise twist distribution. A formula for the torsion constant of a multicell sandwich beam has also been developed.

TN 1750 BUCKLING TESTS OF FLAT RECTANGULAR PLATES UNDER COMBINED SHEAR AND LONGITUDINAL COMPRESSION, Roger W. Peters, Langley Aero. Lab., November 1948

An experimental investigation made to validate a theoretical parabolic interaction curve for the elastic buckling of flat rectangular plates under combined shear and longitudinal compression loads. The four flat rectangular plates tested formed the sides of a square box having corner angles. Although some of the experimentally determined points lie above and others below the theoretical interaction curve, the average of the individual experimental points plotted very closely to this theoretical curve recommended for design use.

TN 1751 BUCKLING OF A LONG SQUARE TUBE IN TORSION AND COMPRESSION, Bernard Budiansky, Manuel Stein, and Arthur C. Gilbert, Langley Mem. Aero. Lab., November 1948

The buckling of an infinitely long square tube under combined torsion and compression is investigated by means of an exact energy method utilizing Lagrangian multipliers. An interaction curve is obtained from which it is possible to determine the amount of one loading required to produce buckling when a given amount of the other loading is present.

From this curve it can be concluded that an appreciable amount of torsion may be present without in anyway reducing the compression required for buckling.

TN 1756 ULTIMATE STRESSES DEVELOPED BY 24S-T AND ALCLAD 75S-T ALUMINUM ALLOY SHEET IN INCOMPLETE DIAGONAL TENSION, L. Ross Levin, Langley Aero. Lab., November 1948

Strength tests were made on 24S-T and Alclad 75S-T aluminum sheet in diagonal tension. These tests indicated that the ultimate shear stress was essentially independent of the rivet factor if the rivet factor was greater than 0.6, which covers most of the practical range. Curves showing the effect of diagonal tension on the ultimate shear stress in the gross section are presented. These curves supersede those given in NACA TN 1364.

TN 1758 PROPERTIES OF 19-9DL ALLOY BAR STOCK AT 1200° F, J. W. Freeman, E. E. Reynolds, D. N. Frey and A. E. White, November 1948

Although 19-9DL was used for these tests, the main purpose of the test was to establish a relationship between processing of a good heat resistant alloy and the relative properties. The samples were tested in three different conditions, hot-cold worked, hot-rolled, and solution-treated.

It was found that hot-cold-worked samples produced the highest strengths in rupture when tested at high stresses and rapid strain rates; this condition also had the highest strength in the creep test. As the time was increased the strengths of the hot-rolled and the solution treated samples increased. The solution treated material had the best strength at time periods longer than several thousand hours. The effect of time and strain rate on properties indicates that the optimum treatment for any particular application depends on the service conditions. It may be important that the material have other properties than load carrying ability under tension; those treatments that may develop strength at high temperature may be bad for the corrosion resistance properties of the material. The strength of the material was found to be a function of the size and dispersion of precipitate particles together with the amount of cold work. Loss of strength by the cold-hot-worked material at prolonged time periods seems to be caused by structural instability due to cold-work.

The report also contains 12 pages of charts and graphs on the properties of 19-9DL.

TN 1777 DIRECT-READING DESIGN CHARTS FOR 24S-T ALUMINUM-ALLOY FLAT COMPRESSION PANELS HAVING LONGITUDINAL STRAIGHT-WEB Y-SECTION STIFFENERS, Norriw F. Dow, January 1949

(a) Direct-reading design charts are presented for 24S-T aluminum-alloy flat compression panels having longitudinal straight-web Y-section stiffener. These charts make possible the direct determination of the stress and all the panel proportions required to carry a given intensity of loading with a given skin thickness and effective length of panel.

(b) This TN contains 25 pages of charts and graphs.

TN 1778 DIRECT READING DESIGN CHARTS FOR 24S-T ALUMINUM-ALLOY FLAT COMPRESSION PANELS HAVING LONGITUDINAL FORMED Z-SECTION STIFFENERS, Norris F. Dow and Albert S. Keevil, Jr., Langley Lab., January 1949

Direct reading charts are presented. These charts make possible the direct determination of the stress and all the panel proportions required to carry a given intensity of loading with a given skin thickness and effective length of panel.

The charts are quite detailed.

TN 1786 RECOMMENDATIONS FOR NUMERICAL SOLUTION OF REINFORCED-PANEL AND FUSELAGE-RING PROBLEMS, N. J. Hoff and Paul A. Libby (superseded by Report 934), December 1948

This report contains recommendations as to the choice of the most expeditious method of solution of the simultaneous linear equations represented by the operations table and the external loads. The operations table is first established in accordance with Southwell's suggestions and, together with the external loads, defines completely the problem of stress distribution in a reinforced panel or of the moment distribution of a fuselage ring. However, the following generalized suggestions can be made:

1. In most reinforced panel problems the use of the relaxation procedure is advantageous.

2. Solution of the equations defining a reinforced panel problem by means of the electric analogue is advisable when any closely related problems have to be investigated.

3. Ring problems are best solved by matrix methods.

4. In very complicated ring problems a combination of matrix methods with the growing-unit and relaxation methods may become advisable.

TR 934 contains no new information.

TN 1787 COMPARISON OF THE STRUCTURAL EFFICIENCY OF PANELS HAVING STRAIGHT-WEB AND CURVED-WEB Y-SECTION STIFFENERS, Norris F. Dow and William A. Hickman, January 1949

Comparisons are made of the structural efficiency of panels having straight web and curved web Y-section stiffeners. The comparisons show that, in the high-stress region in which failure is at least in part associated with local buckling, panels having curved web Y-section stiffeners have higher structural efficiencies are evidenced by higher average stresses at failure, smaller stiffener heights, or wider average spacing of rivet lines, in various combinations depending on the design requirements.

TN 1806 DETERMINATION OF PLATE COMPRESSIVE STRENGTHS AT ELEVATED TEMPERATURES, George J. Heimerl and William M. Roberts, TR 960, February 1949

The results of the local-instability tests of extruded H-sections of 75S-T6 aluminum alloy warrant the following conclusions regarding the determination of compressive strengths of flat plates or plate assemblies of various materials at elevated temperatures:

1. The critical compressive stress for H-section plate assemblies of extruded 75S-T6 aluminum may be determined approximately at room temperature by the use of the compressive stress-strain curve for the material for the desired temperature, strain rate, and exposure time. At elevated temperature, the secant-modulus method is slightly unconservative in the plastic region as was found to be the case at room temperature for this material.

2. Approximately the same relationship exists between the compressive stress, the average stress at maximum load, and the compressive yield stress at elevated temperature as at room temperature for H-section plate assemblies. For stresses above 3/4 compressive yield stress, the average stress at maximum load is only slightly greater than the critical compressive stress; whereas, below 3/4 of the compressive yield stress, the average stress at maximum load may be appreciably greater than the critical compressive stress.

3. In view of the consistent general relationship previously found at room temperature between the H-section plate-assembly test results for the critical compressive stress and the compressive stress-strain relationship curve for a number of materials, and the fact that this relationship now appears to be valid at elevated as well as at room temperature, it is reasonable to expect that the critical compressive stress may be approximately determined at elevated temperature for individual plates and various plate assemblies by methods which are satisfactory at room temperature, provided that the compressive stress-strain curve for the material at the desired temperature, strain rate, and exposure time is given.

TN 1817 PLASTIC BUCKLING OF SIMPLY SUPPORTED COMPRESSED PLATES, Richard A. Pride and George J. Heimerl, April 1949

The results of the local-instability tests of drawn square tubes warrant the following conclusions as regards the plastic buckling of a long, flat, simply supported compressed plate:

1. The results of these tests show good agreement with Stowell's theory for the plastic buckling of a simply supported plate which is based on a deformation theory of plasticity. This confirmation, together with that previously shown for a flange and column, is considered to constitute a satisfactory experimental verification of the theory.

2. Good agreement with the test results is evidenced in general by the deformation type theories for plastic buckling. Stowell's theory is in the closest agreement with the test results reported herein, but Ilyushin's and Bijlaard's theories give results only slightly higher.

3. Marked disagreement is shown between the test results and the Handelman-Prager theory which is based on a flow theory of plasticity.

4. Buckling stress calculated by the empirical secant-modulus method are reasonable, though higher than the test results. This convenient rapid method can therefore be used for an approximate determination of the critical compressive stress.

TN 1820 STRENGTH ANALYSIS OF STIFFENED THICK BEAM WEBS, L. Ross Levin and Charles W. Sandlin, Jr., March 1949

Methods to predict the critical shear stress, forced crippling failures of the uprights, the rupture of the webs were presented for stiffened beam webs with ratios of web depth to web thickness between 115 and 1500.

The formula for the critical shear stress is:

$$\tau_{cr} = K_{ss} \; E\left(\frac{t}{d_c}\right)^2 \left[R_n + \frac{1}{2}(R_d - R_n)\left(\frac{d_c}{n_c}\right)^3\right]$$

This is the same as given in TN 1364.

If the critical shear stress computed by the previous formula is in the plastic region it must be recomputed by the following formula:

$$\tau_{cr} = \eta \, K_{ss} \; E\left(\frac{t}{d_c}\right)^2 \left[R_n + \frac{1}{2}(R_d - R_n)\left(\frac{d_c}{n_c}\right)^3\right]$$

These formulas give results to the same degree of accuracy as the results in TN 1364.

TN 1822 ELASTIC AND PLASTIC BUCKLING OF SIMPLY SUPPORTED METALITE TYPE SANDWICH PLATES IN COMPRESSION, Paul Seide and Elbridge Z. Stowell, (report 967), February 1949

A solution is presented for the problem of the compressive buckling of simply supported, flat, rectangular, Metalite type sandwich plates stressed either in the elastic range or in the plastic range. Charts for the analysis of long sandwich plates are presented for plates having face materials of 24S-T3 aluminum alloy, 75S-T6 Alclad aluminum alloy, and stainless steel.

The theory is checked by a comparison of computed and experimental results for square sandwich plates. Fair agreement is found.

TN 1823 THE BUCKLING OF PARALLEL SIMPLY SUPPORTED TENSION AND COMPRESSION MEMBERS CONNECTED BY ELASTIC DEFLECTIONAL SPRINGS, Paul Seide and John F. Eppler, February 1949

An investigation of the problem of the buckling of parallel simply supported tension and compression members connected by equally stiff and equally spaced elastic deflectional springs is made as an approximation to the problem of the effect of finite stiffness of ribs and tension surface on the buckling load of the compression surface of a wing.

For simplicity, the tension surface of the wing can be assumed to be equivalent to a rigid foundation and the shear webs and ribs can be assumed to be equivalent to rigid supports that divide the compression surface into small panels so that the compressive buckling load of the wing surface is the buckling load of the small panels. Actually, the shear webs and ribs and the tension surface have finite stiffness; therefore, the buckling load of the compression surface is reduced because of the deflection of the supports. An exact analysis of this problem is given in the appendix of this report which is available in the NCSU Library. The exact analysis is by Rayleigh and Ritz.

TN 1825 COMPRESSIVE BUCKLING OF SIMPLY SUPPORTED PLATES WITH LONGITUDINAL STIFFENERS, Paul Seide and Manuel Stein, March 1949

Charts are presented for the analysis of the stability under compression of simply supported rectangular plates with one, two, three, and an infinite number of identical equally spaced longitudinal stiffeners that have zero torsion.

These charts indicate that relationship between the buckling stress coefficient and the plate bay aspect ratio for various values of the ratio of the stiffener flexural stiffness to the flexural stiffness of a plate bay and the ratio of the stiffener area to the area of a plate bay.

The stability equations from which the charts were computed are derived by means of the Rayleigh-Ritz energy method.

TN 1827 MATRIX METHODS FOR CALCULATING CANTILEVER-BEAM DEFLECTIONS, Stanley U. Benscoter and Myron L. Gossard, March 1949

The method of numerical integration for calculation of beam deflection is presented in matrix form to give it the advantages which are inherent in an influence-coefficient method.

The advantage of an influence coefficient method of deflection analysis is that it provides a direct linear relation between the loading and the deflection in explicit form. The same advantage may be obtained in a numerical integration process, employing beam stiffness properties, if the analysis is expressed in matrix form. The linear relationships for distributed loading have been developed.

The accuracy of both the numerical integration and influence coefficient methods can be improved by the introduction of weighting matrices. Consequently, for a desired appreciable saving in calculation time since the computing work varies as the square of the order of the matrices.

TN 1829 DATA ON THE COMPRESSIVE STRENGTH OF 75S-T6 ALUMINUM ALLOY FLAT PANELS WITH LONGITUDINAL EXTRUDED Z-SECTION STIFFENERS, William A. Hickman and Norris F. Dow, March 1949

DATA ONLY:

Part of an extensive study on stiffeners at Langley. Since investigation is expensive and time required to complete experimental work and to analyze data will be prolonged, the data is presented, without analysis, as it is obtained.

In this paper, the results are presented for panels in which the stiffeners are relatively thick and closely spaced; specifically for panels for which the ratio of the thickness of the stiffener material to the skin material varies from 0.4 to 1.0 and the ratio of stiffener spacing to skin thickness varies from 15 to 40.

TN 1830 TENSION PROPERTIES OF ALUMINUM ALLOYS IN THE PRESENCE OF STRESS RAISERS - I - EFFECTS OF TRIAXIAL STRESS STATES ON THE FRACTURING CHARACTERISTICS OF 24S-T86 ALUMINUM ALLOYS, E. E. Aul, A. W. Dana and G. Sachs, March 1949

TN 1831 II - COMPARISON OF NOTCH STRENGTH PROPERTIES OF 24ST, 75ST, AND 24S-T86 ALUMINUM ALLOYS, March 1949

CONCLUSIONS FOR PART I:

1. The fracture strain decreases continuously with increasing triaxiality. The rate of this decrease probably differs considerably for different materials.

2. The actual fracture stress increases with increasing triaxiality. For a ductile metal the rate of increase is a large fraction of that of the stress required for plastic flow. No conclusions can be drawn from notched-bar tensile tests regarding the condition of fracture for metals which are brittle within the accessible range of triaxiality.

3. The actual fracture stresses, for various triaxialities, are associated with various strains. For any constant strain, the fracture stress must be located somewhere between the actual

fracture stress and the stress required for plastic flow. Therefore, the hypothetical fracture stress for any given strain depends upon triaxiality in almost the same manner as the stress required for plastic flow.

4. The stress required for plastic flow is determined by the condition of plasticity. Consequently, the condition of fracture for ductile metals deviates only slightly from the condition of plasticity. Under conditions of rotational symmetry, the condition of plasticity is identically described by a constant maximum shear stress and a constant distortion energy.

5. In order to account for the decrease in ductility with increasing triaxiality, the unknown condition of fracture must deviate from the maximum shear stress condition to yield lower stresses. This requirement is fulfilled if the condition of fracture is located somewhere between the condition of maximum shear stress and the condition of maximum principal stress. For ductile metals, the condition of fracture has been found to be considerably closer to that yielding a constant maximum shear stress than to that determined by a constant maximum principal stress.

CONCLUSIONS TO II:

1. Notching of metal subjected to tension generally reduces the ductility. For a given notch shape, the decrease in ductility from the value for regular tension is very different for various metals.

2. The relative magnitude of the reduction in ductility is similar for mildly and for sharply notched bars.

3. The notch sensitivity regarding ductility is not related in a simple manner to the notch sensitivity regarding strength. Only if the materials are very similar regarding their stress-strain characteristics do the notch strength and the fracture stress become universal functions of the notch ductility. No definite relation between ductility and strength can be derived at present for aluminum alloys.

TN 1832 SMALL BENDING AND STRETCHING OF SANDWICH-TYPE SHELLS, Eric Reissner (superseded by report 975), March 1949

A system of basic equations has been derived for the analysis of small-deflection problems of sandwich-type thin shells. This system of equations reduces to Love's theory of thin shells when the transverse shear and normal stress deformability of the core of the sandwich is of negligible importance. The system of basic equations has been applied to a number of specific problems from the theory of plates, circular rings, circular cylindrical shells, and spherical shells, and it has been found that the effects of both transverse shear and transverse normal stress deformation may be of such magnitude that an analysis which disregards them gives values for deflections and stresses which are appreciably in error.

The general analysis has been restricted by the following two order-of-magnitude relations: (1) $t/h \ll 1$ and (2) $tE_f/hE_c \gg 1$, where t is the face-layer thickness, h is the core-layer thickness, E_f is the elastic modulus of the isotropic face-layer material, and E_c is the elastic modulus of the core layer material in the transverse direction. Therewith it is felt that very likely nearly all situations have been covered in which the effect of transverse core flexibility is of significant practical importance. If desired, the theory could be extended so as to include cases where one or both of these two order-of-magnitude relations are not satisfied. The main limitation of the present analysis is the omission of all finite-deflection and instability effects.

TN 1833 NOTES ON THE FOUNDATIONS OF THE THEORY OF SMALL DISPLACEMENTS OF ORTHOTROPIC SHELLS, F. B. Hildebrand, E. Reissner, and G. B. Thomas, March 1949

From a survey of various systems of equations given in the literature for the analysis of small deflections of thin elastic shells, it appears that the question concerning the best form of the basic system of equations of shell theory has not yet been decided, even in the small-deflection theory.

TN 1837 ELEVATED-TEMPERATURE COMPRESSIVE STRESS-STRAIN DATA FOR 24S-T3 ALUMINUM-ALLOY SHEET AND COMPARISONS WITH EXTRUDED 75S-T6 ALUMINUM ALLOY, William M. Roberts and George J. Heimerl, March 1949

This report presents results on compressive strain-stress tests of 24S-T3 aluminum-alloy at stabilized elevated temperatures up to 700° F, with exposure times of 1/2 to 2 hours, and strain rates of 0.002 to 0.006 per minute. The results were compared with similar data obtained in TN 1806 for 75S-T6 Al.

At room temperature the compressive maximum stress was 54 ksi, at 300° F it was 48 ksi, at 400° F it was 54 ksi, and at 700° F it was 8 ksi. The compressive yield stress decreases at first, as the temperature is raised, and then may increase again depending on the exposure time, but above 400° F the compressive yield stress shows a rapid decrease. While 75S-T6 has higher yield stress values at room temperature than does 24S-T3 once above 400° F this report shows that 24S-T3 has the higher compressive yield stress.

TN 1840 ANALYSIS OF PROPERTIES OF FOAM, J. W. McBain, Syney Ross and A. P. Brady, March 1949

This is a report on the volume of foam that different types of liquid produce when produced by different types of agitation. It was a first thought that the volume of foam might be directly related to the foam stability. The stability of foam is directly related to the viscosity of the liquid. However it was found that the amount of foam depends not only on the stability but on the mechanism of its production.

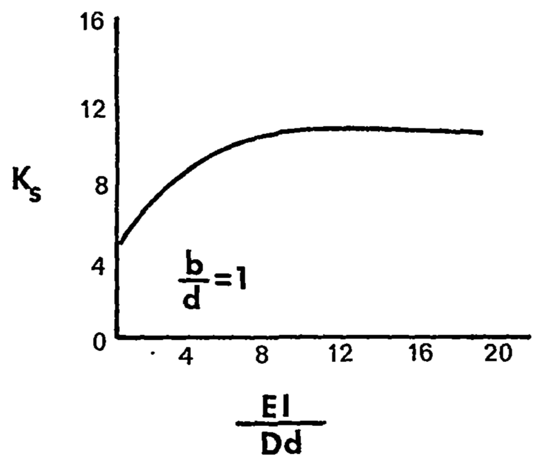
TN 1851 CRITICAL SHEAR STRESS OF INFINITELY LONG, SIMPLY SUPPORTED PLATE WITH TRANSVERSE STIFFENERS, Manuel Stein and Robert W. Fralich, April 1949

(a) This TN presents a theoretical solution for an infinitely long, simply supported, flat plate with identical, equally spaced, transverse stiffeners of zero torsional stiffness.

$$\tau = k_s \frac{\pi^2 D}{b^2 t} \qquad D = \frac{E_p t^3}{12(1 - \mu^2)}$$

τ = critical shear stress
k_s = critical shear-stress coefficient
t = thickness of plate
b = width of plate
E_p = Young's modulus for plate
μ = Poisson's ratio for material
$\frac{EI}{Dd}$ = ratio of stiffener stiffness to plate stiffness
E = Young's modulus for stiffener
I = effective moment of inertia of stiffener
d = stiffener spacing

Different graphs are presented for aspect ratios, $\frac{b}{d}$, of 1, 2, 5 for k_s plotted against EI/Dd.



TN 1852 REINFORCED CIRCULAR CUTOUTS IN PLANE SHEETS, H. Reissner and M. Morduchow, April 1949

(a) The purpose of this report is to design a reinforcement of a cutout in a plane sheet in such a way as to provide equivalent support to the part that was cut out. The following expressions were formulated for the cross-sectional area and moment of inertia of the cutout reinforcement ring:

$$A_r = (at) \left[\frac{E_s \Sigma_{n=o} (P_n' \cos n\phi)_{r=a_1, n\neq 1} + \frac{C_2}{t}\sin\phi + \frac{C_3}{t}\cos\phi}{E_r \Sigma_{n=o} \cos n\phi \{ n^2 \gamma \frac{P_n}{a_1} - \gamma P_n' + a_1 P_n'' + n^2 \frac{d}{2a} [\gamma P_n' - \frac{P_n}{a_1} + (n^2-1) \int \frac{P_n}{r^2} dr]\}_{r=a_1}} \right]$$

$$I_r = (a^3 t) \left[\frac{E_s \Sigma_{n=o} \cos n\phi [P_n' a_1 - (P_n' a)_{n\neq 1} - P_n]_{r=a_1} a^{-1} - \frac{C_2}{t}\sin\phi - \frac{C_2}{t}\cos\phi + \frac{C_1}{at}}{E_r \Sigma_{n=o} \cos\phi (n^2-1) [P_n a_1^{-1} - \gamma P_n' - (n^2-1) \int P_n r^{-2} dr]_{r=a_1}} \right]$$

C_1, C_2, and C_3 are integration constants

A_r = cross-sectional area of cutout reinforcement ring
a = radius of center line of ring
a_1 = radius of outer circumference of ring
b = half width of sheet
E_r = modulus of elasticity of ring
E_s = modulus of elasticity of sheet
I_r = cross sectional moment of inertia of ring
n = order of terms of stress function
P_n = coefficients in stress function
t = thickness of sheet
γ = Poisson's ratio
ϕ = angular polar coordinate

Further information on this subject is available in Stresses in Aircraft and Shell Structures by Kuhn.

TN 1856 THEORETICAL STUDY OF THE DIFFUSION CONSTANT FOR SELF-DIFFUSION IN METALS, M. Leichter, April 1949

(a) Age-hardening, annealing, and order-disorder transformation depend on the movement of atoms within a lattice. A method of determining the movement of atoms within a lattice is to study the rate at which metals diffuse into each other.

$$E = Ae^{-Q/RT} \qquad A = \frac{2\pi\nu}{3} W \sqrt{3E_1/Et}\, d^2\, e^{E_f/2RT}$$

- D = diffusion constant
- d = average length of atomic jumps
- E_f = heat of fusion
- E_t = average thermal energy
- E_1 = average energy required to make one jump
- Q = energy of activation
- R = tas constant
- T = temperature
- W = number of nearest neighbors in lattice
- ν = frequency of vibration

The theoretical and experimental data compare very well.

TN 1863 COMPARATIVE STRENGTHS OF SOME ADHESIVE-ADHERENT SYSTEMS, N. J. Dellis, Nancy Rucker, and J. E. Wier, March 1949

This report was a study of various adhesive (polyvinyl acetate, cellulose nitrate, resorcinol resin, casein, gum arabic, rubber, neoprene)-adherent (stainless steel, aluminum alloy, paper-phenolic laminate, glass birch wood, hard rubber)systems.

It was found that polyvinyl acetate was the best adhesive in the shear and tensile test, while rubber was a very poor adhesive with respect to tensile and shear strengths it was vastly superior during the impact test. Polyvinyl acetate was such a good adhesive that all of the adherents failed during the tensile and shear test except the steel and aluminum. It should be noted that long time tests show that thermosetting adhesives were superior to thermoplastic adhesives. For example polyvinyl acetate (thermoplastic) failed in 45 days with a 200 psi load, while resorcinol resin (thermosetting) showed no sign of failure after 6 months with a 680 psi load. Resorcinol resin gave the second highest values in the static test, but have very little or no adhesion for glass and the metals.

TN 1867 A STUDY OF EFFECTS OF HEAT TREATMENT AND HOT-COLD-WORK ON PROPERTIES OF LOW-CARBON N-155 ALLOY, J. W. Freeman, E. E. Reynolds, D. N. Frey, and A. E. White, May 1949

Physical properties at room temperature and rupture test characteristics at 1200° F were used as criterions to evaluate the effects of systematic variations of solution treatments, aging, and hot-cold-work on the properties of bar stock from one heat of low-carbon N-155 alloy. The range in yield strength for 0.02% offset at room temperature was from 30,000 to 134,000 psi. Rupture strengths at 1200° F ranged from 40,000 to 66,000 psi at 100 hours and from 35,000 to 56,000 psi at 1000 hours. This rupture-strength range is equivalent to such extreme variation as 100 to approximately 6000,000 hours for fracture at 1200° F under a stress of 40,000 psi for the same bar stock with different treatments.

Other characteristics than physical properties at room temperature and rupture properties at 1200° F have not been considered. "More work on other heats is needed to verify the reliability of the reported data."

TN 1871 A MATHEMATICAL THEORY OF PLASTICITY BASED ON THE CONCEPT OF SLIP, S. B. Batdorf and Bernard Budiansky, April 1949

Quote: "The experimental data however are not very extensive. Before the new theory can be regarded as established, additional experimental data of the same general type must be obtained."

TN 1879 CRITICAL AXIAL-COMPRESSIVE STRESS OF A CURVED RECTANGULAR PANEL WITH A CENTRAL LONGITUDINAL STIFFENER, Murry Schildcrout and Manuel Stein, May 1949

A theoretical solution is presented for the critical axial-compressive stress of a simply supported curved rectangular panel having a central longitudinal stiffener offering no torsional restraint.

$D = Et^3/12(1 - \mu^2)$
b = circumferential dimension of panel
t = thickness of panel

The critical stress:

$$\sigma_x = \frac{K_x \pi^2 D}{b^2 t}$$

The report gives in graphs (6 pages) k_x, axial compressive stress coefficient, as a function of EI/Db.

TN 1886 COMPRESSIVE BUCKLING OF FLAT RECTANGULAR METALITE TYPE SANDWICH PLATES WITH SIMPLY SUPPORTED LOADED EDGES AND CLAMPED UNLOADED EDGES, Paul Seide, May 1949

This report presents a theoretical solution for the problem of the compressive buckling of flat rectangular Metalite type sandwich plates with the loaded edges simply supported and the unloaded edges clamped. The solution is based on the small-deflection theory developed in TN 1526.

$$K = \frac{\frac{16}{3}\left[\frac{\beta^2}{m^2} + \frac{1}{2} + \frac{3}{16}\frac{m^2}{\beta^2}\right]}{1 + \frac{r}{1 + \frac{4}{3}\frac{\beta^2}{m^2}}\,\frac{16}{3}\left[\frac{\beta^2}{m^2} + \frac{1}{2} + \frac{3}{16}\frac{m^2}{\beta^2}\right]}$$

$$\sigma_{cr} = K\left[\frac{\pi^2 D}{2b^2 t_f}\right]$$

σ_{cr} = critical compressive stress in x-direction
β = plate aspect ratio (a/b)
a = plate length
b = plate width
r = core shear-flexibility coefficient $(D/b^2 G_c h_c)$
D = $E_f t_f (h_c + t_f)^2 / 2(1 - U_f^2)$
G_c = shear modulus of core material
E_f = Young's modulus for face material
U_f = Poisson's ratio for face material
t_f = face thickness
h_c = core thickness
m = number of half waves in buckled-plate deflection surfaces in direction of loading

TN 1887 EFFECT OF HIGH SHEAR RATE ON EROSION OF COMMON BEARING METALS, Charles D. Strang and Thomas P. Clark, June 1949

This is a report that gives the results of an investigation on the scoring of different samples of types of bearings. It was found that annealed copper, silver, and lead specimens showed no erosion when exposed to flowing oil at mean shear stresses as high as 43 pounds per square inch. The only erosion that could be achieved was when foreign particles were introduced into the flow, small foreign particles could cause erosion whenever they were forced to change direction by the erosion specimens.

TN 1889 BIAXIAL FATIGUE STRENGTH OF 24S-T ALUMINUM ALLOY, Joseph Marin and William Shelson, May 1949

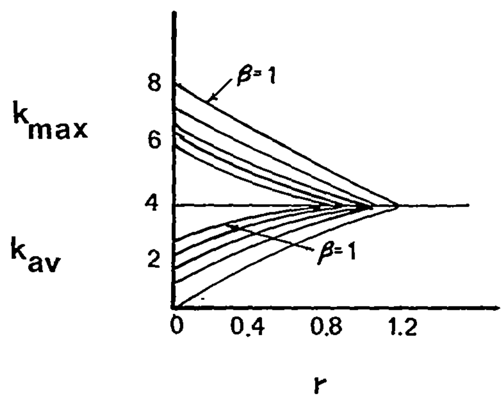
Biaxial tensile fatigue strengths of 24S-T aluminum-alloy tubing were obtained for various ratios of biaxial maximum stresses and with the minimum stresses approximately equal to zero. The test showed that the biaxial fatigue strength may be as low as 50% of the uniaxial strength.

TN 1891 ELASTIC BUCKLING OF A SIMPLY SUPPORTED PLATE UNDER A COMPRESSIVE STRESS THAT VARIES LINEARLY IN THE DIRECTION OF LOADING, Charles Libove, Saul Ferdman, and John J. Reusch, June 1949

The report presents a method of calculating the buckling load, maximum stress, and the average stress of a plate on which the stress varies linearly from one edge to the other, the plate is of uniform thickness and is subjected to unequal compressive stresses at the two opposite edges. The plate stressed in this report is similar to the stress that the wing of an airplane undergoes.

The method presents the average and maximum stress as functions of two parameters, the parameters k_{max} and k_{av} are presented on graphs as functions of r the load gradient parameter.

$$\sigma_{av} = k_{av} \left(\frac{\pi^2 D}{b^2 t}\right) \qquad \sigma_{max} = k_{max} \left(\frac{\pi^2 D}{b^2 t}\right)$$



B is the ratio of the length over the width
r is the ratio of the minimum stress to the maximum stress

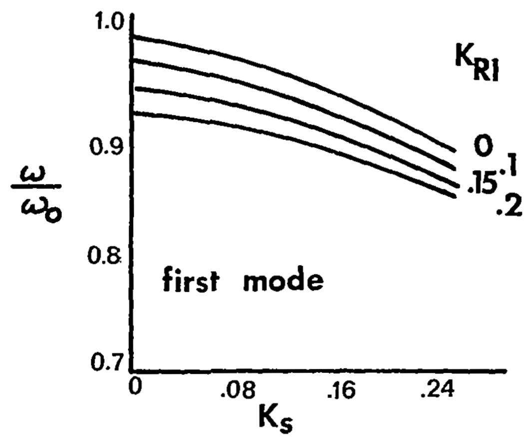
TN 1909 EFFECT OF TRANSVERSE SHEAR AND ROTARY INERTIA ON THE NATURAL FREQUENCY OF A UNIFORM BEAM, Edwin T. Kruszewski, July 1949

(a) A theoretical analysis of the effect of transverse shear and rotary inertia on the natural frequencies of a uniform beam is presented.

(b) The natural frequency ω is plotted in the ratio ω/ω_o as a function of the shear-stiffness parameter and the rotary-inertia parameter, k_s and k_{RI}. ω_o is obtained by neglecting secondary effects, transverse shear and rotary inertia. In order to obtain ω from the graphs, ω_o is calculated from:

$$\omega_o = k_{Bo}\sqrt{\frac{EI}{mL^4}}$$

k_{Bo} = is a constant for a particular mode and is given on the graph
EI = flexural stiffness, lb-in^2
L = length of cantilever beam and half-length of free-free beam, inches
m = distributed loading, pounds per inch
A_s = shear area, in^2
G = shear modulus, psi



Change in the natural frequency of a cantilever beam due to shear and rotary inertia:

$$k_s = \frac{1}{L}\frac{EI}{A_s G}$$

TN 1909 also contains graphs for the 2nd and 3rd modes of the cantilever beam and for three symmetrically vibration modes and three anti-symmetrically vibration modes of a free-free beam. TN 1909 is available in the NCSU Library.

TN 1910 SHEAR BUCKLING OF INFINITELY LONG SIMPLY SUPPORTED METALITE TYPE SANDWICH PLATES, Paul Seide, July 1949

(a) In this report the sandwich-plate theory developed in TN 1526 was applied to the problem of shear buckling in infinitely long simply supported plates.

(b) Good agreement was found between this and several other methods.

TN 1928 CRITICAL COMBINATIONS OF SHEAR AND DIRECT AXIAL STRESS FOR CURVED RECTANGULAR PANELS, Murry Schildcrout and Manuel Stein, August 1949

A solution is presented for the problem of the buckling of curved rectangular panels subjected to combined shear and direct axial stress. Charts giving theoretical critical combinations of shear and direct axial stress are presented for panels having five different length-widths ratios.

Because the actual critical compressive stress of rectangular panels having substantial curvature is known to be much lower than the theoretical value, a semi-empirical method of analysis of curved panels subjected to combined shear and direct axial stress is presented for use in design.

TN 1940 FUNDAMENTAL EFFECTS OF AGING ON CREEP PROPERTIES OF SOLUTION-TREATED LOW-CARBON N-155 ALLOY, D. N. Frey, J. W. Freeman, and A. E. White, (superseded by 1001), August 1949

This is one of a series of reports (TN 1867) that investigates by which processing, heat treatment, and chemical composition control the properties of alloys at high temperature. A study was made in this report on the effect of aging on short-time creep, and on the rupture properties of solution-treated low-carbon N-155 alloy.

It was found that aging progressively lowered the short-time creep. Short-time aging resulted in an increase in rupture strength and long time aging resulted in little more increase. Aged material also increased the ductility of the material.

TN 1962 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS - VII - EXPERIMENTAL INVESTIGATION OF CYLINDERS HAVING EITHER LONG BOTTOM CUTOUTS OR SERIES OF SIDE CUTOUTS, N. J. Hoff, Bruno A. Boley, and Joseph J. Mele, October 1949

(a) Eight 24S-T cylinders having 45° cutouts of varying lengths and varying numbers of cutouts. All cylinders but one failed in general-instability and it failed in tension. The tests were run to find if the axial length of the general-instability bulge would always be longer than the cutout and they were run to find what the length of the cutout would do to magnitude of the buckling.

(b) It was found that when the only difference in cylinders was the length of the cutout the cylinder with the longer cutout failed at the lower buckling load. It was also found that the general-instability bulge can be smaller than the cutout.

TN 1963 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS - VIII - CALCULATION OF THE BUCKLING LOAD OF CYLINDERS WITH LONG SYMMETRIC SUBJECTED TO PURE BENDING, N. J. Hoff, Bruno A. Boley, and Merven W. Mandel, October 1949

(a) The strain energy theory presented in TN 1263 was used in this report with the addition of the axial wave length as an additional parameter. This reduced the average error from 33.9 to 18.1 percent.

(b) A better report on the calculations of stresses in cylinders with cutouts is presented in Stresses in Aircraft and Shell Structures by Kuhn.

TN 1971 PLASTIC BUCKLING OF EXTRUDED COMPOSITE SECTIONS IN COMPRESSION, Elbridge Z. Stowell and Richard A. Pride, October 1949

(a) This report presents a method for determining the critical stress of an extruded shape. The method ends up with two equations, one for the critical stress of the web and one for the critical shape of the flange; each equation has two unknowns, but the critical stress of the flange must equal the critical stress of the web. The formulas in this method are long and complex. Kuhn in Stresses in Aircraft and Shell Structures presents a method on the buckling stress of the web on page 56. He also gives graphs for correcting the critical stress calculated in the elastic region for use in the plastic region for 75S-T6 and 24S-T3. The critical stress of the web is identical with the critical stress for the entire extruded shape.

TN 1972 CRITICAL SHEAR STRESS OF A CURVED RECTANGULAR PANEL WITH A CENTRAL STIFFENER, Manuel Stein and David J. Yaeger, October 1949

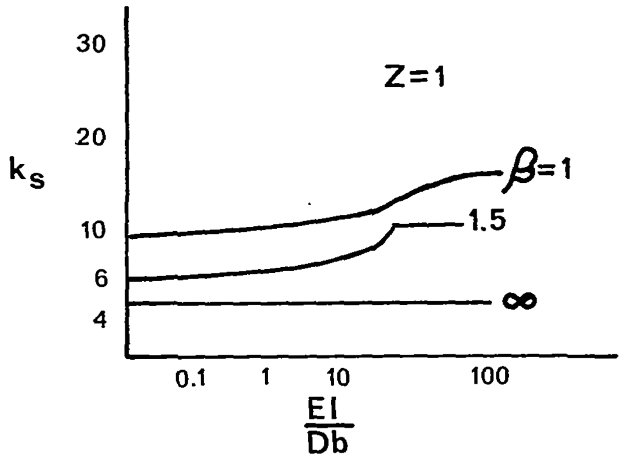
(a) A theoretical solution is given for the critical shear stress of a simply supported curved rectangular plate stiffened by a central stiffener offering no torsional restraint which lies in either the axial or circumferential direction.

(b) The following equation gives the critical shear stress in terms of the constant k_s. k_s is plotted at the end of this report for different curvature parameter Z and aspect ratio β as a function of EI/Db.

$$\tau = k_s \frac{\pi^2 D}{b^2 t}$$

a = length of panel
b = width of panel
r = radius of curvature of panel
t = thickness of panel
$D = Et^3/(12(1 - \mu^2))$
E = Young's modulus
I = effective moment of inertia of stiffener
μ = Poisson's ratio
β = a/b aspect ratio
$Z = \frac{b^2}{rt}\sqrt{1 - \mu^2}$

(c) The report gives k_s in tables as well as in graphs.



TN 1974 EFFECT OF OPEN CIRCULAR HOLES ON TENSILE STRENGTH AND ELONGATION OF SHEET SPECIMENS OF SOME ALUMINUM ALLOYS, H. N. Hill and R. S. Barker, October 1949

This report deals with the effect of holes in the tensile strength and percent reduction of some aluminum alloys under tensile loadings.

In practical cases it was found that the reduction in strength resulting from holes was about 5% for Alclad 14S-T6 and 75S-T6, 24S-T81, and 24S-T86. The reduction in the case of 24S-T3, 24S-0, and Alclad 14S-T3 was about 10%.

The specimens were tested with a single hole, two staggered holes, and four holes in a diamond pattern. The two holes in the staggered pattern presented the greatest reduction in strength, 25%, the diamond pattern was next with 15%, and then the single hole with a maximum reduction in strength of 5%.

The materials with the greatest ductility showed the greatest reduction in strength, while the less ductile materials showed the largest reduction in elongation.

TN 1978 DATA ON THE COMPRESSIVE STRENGTH OF 75S-T6 ALUMINUM ALLOY FLAT PANELS HAVING SMALL THIN, WIDELY SPACED, LONGITUDINAL EXTRUDED Z-SECTION STIFFENERS, William A. Hickman and Norris F. Dow, November 1949

This report is the second part of a series of tests run on 75S-T6 panels having Z-section stiffeners. The report ismostly data on the effect: ratio of the thickness of the stiffener material to skin material is small and the ratio of stiffener spacing to skin thickness is large. This report contains 15 pages of tables and graphs on the effect of the ratio of stiffener thickness to skin thickness and the effect of the structural index on strength of the panel.

As long as the small stiffeners were not very long they carried the load adequately. It was found that in cases where the stiffeners had high width-to-thickness ratios that the stiffeners failed by local instability. There was found to be little difference between panels having stiffeners .102 and .064 inches thick insofar as strength is concerned.

TN 1981 CRITICAL STRESS OF RING-STIFFENED CYLINDERS IN TORSION, Manuel Stein, J. Lyell Sanders, Jr., and Harold Crate, (superseded by Report 989), November 1949

This report presents a theoretical solution for the critical-shear-stress of a ring stiffened cylinder.

$$\tau_{cr} = \frac{T}{2r^2 t}$$

This method gives answers that differ from the experimental answers by 15%. A similar method is presented in NASA CR 912, April 1968, Frame-Stiffened Cylinders, page 637.

TN 1985 ELASTIC BUCKLING OF OUTSTANDING FLANGES CLAMPED AT ONE EDGE AND REINFORCED BY BULBS AT OTHER EDGE, Stanley Goodman, October 1949

In this report the compressive buckling stress of an outstanding flange reinforced by a bulb was computed by the strain-energy method.

A_f = cross sectional area of flange
A_s = cross sectional area of sheet in sheet-stringer structure
I_f = moment of inertia of flange about its base
L = flange length
E = Young's modulus

$$\frac{A_s}{A_f} = \frac{\pi^2 I_f}{A_f^{\,2}\left(\frac{\sigma_{crs}}{E}\right)\left(\frac{L}{\sqrt{A_f}}\right)} - 1$$

It was found that the flange able to give the most support had a flange width of $3.4\sqrt{A_f}$.

TN 1986 STABILITY OF ALCLAD PLATES, Kenneth P. Buchert, December 1949

The report presents a theoretical solution for the buckling of plates, it is felt, that NASA TN D 2505 and NASA CR 864 present better solutions to this problem.

TN 1990 PLASTIC BUCKLING OF A LONG FLAT PLATE UNDER COMBINED SHEAR AND LONGITUDINAL COMPRESSION, Elbridge Z. Stowell, December 1949

The condition for plastic buckling of a plate under combined shear and longitudinal compression is obtained by using the theory of plastic buckling. The combination of shear and direct stress that will cause buckling are given by:

$$R_c + R_s^{\,2} = 1$$

$$\sigma_x = k_c \frac{(E_s)\sigma_1}{E} \frac{\pi^2 D}{b^2 h} \qquad \sigma_1 = \sqrt{\sigma_x^{\,2} + 3\tau^2}$$

$$\tau = k_s \frac{(E_s)\sigma_1}{E} \frac{\pi^2 D}{b^2 h}$$

σ_x = applied direct stress, positive in compression
τ = applied shear stress
E = elastic modulus

E_s = secant modulus at stress intensity σ_1
D = bending stiffness of plate in elastic range ($Eh^3/9$)
k_c, k_s = constants that depend on the ratio of the direct stress to the shear stress
b = plate width
h = plate thickness

TN 1996 ON INTERNAL DAMPING OF ROTATING BEAMS, Morris Morduchow, December 1949

This report investigates the internal damping of a beam rotating about a transverse axis and harmonically vibrating in a direction normal to its plane of rotation.

It was found that for a beam, as above, the internal logarithmic decrement of such a beam will increase asymptotically with the mode of vibration and will approach the value πg which it would have in all modes if the beam were not rotating. If the beam is vibrating in its plane of rotation then the internal logarithmic decrement will be equal or less than πg, in the fundamental mode; will decrease in the second mode; and then will increase asymptotically with the higher modes to the value of πg. Thus the greatest variation of the logarithmic decrements with the mode will occur in the lower modes, rotation of a beam diminishes the structural logarithmic decrements.

TN 2012 RESULTS OF SHEAR FATIGUE TESTS OF JOINTS WITH 3/16 INCH DIAMETER 24S-T31 RIVETS IN 0.064 INCH THICK ALCLAD SHEET, Marshall Holt, Alcoa, February 1950

Results showed that the design of the joint gives a wider range of fatigue strengths than does the choice of material from the group studied. The results also showed that no one sheet alloy showed superiority over the others.

TN 2017 A SMALL DEFLECTION THEORY FOR CURVED SANDWICH PLATES, Manuel Stein and J. Mayers, Langley Aero. Lab., February 1950

A small deflection theory that takes into account deformation due to transverse shear is presented for the elastic-behavior analysis of orthotropic plates of constant cylindrical curvature, with considerations of buckling included. The theory is applicable primarily to sandwich construction.

Considerable amount of work on sandwich structures on the Theory of Shells and Plates translation from Russian. October 1962.

TN 2020 COMPRESSIVE STRENGTH OF FLANGES, Elbridge Z. Stowell, Langley Mem. Aero. Lab., January 1950

A theoretical analysis of the compressive strength of flanges, based on a deformation theory of plasticity combined with the theory for finite deflections for this structure, and comparison with experimental data lead to the following conclusions:

1. The maximum load for a flange under compression and hinged along one edge may be accurately computed from the dimensions of the flange and the compressive stress-strain curve for the material.

2. Maximum loads occur when, because of the onset of plasticity, the effective modulus has been reduced to such a low value that it is no longer possible for the average stress to increase with increasing strain. Failure is not a local phenomenon but is an integrated effect over the cross section of the flange.

3. For a wide variety of cruciform sections, the stress intensity along the hinge line at maximum load is a constant to about 1 percent.

4. The fact that maximum loads may be computed in this case suggests that the deformation theory of plasticity is sufficiently accurate when the stress state changes from compression to combined compression and shear in the case when the shear strains are less than about two-thirds of the compressive strains.

TN 2021 BUCKLING OF THIN WALLED CYLINDER UNDER AXIAL COMPRESSION AND INTERNAL PRESSURE, Hsu Lo, Harold Crate, and Edward B. Schwartz, Langley Aero. Lab., January 1950

This information is similar to that contained in Shell Analysis Manual, NASA CR 912.

TN 2024 SOUND MEASUREMENTS FOR FIVE SHROUDED PROPELLERS AT STATIC CONDITIONS, Harvey H. Hubbard, April 1950

It was found that the shrouded propeller produces from one-half to twice the noise of an unshrouded propeller. The shrouded propeller produces far less noise when the flow about the shroud has not separated and more noise when the flow separates from the shroud than does the unshrouded propeller. It was also found that as the number of propeller blades was increased the sound level decreased. When tip clearance and shroud chord are adjusted to give the best aerodynamics the sound decreases.

TN 2029 THE INTERPRETATION OF BIAXIAL-TENSION EXPERIMENTS INVOLVING CONSTANT STRESS RATIOS, S. B. Batdorf, February 1950

Slip theory of plasticity is applied to calculating the strains associated with biaxial tension, in which the stress ratios and directions are kept constant.

$$F(\tau_{12}) = \sum_{n=1}^{N} a_n \left(\frac{\tau_{12}}{\tau_L}\right)^n \qquad \epsilon'' = \sum_{n=1}^{N} a_n g_n \left(\frac{\sigma}{\sigma_L}\right)$$

ϵ'' = plastic strain

τ_L = shear stress at which plastic deformation begins

$g_n\left(\frac{\sigma}{\sigma_L}\right)$ = function giving variation of plastic strain with applied stress

F = shear function

a_n = coefficient of n-th term in series

This theory has been checked with data and shows good agreement.

TN 2037 RESISTANCE OF SIX CAST HIGH-TEMPERATURE ALLOYS TO CRACKING CAUSED BY THERMAL SHOCK, M. J. Whitman, R. W. Hall, and C. Yaker, February 1950

The thermal-shock evaluation unit utilized a controlled water quench of the symmetrical edge of a uniformly heated, modified wedge-shaped specimen. The specimens were heated at a uniform temperature of 1750° F for 1 hour and water quenched at 45° F. This cycle was repeated until thermal-shock failure occurred. The order of decreasing resistance to thermal-shock cracking of the alloys was S-816, S-590, Vitallium, 422-19, S-40 and Stellite 6.

TN 2038 COMPRESSIVE PROPERTIES OF TITANIUM SHEET AT ELEVATED TEMPERATURES, Paul F. Barrett, Langley Aero. Lab., February 1950

Results are presented of compressive stress-strain tests of titanium sheet at temperatures from room temperature up to 800° F, exposure times of 1/2 to 2 hours, and strain rates of 0.002 to 0.006 per minute. The results show that titanium has favorable compressive properties, comparable to those in tension, up through 800° F. Marked anisotropy in compression was also noted.

TN 2039 INVESTIGATION OF FRETTING CORROSION BY MICROSCOPIC OBSERVATION, Douglas Godfrey, Lewis Flight Propulsion Lab., February 1950

An experimental investigation using microscopic observation of the action was conducted to determine the cause of fretting corrosion. Glass and other noncorrosive materials, as well as metals, were used as specimens. A very simple apparatus vibrated convex surfaces in contact with stationary flat surfaces at frequencies of 60 cycles or less than 1 cycle per second, an amplitude of 0.001 inch, and a load of 0.2 pound.

The observations and analysis led to the conclusions that fretting corrosion was caused by the removal of thinly divided and apparently virgin material due to inherent adhesive forces, and that its primary action is independent of vibratory motion or high sliding speeds. The fretting corrosion of platinum, glass, quartz, ruby, and mica relegated the role of oxidation as a cause to that of secondary factor. Fretting corrosion occurred to clean non-metals and metals readily and glass microscope slides and steel balls provided an excellent method for visual studies.

TN 2050 PROPERTIES OF A BORON CARBIDE-IRON CERAMAL, W. G. Lidman and H. J. Hamjian, Lewis Flight Propulsion Lab., March 1950

An investigation of boron carbide and of a ceramal comprising 36% (by weight) iron and 64% boron carbide yielded the following results:

Microscopic examination showed the ceramal to be composed of at least two phases: boron carbide, and a solution or chemical combination of iron and boron carbide. Ceramals containing materials that form a bonding phase may possess desirable strength properties at temperatures approaching the melting point of the metal.

The hot-pressed boron carbide was superior to the ceramal in modulus-of-rupture strength (50, 300 to 39,100 psi for the ceramal at room temperature, and 28,900 compared with 23,400 psi for the ceramal at 2600° F). The high percentage of room temperature strength retained by the ceramal at 2600° F can be attributed to the high strength of the carbide network, strengthening of the iron by combination with some of the boron carbide, or both. The ceramal was superior to the boron carbide in resistance to thermal shock. At 1600° F, the resistance to oxidation of the ceramal was better than that of the ceramic; although both metals oxidized rapidly at 2000° F, the ceramic was superior. The poor oxidation resistance of the ceramal indicated that a protective coating would be required for continued operation above 1600° F.

Density of the ceramal varied from 3.17 to 3.29 grams per milliliter. The low density of the ceramal gives it an additional advantage when it is compared with metals or other ceramals on the basis of strength-density ratio.

TN 2054 STRESS AND DISTORTION MEASUREMENTS IN A 45° SWEPT BOX BEAM SUBJECTED TO ANTISYMMETRICAL BENDING AND TORSION, George W. Zender and Richard R. Heldenfels, Langley Aero. Lab., April 1950

An untapered aluminum-alloy box beam, representing the main structural component of a full-span, two spar, 45° swept wing with a carry through section, was subjected to antisymmetrical tip bending and twisting loads such that the stresses were kept below the proportional limit.

Similar analysis is in Kuhn's Stresses in Aircraft and Shell Structures but a 45° swept wing is not considered applicable for this project.

An untapered aluminum box beam, representing the main structural component of a 45° swept wing was subjected to antisymmetrical tip bending and twisting loads such that the stresses were kept below the proportional limit. Antisymmetric load magnifies the effects of sweep in such a way that there is a build-up of normal stress and vertical shear stress in the rear spar. Antisymmetrical loading also produces large shear-lag stresses especially in the bending case. Antisymmetrical torque loads cause an appreciable decrease in the shear stress in the covers and front spar in that portion of the triangular section nearest the carry-through section. Antisymmetrical torsion loads also cause vertical shear and torque in the carry-through section. Deflections from antisymmetric loading cannot be calculated as accurately as from symmetric loading.

TN 2073 STRESS AND STRAIN CONCENTRATION AT A CIRCULAR HOLE IN AN INFINITE PLATE, Elbridge Z. Stowell, April 1950

The theory of elasticity shows that the maximum stress at a circular hole in an infinite plate in tension is three times the applied stress when the material remains elastic.

The formula for the stress concentration at a circular hole in an infinite sheet is σ:

$$\sigma: \quad 1 + 2 \; \frac{(Es)_{A,\pi/2}}{(Es)_{\infty}}$$

where $(Es)_{A,\pi/2}$ is the secant modulus at the point of maximum stress and $(Es)_{\infty}$ is the secant modulus at points far removed from the hole, where the load is applied. This relation must be solved by trial and error. Values of stress concentrations obtained from the previous formula are in good agreement with limited tests on 24S-T3 aluminum-alloy tension panels.

TN 2082 A REVIEW OF INFORMATION ON THE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS AT LOW TEMPERATURES, K. O. Bogardus, G. W. Stickley, and F. M. Howell, May 1950

This report presents the works (by author and title) of 66 works on the mechanical properties of aluminum at low temperatures. The report also presents some of the more important data from each report.

The tensile and yield strength of aluminum are higher at low temperature than at room temperature and wrought alloys show a greater increase in strength than do cast alloys. The percent elongation, hardness, and fatigue strength increase, while the reduction in area decreases at low temperature when compared to the properties at room temperature, and the notch sensitivity of Al is not adversely affected by low temperature.

TN 2084 STRENGTH PROPERTIES OF RAYON-MAT HONEYCOMB CORE MATERIAL, W. J. Kommers, April 1950

This is one of a series of reports on different materials for use as core materials in honeycomb structures. Cores were made and tested with the fibers running either perpendicular or parallel to the direction of corrugation and with either 70 or 20% of the total weight of the finished core as contact resin. The cores with fibers perpendicular had higher yield strength, but the parallel fibers had the higher tensile strength. The cores having 20% of the weight as contact resin had a higher tensile strength than the 70% core. The resin-impregnated paper honeycomb cores were a much better overall core material than the resin-impregnated rayon mat. The paper honeycomb material was tested in TN 1529.

TN 2085 STRESS-STRAIN AND ELONGATION GRAPHS FOR ALUMINUM-ALLOY 75S-T6 SHEET, James A. Miller, April 1950

This report is one of a series of reports (TN 1010, 1385, 1512, 1513) on high strength aluminum-alloy sheet. It presents some 27 pages of charts and graphs on:

Tensile and compressive stress-strain relations up to a strain of 1%
Tangent modulus versus stress, in compression
Stress-strain relations for tensile test to failure
Plastic buckling stress values
Local elongation and elongation against gage length for tensile test to failure

TN 2094 STRESS-STRAIN AND ELONGATION GRAPHS FOR ALCLAD ALUMINUM-ALLOY 24S-T86 SHEET, James A. Miller, May 1950

This report is one of a series of reports (TN 1010, 1385, 1513, 1512, 2085) on high-strength aluminum-alloy sheet. The report presents some 22 pages of charts and graphs on the following properties of 24S-T86 Al sheet:

Tensile and compressive stress-strain relations up to a strain of 1%
Stress-strain relations for tensile test run to failure
Data for local elongation and of elongation against gage length for tensile test run to failure

TN 2097 IMPROVEMENT OF HIGH-TEMPERATURE PROPERTIES OF MAGNESIUM-CERIUM FORGING ALLOYS, K. Grube, J. A. Davis, L. W. Eastwood, C. H. Lorig, and H. C. Cross, May 1950

This report deals with a number of experiments seeking to find a way to improve the tensile strength and creep characteristics of magnesium alloys containing 6% cerium and 2% manganese. Nickel was found to give the greatest increase in tensile strength and aluminum to aid the resistance to creep the most. It was also found that 2% aluminum added to the alloy also helped to reduce oxidation. The report does not say what the effect of Al on tensile strength is, or what the effect of nickel on creep reduction is, however it should be noted that the report does state that several metals produced adverse effects on the reduction of creep.

TN 2106 EVALUATION OF SEVERAL ADHESIVES AND PROCESSES FOR BONDING SANDWICH CONSTRUCTIONS OF ALUMINUM FACINGS ON PAPER HONEYCOMB CORE, H. W. Eickner, May 1950

This was a two part report to find the best way of bonding aluminum and honeycomb core. In the first part of the report tensile tests were run on 14 processes of these, 6 gave good results with 75-percent of the failure in the core and the average tensile strength above 350 psi. The best four of these, liquid phenol resin and a polyvinyl resin powder, thermosetting resins and synthetic rubbers and an acid-catalyzed intermediate-temperature-setting phenol resin, high-temperature-setting polyvinyl phenol resin, were used to determine the best amount of adhesive to use. When moderately heavy spreads were applied to both core and facing then all four adhesives produced good joints. Process D (thermosetting resins and synthetic rubbers with an acid-catalyzed phenol resin) produced bonds of 300 psi and 50% failure in the core when the process was applied only to the facings. This was the only process which produced good results when applied only to one surface.

TN 2132 THE CALCULATION OF MODES AND FREQUENCIES OF A MODIFIED STRUCTURE FROM THOSE OF THE UNMODIFIED STRUCTURE, Edwin T. Kruszewski and John C. Houbolt, Langley, July 1950

A method is developed for the calculation of the natural coupled or uncoupled frequencies and modes of a structure with modifications, such as the addition of concentrated masses or springs, directly from the known modes and frequencies of the unmodified structure. The modes of the modified structure are expanded in terms of the modes of the unmodified structure. A characteristic equation and frequency determinant, the order of which is twice the number of modifications, are derived by the use of the Galerkin method. Numerical examples are presented to show the accuracy of the method and the number of modes and frequencies of the unmodified structure necessary for agreement with exact solutions.

TN 2139 EFFECT OF VARIATION IN RIVET DIAMETER AND PITCH ON THE AVERAGE STRESS AT MAXIMUM LOAD FOR 24S-T3 AND 75S-T6 ALUMINUM ALLOY, FLAT Z-STIFFENED PANELS THAT FAIL BY LOCAL INSTABILITY, Norris F. Dow and William A. Hickman, Langley, July 1950

Charts are presented for design purposes. They determine the diameter and pitch required to insure the development of a given average stress for local instability.

TN 2152 SHEAR STRESS DISTRIBUTION ALONG GLUE LINE BETWEEN SKIN AND CAP-STRIP OF AN AIRCRAFT WING, C. B. Norris and L. A. Ringelstetter, July 1950

This report investigated the stress distribution between the skin and the cap of the spar or beam; because of the forces on the wing the skin and cap are distorted which causes the stress distribution to be non-uniform. It was found that the stresses increased rapidly from zero at the re-entrant corner to a maximum at a very short distance then gradually diminished throughout the length until within a very short distance from the other edge where it decreased rapidly to zero. The maximum which occurred very near the re-entrant corner was 50% above the average stress.

TN 2153 THE STABILITY OF THE COMPRESSION COVER OF BOX BEAMS STIFFENED BY POSTS, Paul Seide and Paul F. Barrett, Langley, August 1950

An investigation is made of the buckling of the compression cover of post-stiffened box beams subjected to end moments. Charts are presented for the determination of the minimum post axial stiffnesses and the corresponding compressive buckling loads required for the compression cover to buckle with nodes through the posts. Application of the charts to design and analysis and the limitations of their use are discussed.

TN 2157 STATIC AND IMPACT STRENGTHS OF RIVETED AND SPOT-WELDED BEAMS OF ALCLAD 14S-T6, ALCLAD 75S-T6, AND VARIOUS TEMPERS OF ALCLAD 24S ALUMINUM ALLOY, H. E. Grieshaber, Alcoa, August 1950

1. For static loads on riveted beams, the values of modulus of failure were about the same as the tensile strengths for all alloys except Alclad 24S-T3, for which the modulus of failure was about 12% lower than the tensile strength.

2. For static loads on spot-welded beams, the values of modulus of failure were about 10% lower than the tensile strengths for Alclad 24S-T81, Alclad 24S-T36, Alclad 24S-T86, Alclad 14S-T6, and Alclad 75S-T6 and about 25% lower for Alclad 24S-T3 and Alclad 24S-T3 aged to -T81 after assembly.

3. In general, beams of highest-strength materials had the greatest resistance to impact. Of the riveted beams, Alclad

75S-T6 required the highest drop and Alclad 24S-T3 the lowest. Of the spot-welded beams Alclad 24S-T36 required the highest drop and Alclad 24S-T3 aged to -T81 after assembly the lowest.

4. The height of drop producing failure of the spot-welded beams averaged about 70% of that producing failure of the riveted beams.

5. No direct relationship seems to exist between the toughness value of the material as determined from the tensile properties and relative ability to resist impact of the material in the form of a riveted or welded structure.

6. Aging of beams of Alclad 24S-T3 to -T81 after assembly is certainly not advantageous and probably undesirable, at least for spot-welded beams, from the standpoint of static and impact strength.

TN 2163 CRITICAL STRESS OF PLATE COLUMNS, John C. Houbolt and Elbridge Z. Stowell, Langley, August 1950

Superseded by the treatment in Kuhn's book.

TN 2185 ANALYTICAL DETERMINATION OF COUPLED BENDING-TORSION VIBRATIONS OF CANTILEVER BEAMS BY MEANS OF STATION FUNCTIONS, Alexander Mendelson and Selwyn Gendler, Lewis Flight Propulsion Lab., September 1950

Primarily concerned with compressor blades failure.

Similar methods are presented in the books by Kuhn and Bruhn cited previously.

TN 2188 EXPERIMENTAL INVESTIGATION OF STIFFENED CIRCULAR CYLINDERS SUBJECTED TO COMBINED TORSION AND COMPRESSION, James P. Peterson, Langley Aero. Lab., September 1950

Five stiffened circular cylinders tested to failure under various combinations of torsion and compression. Results presented in form of plots of stringer stress against cylinder load and an interaction curve for the strength of stringers that fail by local crippling. A method is given for calculating stiffener stresses in cylinders subjected to combined loads, and a comparison between calculated and experimental stringer stress is made.

"Because the method is semi-empirical, however, more tests would be desirable in order to assess the accuracy of the method."

TN 2201 MEASUREMENT OF THE MOMENTS OF INERTIA OF AN AIRPLANE BY A SIMPLIFIED METHOD, Howard L. Turner, October 1950

Because airplanes are getting heavier it is no longer practical to suspend the plane for experimentally determining the moment of inertia by the compound and bifilar pendulum.

The new method of determining the moment of inertia consists of mounting the plane on knife edges along the centerline of the plane running in the x direction and attaching a spring to each wing tip. The moment of inertia about the axis of rotation is now a function of the spring constant, the location of the spring, and the period of the resulting oscillation. The measurement of the moment of inertia about the pitch·axis is nearly the same with the knife edges located under the rear spar, aft of the center of gravity, and the spring was secured to the tail. The moment of inertia about the z or yaw axis is measured by the use of a bifilar torsional axis. The long length of the pendulum necessary to keep the plane near the ground is actually beneficial to the accuracy of the measurements made with the bifilar torsional pendulum.

This new method is an improvement over older methods of measuring the moment of inertia, the plane remains near the ground and does not assume any unnatural positions. The use of the Null method makes the calculation of the inclination of the principal axis simple.

TN 2208 ANALYSIS OF SHEAR STRENGTH OF HONEYCOMB CORES FOR SANDWICH CONSTRUCTIONS, Fred Warren and Charles B. Norris, October 1950

Analysis undertaken to get a mathematical formula for shear strengths of honeycomb cores for sandwich constructions. Analysis is partly empirical, being based upon data obtained from previous tests of plywood panels. It was applied successfully to honeycomb cores composed of resin-impregnated papers, but should be verified for materials greatly different before it is generally applied.

This report is superseded by more current data.

TN 2217 ANALYSIS OF PLANE STRESS PROBLEMS WITH AXIAL SYMMETRY IN STRAIN-HARDENING RANGE, M. H. Lee Wu, December 1950

A simple method developed to solve plane-stress problems with axial symmetry in the strain-hardening range based on the deformation theory of plasticity employing the finite-strain concept. The equations defining the problems are first reduced to two simultaneous nonlinear differential equations involving two independent variables: (a) the octahedral shear strain, and (b) a parameter indicating the ratio of principal stresses. By multiplying the load and dividing the radius by an arbitrary constant, it is possible to solve these problems without iteration for any value of the modified load. The constant is determined later by the boundary condition.

TN 2225 BENDING AND BUCKLING OF RECTANGULAR SANDWICH PLATES, N. J. Hoff, November 1950

Differential equations and boundary conditions are derived for the bending and buckling of sandwich plates. The buckling load is calculated for a simply supported plate subjected to edgewise compression. The formulas obtained are evaluated numerically and the results are plotted in a diagram. The theory is in satisfactory agreement with results of tests carried out at the Forest Products Laboratory.

TN 2231 COMPARISON OF FATIGUE STRENGTHS OF BARE AND ALCLAD 24S-T3 ALUMINUM ALLOY SHEET SPECIMENS TESTED AT 12 AND 1000 CYCLES PER MINUTE, Frank C. Smith, William C. Brueggeman, and Richard H. Harwell, December 1950

This report describes the results of axial fatigue tests conducted on 0.032-inch-flat-sheet specimens of bare and Alclad 24S-T3 aluminum alloy to determine the effect of frequency of loading on the fatigue strengths of these materials. The number of cycles to failure varied from about 150 to over 10,000,000. Tests were conducted using completely reversed axial load at two frequencies of loading: 12 and 1000 cycles per minute.

The tests showed that the fatigue strengths of the materials were slightly less when tested at 12 cycles per minute.

For those specimens which were stresses into the plastic range an investigation was made of the variation of maximum stresses and mean stresses with repeated loading.

TN 2232 STRESS AND DISTORTION ANALYSIS OF A SWEPT BOX BEAM HAVING BULKHEADS PERPENDICULAR TO THE SPARS, Richard R. Heldenfels, George W. Zender, and Charles Libove, November 1950

The report presents a method for approximate calculation of the stress and distortions of the structure of a swept wing. The outer and carry-through sections can be analyzed by existing methods and the triangular section that connects them is divided into free bodies and analyzed using equilibrium and continuity. Numerical examples are presented. There is only fair agreement with test data because shear lag was not included in the method. A method for including the effects of shear lag and multiple spars has been indicated in the report.

TN 2243 EFFECT OF CELL SHAPE ON COMPRESSIVE STRENGTH OF HEXAGONAL HONEYCOMB STRUCTURES, L. A. Ringelstetter, A. W. Voss, and C. B. Norris, December 1950

The shape of the cells in a hexagonal honeycomb structure was found, in tests at the Forest Products Lab., to be an important factor in determining the compressive strength of the structure parallel to the flutes.

From the results obtained with 35 test specimens of untreated 50-weight kraft paper, a family of curves was obtained by means of which it is possible to estimate the specific compressive strength of such honeycomb structures within the range of the test data. These curves apply only when the cell walls buckle at stresses less than the compressive strength of the material.

The test results indicate that the strength of the cell changes with its shape. It appears from the curves mentioned above that, within the range of the seven shapes studied, for any value of the apparent specific gravity the strength of the structure increases with each increase in cell width, and the strongest cell is that which is widest and had the shortest walls of double thickness. The data indicate that the strongest honeycomb structure for its weight is that for which the hexagonal shape is reduced to a square by shortening the double-thickness walls until they are virtually eliminated.

TN 2266 STRENGTH OF HEAT-RESISTANT LAMINATES UP TO 375° C, B. M. Axilrod and Martha A. Sherman, February 1951

For several conditions of heating and testing, the results of tests to determine the flexural properties of samples of glass-fabric laminates bonded with various resins may be summarized as follows. It should be noted that these results, except for those of the polyester laminates, are based on data for only one sample of each type of glass-fabric laminate and hence can be considered only tentatively as being representative of the various types of material.

1. The silicone laminate was superior to the other laminates tested in retention of flexural properties at temperatures of 250° to 300° C. When tested at above 325° C after either 0.5 hours or 200 hours heating at that temperature, this laminate retained at least 30 percent of its initial flexural strength and over 50 percent of its initial flexural modulus of elasticity.

2. The phenolic laminate showed good retention of its flexural properties when tested at elevated temperatures after heating for 0.5 hours at the test temperature.

3. The melamine laminate, although much inferior to the phenolic laminate when tested at a temperature of 375° C after 0.5 hours heating, was superior to the phenolic in retention of flexural strength after 200 hours heating at 250° C.

4. The four polyester laminates lost at least 80% of their flexural strengths when tested at 250o C after either 0.5 or 200 hours of heating.

5. The acrylic addition laminate lost at least 80% of its flexural strength when tested at 150° C after either 0.5 or 200 hours heating.

6. For each laminate and each test condition, loss in flexural modulus of elasticity correlated with loss in flexural strength; the former loss was less than the latter.

7. The loss in flexural properties during prolonged heating may depend on the method of exposing the specimens in the oven. For specimens of the polyester and phenolic laminates, heating in a circulating air oven in open bottles caused significantly less loss in flexural properties than did heating on the shelves of the oven.

TN 2267 INELASTIC COLUMN BEHAVIOR; John E. Duberg and Thomas W. Wilder, III, January 1951

TR 1072 supersedes this TN.

TN 2272 LATERAL ELASTIC INSTABILITY OF HAT-SECTION STRINGERS UNDER COMPRESSIVE LOAD, Stanley Goodman, January 1951

The high value of computed elastic strain for lateral instability for the five stringer section investigated substantiates the widely held opinion that cloised section stringers of reasonable proportions fail in ways other than lateral instability of the top. Even in the case of the narrowest section, $\sigma_{cr,min}/E$ is 0.0141, a value well into the plastic range of aluminum alloys.

$\sigma_{cr,min}$ = critical stress for primary lateral elastic instability of an infinitely long stringer

E = Young's modulus

TN 2276 STATIC AND FATIGUE STRENGTHS OF HIGH-STRENGTH ALUMINUM-ALLOY BOLTED JOINTS, E. C. Hartmann, Marshall Holt, and I. D. Eaton, February 1951

RESULTS:

1. The mechanical properties of the 75S-T6, 24S-T4, and 14S-T6 aluminum alloys used in this investigation are typical of the values obtained for these alloys.

The results of this investigation are believed to be included in a manual by the Society of Metals. The alloys are not numbered as present usage types.

TN 2287 AN INVESTIGATION OF PURE BENDING IN THE PLASTIC RANGE WHEN LOADS ARE NOT PARALLEL TO A PRINCIPAL PLANE, Harry A. Williams, February 1951

Rectangular beams and I-beams of aluminum alloy 75S-0 were tested in pure bending in the plastic range with the plane of loading at angles of 0, 30, 60, and 90 degrees to the minor principal axis of the cross section. It was found that Cozzone's method of plastic bending analysis gave reasonable correlation between theoretical and experimental bending moments for the plastic range beyond the yield strength. The analysis is approximate since it assumes that the neutral axis does not rotate or translate. The latter occurs in all cases and the former occurs when the loads are not parallel to a principal plane. Similar tests of an exploratory nature were made with angle cross section beams. A modification of Cozzone's method gave reasonable results for some positions of loading but not for others.

Reference: Cozzone, Frank P.: Bending Strength in the Plastic Range. Jour. Aero. Sci., vol. 10, no. 5, May 1943, pp. 137-151.

TN 2289 ELASTIC CONSTANT FOR CORRUGATED-CORE SANDWICH PLATES, Charles Libove and Ralph E. Hubka, February 1951

The sandwich plate consisting of corrugated sheet fastened between two face sheets is considered. Application of existing theories to the analysis of such a sandwich plate requires the knowledge of certain elastic constants. Formulas and charts are presented for the evaluation of these constants in this report. The formulas for three of these constants were checked experimentally and found to give values in close agreement with the experimental values.

TN 2290 A METHOD FOR CALCULATING STRESSES IN TORSION BOX COVERS WITH CUTOUTS, Richard Rosecrans, February 1951

A theory is presented for calculating stresses in the covers of torsion boxes containing large cutouts. Half the cymmetrical uncut portion of the cover is represented by three stringers that carry all direct stresses and the intermediate cover material which is assumed to carry only shear stress. Differential equations of equilibrium are derived and solved to obtain stresses along each stringer. Illustrative examples are solved and the results are compared with experimental values. For one of these examples the results are also compared with a more detailed solution made by numerical method of analysis. The agreement between theory and experiment is satisfactory in all cases except those with very large cutouts and flexible bulkheads.

TN 2299 EXPOSURE TESTS OF BALVANIZED-STEEL-STITCHED ALUMINUM ALLOYS, Fred M. Reinhart, February 1951

Sheets of 24S-T3 and Alclad 24S-T3 aluminum alloys were joined to themselves by stitching with galvanized steel wire and were exposed to a marine atmosphere and tidewater to determine whether they would have a satisfactory service life in these environments. Both alloys joined by this method are satisfactory with respect to corrosion resistance for service in marine atmospheres. The Alclad 24S-T3 is satisfactory for short periods of time, where the installation is subject to frequent wetting by sea water. The use of 24S-T3 sheet joined by stitching with galvanized wire is not satisfactory when subject to wetting by sea water.

TN 2300 ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF EFFECT OF TWIST ON VIBRATIONS OF CANTILEVER BEAMS, Alexander Mendelson and Selwyn Gendler, March 1951

An analytical and experimental investigation was made of the effect of twist on the vibrations of cantilever beams. The analytical investigations were made by the use of Station Functions. General equations are developed for the coupled bending-bending torsion vibrations of a cantilever beam, and it is shown how these equations reduce to simpler cases. The use of tabulated Station Numbers makes the analytical method presented herein particularly simple to apply.

An example is worked out in detail to illustrate the application of the method. Good agreement is obtained among the method presented, an exact theoretical solution developed, and experimental results.

It is shown that for beams with a ratio of bending stiffness in the two principal directions equal to 144, the effect of coupling due to twist is to raise the value of the first natural frequency by a negligibly small amount, to decrease steadily the second frequency, and to lower the third frequency considerably.

TN 2301 LINEARIZED SOLUTION AND GENERAL PLASTIC BEHAVIOR OF THIN PLATE WITH CIRCULAR HOLE IN STRAIN-HARDENING RANGE, M. H. Lee Wu, March 1951

1. The results obtained by the linearized solution agree very well with those obtained by the exact solution based on the deformation theory of plasticity. The amount of computation required is very much reduced by the linearization.

2. The variation of a parameter determined from the octahedral shear stress strain curve of the material can be used as a simple general criterion of applicability of deformation theory for this problem.

3. The results obtained for the ideally plastic material with the infinitesimal strain concept give good approximate values of principal strains, but not of principal stresses.

4. Sufficiently accurate values of principal stresses can be obtained by the approximate method of using the strains obtained by the ideally plastic material, together with the actual octahedral shear stress-strain relation of the material.

5. If a simple analytical function representing the octahedral shear stress-strain relation is required for analysis, the power-law approximation can be used.

TN 2312 BEARING STRENGTHS OF SOME ALUMINUM-ALLOY PERMANENT-MOLD CASTINGS, E. M. Finley, February 1951

Properties of outdated materials numbers.

TN 2319 SOME PROPERTIES OF HIGH-PURITY SINTERED WROUGHT MOLYBDENUM METAL AT TEMPERATURES UP TO 2,400° F, R. A. Long, K. C. Dike, and H. R. Bear, March 1951

1. Commercially pure sintered wrought molybdenum possessed tensile strength and ductility in the temperature range of 1800° to 2400° F comparable with or higher than the other proposed high temperature materials. At a temperature of 1800° F, the short-time tensile strength varied between 25,310 and 33,670 pounds per square inch. At 2400° F, the tensile strength varied between 13,070 and 26,100 psi, depending upon manufacturing swaging variables and whether the evaluation temperature was above or below the recrystallization temperature of the specimen evaluated.

2. At 1800° F the stress for the 100 hour stress-rupture life of as-swaged molybdenum was approximately 19,300 ± 300 pounds per square inch, which is higher than that of other proposed high-temperature alloys. The stress for 100 hour life of recrystallized molybdenum at 1800° F was approximately 10,000 psi.

3. Recrystallization lowered the tensile strengths of molybdenum at all temperatures. Recrystallized metal was quite ductile at elevated temperatures but extremely brittle at room temperatures.

4. Swaging, from 38 to 96% ingot-area reduction, has little effect on increasing the room temperature and the elevated temperature tensile strength, but had a pronounced effect upon lowering the recrystallization temperature.

5. The effect of tensile specimen "test-section" cross sectional area upon the ultimate tensile strength was negligible.

6. As-swaged molybdenum exhibited a transgranular failure under tension at all temperatures at which effective recrystallization did not occur.

7. Recrystallized metal exhibited an intergranular failure at room temperature. From 1500° to 2000° F the fracture was predominately transgranular; and above 2000° to 2400° F, the fracture reverted to the intergranular type.

8. Rolled plate 1/4 inch thick possessed definite directional properties. The tensile strength in the transverse direction was 10 to 15 percent higher than that in the longitudinal direction at all evaluation temperatures below the recrystallization temperature. Ductility in the longitudinal direction was almost double that in the transverse direction at elevated temperatures.

9. Molybdenum with similar amounts of ingot reduction but from two manufacturers possessed considerably different strengths and recrystallization properties.

TN 2322 CREEP OF LEAD AT VARIOUS TEMPERATURES, Peter W. Neurath and J. S. Koehler, March 1951

Bending will produce spurious results particularly when very small strain measurements are made. The two strain gages used simultaneously agreed to within about 25 percent over the 1 percent range, but in the initial one-hundredth or one-thirtieth of that range, the differences are often much larger. Another problem is that of vibration and/or shock. This prevents the accurate measurement of creep rates of less than 10^{-6} inch per inch per minute, or at least makes them suspect.

TN 2324 FATIGUE STRENGTHS OF AIRCRAFT MATERIALS. AXIAL-LOAD FATIGUE TESTS ON UNNOTCHED SHEET SPECIMENS OF 24S-T3 AND 75S-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL, H. J. Grover, S. M. Bishop, and L. R. Jackson, March 1951

1. The data obtained constitute an extension of information obtained previously by other investigators and, where duplication occurs, the results are in agreement with those obtained previously.

2. Slow-speed tests (90 cpm) indicate, but have not conclusively shown, that the fatigue strength may be reduced about 10 percent when the speed of testing is changed from 1100 to 90 cycles per minute.

3. Two-stress-level tests of fatigue damage show damage ratios different from cycle ratios.

TN 2325 DEVELOPMENT OF MAGNESIUM-CERIUM FORGED ALLOYS FOR ELEVATED TEMPERATURE SERVICE, K. Grube, R. Kaiser, L. W. Eastwood, C. M. Schwartz, and H. C. Cross, March 1951

Interesting but somewhat obsolete. Newer developments can be found in publications of the American Society of Metals.

TN 2362 TORSIONAL STRENGTH OF STIFFENED D-TUBES, E. S. Kavanaugh and W. D. Drinkwater, May 1951

The average ultimate strength in torsion can be calculated for stiffened or unstiffened D-tubes having a cross section similar to the NACA 0012 airfoil section and a closing web at 30 percent of the chord. The relationship involved in this calculation is:

$$(1 - \mu^2) \frac{\tau_u L^2 S^2}{E t^{1.75}} = 3.24 \left(\sqrt{1 - \mu^2} \; \frac{L^2 S^2}{2at} \right)^{0.74}$$

where

- μ = Poisson's ratio
- τ_u = torsional shearing stress at ultimate moment, inch pounds
- L = distance between ribs, inches
- S = actual skin length of largest panel in chordwise direction, inches
- E = modulus of elasticity of material; 10.2×10^6 psi
- t = thickness of skin, inches
- a = semi-major axis of section on basis of complete oval; 18 in.

The average-ultimate strength curve presented in this report and based on the above equation should be useful in determining the ultimate load-carrying ability of this type of structure. With the advent of high-speed aircraft the use of symmetrical airfoils should become quite common and should enhance the value of the report.

Comparison of the measured twist with Bredt's theory has shown good agreement below the buckling point, although the buckling point itself was not well-defined.

TN 2384 PRELIMINARY INVESTIGATION OF WEAR AND FRICTION PROPERTIES UNDER SLIDING CONDITIONS OF MATERIALS SUITABLE FOR GAGES OF ROLLING-CONTACT BEARINGS, Robert L. Johnson, Max A. Swikert, and Edmond E. Bisson, June 1951

1. The ability of materials to form surface films that prevent welding is a most important factor in both dry friction and boundary lubrication. These surface films were probably supplied from within the structure of the cast irons by graphitic carbon

and of the bronze, by lead. Monel, Nichrome V, and beryllium copper formed films, believed to be oxides, under dry and lubricated conditions. When present, the films improved the performance of these materials.

2. On the basis of wear and resistance to welding only, cast irons were the most promising materials investigated. They showed the least wear and the least tendency toward surface welding of any of the materials when run dry. The same observations were made for boundary lubricated conditions where it was established that the cast irons had the highest load capacities of all the materials. Nodular iron has physical properties that are superior to those of grey iron.

3. The performance of monel and Nichrome V depended on whether or not a film was present but the materials with films had relatively high load capacity when boundary lubricated.

4. Bronze had the lowest friction coefficient under dry sliding conditions, however, it was subject to surface failure and increasing friction as the sliding conditions became more severe.

5. Brass, beryllium copper, and 24S-T aluminum showed continuous failure under all conditions investigated.

TN 2389 FATIGUE STRENGTHS OF AIRCRAFT MATERIALS. AXIAL-LOAD FATIGUE TESTS ON NOTCHED SHEET SPECIMENS OF 24S-T3 AND 75S-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL WITH STRESS-CONCENTRATION FACTORS OF 2.0 AND 4.0, H. J. Grover, S. M. Bishop, and L. R. Jackson, June 1951

Axial load fatigue tests results have been obtained on notched sheet specimens of 24S-T3 and 75S-T6 alloys and of Sae 4130 steel. Several notches forms were used and tests were run at several levels of mean stress. The results show that:

1. Reduction in fatigue strength (in terms of nominal stresses) varies with:
   a. Notch severity (theoretical stress-concentration factor)
   b. Notch form, especially for severe notches
   c. Material
   d. Stress level - both nominal mean stress and nominal stress amplitude

2. Simply defined fatigue-strength reduction factors do not appear to have useful correlation with the theoretical stress-concentration factor.

TN 2390 FATIGUE STRENGTHS OF AIRCRAFT MATERIALS. AXIAL-LOAD FATIGUE TESTS ON NOTCHED SHEET SPECIMENS OF 24S-T3 AND 75S-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL WITH STRESS-CONCENTRATION FACTOR OF 5.0, H. J. Grover, S. M. Bishop, and L. R. Jackson, June 1951

Comparison of results indicates increasing fatigue-strength reduction with increase in notch severity (as indicated by the theoretical stress-concentration factor).

The increase in fatigue-strength reduction, however, is not in direct proportion to the increase in theoretical stress-concentration factor of the notch.

TN 2392 CHARTS GIVING CRITICAL COMPRESSIVE STRESS OF CONTINUOUS FLAT SHEET DIVIDED INTO PARALLELOGRAM-SHAPED PANELS, Roger A. Anderson, June 1951

Charts giving compressive buckling stress using the energy method. Comparison of parallelogram-panels and rectangular-panels and showed the parallelogram-panel more stable than the equivalent rectangular-panel.

TN 2394 EFFECTS OF DESIGN DETAILS ON THE FATIGUE STRENGTH OF 355-T6 SAND-CAST ALUMINUM ALLOY, M. Holt and I. D. Eaton, July 1951

Of the design details studied, the unreinforced hole was the most effective stress raiser for fatigue lives from 10,000 to 25,000,000 cycles. The unreinforced hole in the sand-cast specimen was not so severe in reducing the fatigue strength as a similar hole in wrought 17S-T4, 27S-T6, 53S-T6 or 14S-T6 plate.

The fractures of both the static fatigue specimens with a boss or rib were generally in cross sections close to the edge of the boss or rib.

TN 2414 AN EXPERIMENTAL DETERMINATION OF THE CRITICAL BENDING MOMENT OF A BOX BEAM STIFFENED BY POSTS, Paul F. Barrett and Paul Seide, July 1951

This experiment was made in order to compare experimental values with the analytical values obtained in TN 2153. It was found that the bending moment was 2 percent below the calculated bending moment. The structure continued to take load until failure occurred when several posts were crippled at a point about 8 percent above the strain-reversal buckling load. Buckling occurred with transverse nodes through the posts. The report points out that consideration should be given to the possibility and importance of cross-sectional deformation in any application of stiffening by the use of posts.

TN 2425 PLASTIC STRESS-STRAIN RELATIONS FOR 75S-T6 ALUMINUM ALLOY SUBJECTED TO BIAXIAL TENSILE STRESSES, Joseph Marin, B. H. Ulrich, and W. P. Hughes, August 1951

In this report the material tested was 75S-T6 aluminum alloy subjected to biaxial and tensile stresses. Plastic stress strain relations for the different biaxial stress conditions were found using an SR-4 strain gage.

Conclusions made were as follows:

1. Biaxial yield strengths may be safely predicted by maximum-shear or stress theories.

2. For constant principal stress ratios, octahedral deformation theory gave a good engineering approximation for the plastic biaxial stress strain relations.

TN 2435 DIRECT-READING DESIGN CHARTS FOR 75S-T6 ALUMINUM-ALLOY FLAT COMPRESSION PANELS HAVING LONGITUDINAL EXTRUDED Z-SECTION STIFFENERS, William A. Hickman and Norris F. Dow, February 1952

These charts may be used for the direct determination of the stress and panel dimensions required to carry a given intensity of loading with a given skin thickness and effective length of panel.

RANGE OF PROPORTIONS TESTED:

$\frac{t_w}{t_s}$ from 0.25 to 1.00

$\frac{b_s}{t_s}$ from 15 to 75

$\frac{b_w}{t_w}$ from 12 to 40

$(\frac{L}{e})_c \approx 3.75$

L = length of panel
t_s = thickness of the panel
t_w = thickness of the channel
b_s = distance from center of web of one channel to the center of the next
b_w = distance from center of one leg of channel to the center of the other leg

TN 2452 FLEXURAL FATIGUE STRENGTHS OF RIVETED BOX BEAMS - ALCLAD 14S-T6, ALCLAD 75S-T6, AND VARIOUS TEMPERS OF ALCLAD 24S, I. D. Eaton and Marshall Holt, November 1951

Of the materials tested, none show any advantage over any of the others for the test conditions in this report.

TN 2512 STRESSES IN A TWO-BAY NONCIRCULAR CYLINDER UNDER TRANSVERSE LOADS, George E. Griffith, October 1951

This report is superseded by TR 1097.

TN 2514 RELATIVE STRUCTURAL EFFICIENCIES OF FLAT BALSA-CORE SANDWICH AND STIFFENED-PANEL CONSTRUCTION, Ralph E. Hubka, Norris F. Dow, and Paul Seide, October 1951

An analysis is made and charts are presented for the determination of regions of efficient application of flat balsa-core sandwich and stiffened panel construction for a large range of design requirements. Optimum sandwiches were found to have relatively low values of the ratio of core thickness to face thickness.

The analysis of this paper should not be construed as appreciative or depreciative of a given type of construction. The choice of any type of wing construction involves the weighing of a number of factors, and the present type of analysis should be considered chiefly as an aid in the more accurate evaluation of the one rather important factor, the structural efficiency.

TN 2529 SECONDARY STRESSES IN THIN-WALLED BEAMS WITH CLOSED CROSS SECTIONS, Stanley Urner Benscoter, October 1951

An accurate method of determining secondary stresses in thin walled, uniform beams of closed cross section is herein presented. The cross sections are assumed to be preserved by closely spaced rigid diaphrams. The cross section, loading distributions, and end conditions are assumed to be arbitrary. By introducing generalized difference equations the mathematical analysis for the stiffened beam may be performed in a manner exactly analogous to the process used for the unstiffened beam. A separation of variables in the homogeneous equation leads to the natural stress or displacement modes for a cross section. The solution of the nonhomogeneous equation is then expressed as an expansion in terms of the natural stress modes. Particular attention is given to cross sections with single symmetry and double symmetry.

TN 2533 EVALUATION OF HIGH-ANGLE-OF-ATTACK AERODYNAMIC-DERIVATIVE DATA AND STALL-FLUTTER PREDICTION TECHNIQUES, Robert L. Halfman, H. C. Johnson and S. M. Haley, November 1951

Report examines in great detail the changes in aerodynamic derivative data with sinusoidal and non-sinusoidal vibration at and near the stall. It finds that the transition from classical to stall flutter is very complex, in spite of the appearance of being a simple phenomena. It finds also that the data vary in a periodic manner, but definitely sinusoidal.

Report goes into great detail on the transient conditions of transition from classical to flutter stall which is not very useful to this report. Looked for a factor to be used to predict maximum loads, but could find none.

TN 2536 CRITICAL COMBINATIONS OF BENDING, SHEAR AND TRANSVERSE COMPRESSION STRESSES FOR BUCKLING OF INFINITELY LONG FLAT PLATES, Aldie E. Johnson, Jr., and Kenneth P. Buchert, December 1951

Three dimensional interaction surfaces are presented for the computation of elastic buckling stresses for an infinitely long flat plate subjected to combinations of bending, shear and transverse compression in its plane - a loading approximating that occurring in a shear web. Surfaces are presented for two sets of edge conditions; both edges simply supported and lower edge simply supported, upper edge clamped. Present results are in good agreement with data for one load and two load limiting cases previously published.

TN 2538 MECHANICAL AND CORROSION TESTS OF SPOT-WELDED ALUMINUM ALLOYS, Fred M. Reinhart, W. F. Hess, R. A. Wyant, F. J. Winsor, and R. R. Nash, December 1951

Exposure to tidewater and weather appeared to reduce the shear strength of spot welds in Alclad 24S-T3 sheet which had been prepared for spot welding by wire brushing.

Exposure to tidewater and weather definitely reduced the shear strength of spot welds in 0.020 inch R-301-T6 made with dirty electrodes and exhibiting surface cracks.

Spot welds in XB75S-T6 were extremely susceptible to localized corrosion and loss of shear strength upon exposure to tidewater and weather.

TN 2540 APPLICATION OF RESPONSE FUNCTION TO CALCULATION OF FLUTTER CHARACTERISTICS OF A WING CARRYING CONCENTRATED MASSES, H. Serbin and E. L. Costilow, November 1951

Concepts involved in the harmonic response function method, such as the direct or conjugate characteristic modes, are illustrated by application of the method to the calculation of the change in flutter characteristics of a wing due to adding concentrated masses. The main purpose of the numerical procedures which are given is to illustrate more specific, rather than to stress the immediate and current practical usefulness. The rigid body is first idealized as a point mass, then as a distributed mass. An appendix is given which contains some of the essential theoretical background.

TN 2548 EQUAL STRENGTH DESIGN OF TENSION FIELD WEBS AND UPRIGHTS, Ralph H. Upson, George M. Phelps, and Tung-Sheng Liu, January 1952

A method is presented for proportioning thin-web beams to attain equal strength of web and uprights which may in turn be employed toward optimum design of these components. Improved empirical formulas for this purpose are developed and the results checked by experimental loading of six beams.

TN 2556 BUCKLING OF RECTANGULAR SANDWICH PLATES SUBJECTED TO EDGEWISE COMPRESSION WITH LOADED EDGES SIMPLY SUPPORTED AND UNLOADED EDGES CLAMPED, Kuo Tai Yen, B. L. Salerno, and N. J. Hoff, January 1952

The compressive stress for buckling is calculated for a rectangular flat sandwich plate with loaded edges simply supported and unloaded edges rigidly clamped. In the calculations Hoff's differential equations are integrated by Leggett's method in order to obtain lower bounds and by Galerkin's method to establish upper bounds. The true values of the buckling stress are estimated as the arithmetic means of these bounds and are presented in a diagram which covers the entire practical range of the geometric and mechanical quantities involved. The theoretical results are in satisfactory agreement with results of tests carried out at the Forest Products Laboratory.

TN 2564 PROPERTIES OF HONEYCOMB CORES AS AFFECTED BY FIBER TYPE, FIBER ORIENTATION, RESIN TYPE AND AMOUNT, R. J. Seidl, D. J. Fahey, and A. W. Voss, November 1951

1. Higher tensile and compressive strengths were obtained in honeycomb structures having the principal fiber grain parallel to the axis of the cells than in those having the fiber grain perpendicular to the axes of the cells. This was true for cotton, rayon or paper.

2. Honeycomb structures made from paper had higher dry and wet tensile and compressive strength values than structures made from rayon or cotton when comparing cores having the fiber grain either parallel or perpendicular to the axes of the cells.

3. Increases in pretreating-resin content of the corrugated paper were more effective in increasing the strength of the structures when tested in the wet condition than in the dry condition, and also for structures made with a small proportion of total resin than with a large proportion of resin.

4. In general, cores made by using alcohol-soluble-resin treatment had higher adjusted strength values than structures made from the polyester resin or from the pretreated paper only.

5. A honeycomb structure having high and equally adjusted compressive and tensile strengths was made from 40 pound corrugated paper bonded with a simple glue and having the fiber grain parallel to the axes of the cells.

6. A core with an actual tensile strength in excess of about 1000 psi and with an actual compressive strength of about 2650 psi was made from 110 pound paper and polyester resin. The specific gravity of this core was 0.234 grams per cubic centimeter.

TN 2566 A STUDY OF ELASTIC AND PLASTIC STRESS CONCENTRATION FACTORS DUE TO NOTCHES AND FILLETS IN FLAT PLATES, Herbert F. Hardrath and Lachlon Ohman, December 1951

Covered in Timoshenko's Theory of Elasticity and Strength of Materials.

TN 2581 DEFLECTIONS OF A SIMPLY SUPPORTED RECTANGULAR SANDWICH PLATE SUBJECTED TO TRANSVERSE LOADS, Kuo Tai Yen, Sadettin Gunturkun, and Frederick V. Pohle, December 1951

The differential equations of the bending of sandwich plates were integrated to obtain the deflections when the four edges of the plate are simply supported and the loading consists of either a uniformly distributed transverse load or a concentrated load applied at the center of the panel. The deflection patterns are shown in diagrams and the maximum deflection of the plate is presented in a number of graphs.

TN 2594 INVESTIGATION OF THE STRUCTURAL DAMPING OF A FULL SCALE AIRPLANE WING, Dwight W. Fearnow, February 1952

An investigation to determine the structural damping characteristic of a full-scale airplane wing was conducted by the shock-excitation method wherein the wing was loaded to a predetermined deflection and the load suddenly released. The test specimen vibrated at its fundamental bending frequency of 1.69 cps. Only the first 2 or 3 cycles showed any indication of a higher frequency being superimposed upon the fundamental bending frequency. The damping was found to increase from about 0.002 of critical at an amplitude of vibration of 0.05 inches to approximately 0.006 of critical at an amplitude of 5 inches.

TN 2600 STRESSES AND DEFORMATIONS IN A WING SUBJECTED TO TORSION, B. F. Ruffner and Eloise Hunt, February 1952

Basic equations of Harman and Chien (given in "Torsion with Variable Twist", Jour. Aero. Sci., vol. 13, no. 10, October 1946) are solved by representing the shape of a torsion box by means of a Fourier series.

Results obtained for angles of twist and normal stresses are in good agreement with calculations except at sharp corners.

TN 2601 COMPRESSIVE BUCKLING OF SIMPLY SUPPORTED CURVED PLATES AND CYLINDERS OF SANDWICH CONSTRUCTION, Manuel Stein and J. Mayers, January 1952

Theoretical solutions are presented for the buckling in uniform axial compression of two types of simply supported curved sandwich plates: the corrugated-core type and the isotropic-core type. The solutions are obtained from a theory for orthotropic curved plates in which deflections due to shear are taken into account. Results are given in the form of equations and curves.

TN 2608 CHARTS AND APPROXIMATE FORMULAS FOR THE ESTIMATION OF AEROELASTIC EFFECTS ON THE LOADING OF SWEPT AND UNSWEPT WINGS, Franklin W. Diedrich and Kenneth A. Foss, February 1952

Charts for estimation of aeroelastic effects on spanwise lift distribution, lift-curve slope, aerodynamic center, and damping in roll of swept and unswept wings at subsonic and supersonic speeds. The types of stiffness considered were variation of stiffness with the fourth power of the chord and variation based on idealized constant stress structure. Charts are limited because they do not apply to wings with very low aspect ratio or a very large angle of sweep, nor to wings with large sources of concentrated aerodynamic forces. Charts were less reliable for wings with zero taper.

TN 2612 STRESS PROBLEMS IN PRESSURIZED CABINS, W. Flugge, February 1952

Possibly not applicable. A detailed study of the various problems noted in pressurized cabins.

TN 2620 PRINCIPLE AND APPLICATION OF COMPLEMENTARY ENERGY METHOD FOR THIN HOMOGENEOUS AND SANDWICH PLATES AND SHELLS WITH FINITE DEFLECTIONS, Chi-teh Wang, February 1952

The principle of complementary energy in the non-linear elasticity theory is shown to be derivable from the principle of potential energy by a Legendre type of transformation. In particular, the expression of the complementary energy is derived for homogeneous and sandwich plates and shells with large deflections. By the method of complementary energy, the stress-strain relations are derived for homogeneous, sandwich plates, and sandwich shells. Without the use of this method much lengthier calculations would be necessary.

TN 2621 DEFLECTION AND STRESS ANALYSIS OF THIN SOLID WINGS OF ARBITRARY PLAN FORM AND WITH PARTICULAR REFERENCE TO DELTA WINGS, Manuel Stein, J. Edward Anderson, and John M. Hedgepath, February 1952

Superseded by TR 1131.

TN 2637 COMPRESSIVE BUCKLING OF FLAT RECTANGULAR METALITE TYPE SANDWICH PLATES WITH SIMPLY SUPPORTED LOADED EDGES AND CLAMPED UNLOADED EDGES, Paul Seide, February 1952

The solution is based upon the general small deflection theory for flat sandwich plates developed in NACA Rep. 899. A comparison is made of the present results and other solutions of the problem.

A comparison is also made between the present theory and experimental results for two types of sandwich plates; plates having Alclad 24S-T aluminum faced and end-grain balsa wood or cellular cellulose acetate cores. Better agreement is found between computed and experimental buckling stresses of sandwich plates with cellular cellulose acetate cores than for sandwich plates having end grain balsa wood cores.

TN 2640 INTERACTION OF COLUMN AND LOCAL BUCKLING IN COMPRESSION MEMBERS, P. P. Bijlaard and G. P. Fisher, March 1952

1. Test results do not show any noticeable interaction effect for the square tubes tests.

2. The interaction effect is negligible for box sections, as indicated by both theory and experiment.

3. Tests confirm the known fact that appreciable postbuckling strength beyond the critical plate stress is possible when the latter is well within the elastic range. Conversely, when the critical plate stress is in the plastic range, complete collapse of the column accompanies beginning of plate buckling.

TN 2661 A SUMMARY OF DIAGONAL TENSION. PART I. METHODS OF ANALYSIS, Paul Kuhn, James P. Peterson, and L. Ross Levin, May 1952

Previously published methods for stress and strength analysis of plane and curved shear webs working in diagonal tension are presented as a unified method.

TN 2662 A SUMMARY OF DIAGONAL TENSION. PART II - EXPERIMENTAL EVIDENCE, Paul Kuhn, James P. Peterson, and L. Ross Levin, May 1952

Continuation of TN 2661.

TN 2671 INVESTIGATION OF STRESS DISTRIBUTION IN RECTANGULAR PLATES WITH LONGITUDINAL STIFFENERS UNDER AXIAL COMPRESSION AFTER BUCKLING, Chi-Teh Wang and Harry Zuckerberg, March 1952

An investigation was carried out to study the elastic behavior after buckling of a rectangular plate reinforced with longitudinal stiffeners and subjected to compressive loads in a direction parallel to the stiffeners. Two possible buckling modes were investigated; namely, the plate may buckle around the stiffeners as nodal lines and the plate may buckle with the intermediate stiffeners as a unit. The edge stiffeners were assumed to have a finite torsion rigidity, infinite bending rigidity perpendicular to the plate, and either infinite or zero bending rigidity in the plane of the plate.

This modified variational procedure will give much better results with the same amount of computational labor.

TN 2679 THE STABILITY UNDER LONGITUDINAL COMPRESSION OF FLAT SYMMETRIC CORRUGATED CORE SANDWICH PLATES WITH SIMPLY SUPPORTED LOADED EDGES AND SIMPLY SUPPORTED OR CLAMPED UNLOADED EDGES, Paul Seide, April 1952

A theory for the elastic behavior of orthotropic sandwich plates is used to determine the compressive buckling load parameters of flat symmetric corrugated core sandwich plates with simply supported loaded edges and simply supported or clamped unloaded edges. Charts are presented for corrugated core sandwich plates for which the transverse shear stiffness in planes parallel to the axis of the corrugation may be assumed infinite. The limits of validity of this assumption are investigated for simply supported plates.

TN 2682 TRANSVERSE VIBRATIONS OF HOLLOW THIN WALLED CYLINDRICAL BEAMS, Bernard Budiansky and Edwin T. Kruszewske, April 1952

Superseded by report 1129.

TN 2737 PLASTIC STRESS STRAIN RELATIONS FOR COMBINED TENSION AND COMPRESSION, Joseph Marin and G. A. B. Wiseman, July 1952

This report treats material previously covered by TN's 1536 and 2425.

TN 2760 DERIVATION OF STABILITY CRITERIONS FOR BOX BEAMS WITH LONGITUDINALLY STIFFENED COVERS CONNECTED BY POSTS, Paul Seide, August 1952

These stability criterions give the axial stiffness of the posts required to achieve desired stress values in the box-beam covers.

The parameters used in the present paper are defined in terms of the transverse spacing of the rows of posts rather than the cover width because more natural parameters are thereby obtained.

TN 2782 BENDING OF THIN PLATES WITH COMPOUND CURVATURE, H. G. Lew, October 1952

An analysis is presented for the deformation of a doubly curved thin plate under edge loads or surface loads for small deflections.

An analytical solution is presented completely for a plate with an arbitrary meridian curve of small curvature and loaded by normal edge loads on one pair of opposite edges.

The method is developed to the point that it may be applied readily to other problems of the deformation of doubly curved thin plates under edge or surface loads. The theory is limited to small deflections of the plate or shell considered.

TN 2785 INTRODUCTION TO ELECTRICAL CIRCUIT ANALOGIES FOR BEAM ANALYSIS, Stanley U. Benscoter and Richard H. MacNeal, September 1952

An application is described of the well known analogy between electrical and mechanical systems to the calculation of stresses and deflections of beams. The object of the paper is to give an explanation of the analogies in an elementary manner which will enable a structural engineer to understand the process of designing the electrical circuits. The analogies which are discussed are those that are now being used in the Cal-Tech analog computer. Analogies are given for beams in bending and torsion with static loads and in vibrational motion.

TN 2786 EQUIVALENT PLATE THEORY FOR A STRAIGHT MULTI-CELL WING, Stanley U. Benscoter and Richard H. MacNeal, September 1952

A structural theory is developed for the analysis of thin multicell wings with straight spars and perpendicular ribs. The analysis is intended to be suitable for supersonic wings of low aspect ratio. It could probably be applied to our purpose. Deflections due to shearing strains are taken into account. The theory is expeessed entirely in terms of first-order differential equations in order that analogous electrical circuits can be readily designed and solutions obtained on the Cal-Tech analog computer.

TN 2792 DIRECT READING DESIGN CHARTS FOR 24S-T3 ALUMINUM ALLOY FLAT COMPRESSION PANELS HAVING LONGITUDINAL FORMED HAT SECTION STIFFENERS AND COMPARISONS WITH PANELS HAVING Z-SECTION STIFFENERS, William A. Hickman and Norris F. Dow, March 1953

"...Charts..."

Structural evaluations of hat section stiffeners, together with the direct reading charts presented for design hat stiffened panels, have indicated that the hat section stiffener is structurally better than the Z section stiffener for only a limited range of applications at best. For carrying simple compression, and when used as the covers of box beams which are subjected to compression plus bending or to compression plus bending plus vertical shear, the Z stiffened panel compared very favorably with the hat stiffened panel, even in the range of close stiffener spacings for which the hat section is best suited.

TN 2812 EFFECTS OF CYCLIC LOADING ON MECHANICAL BEHAVIOR OF 24S-T6 ALUMINUM ALLOYS AND SAE 4130 STEEL, C. W. MacGregor and N. Grossman, October 1952

When fatigued above the endurance limit the transition temperatures for SAE 4130 increased rapidly with the number of prior cycles. There were no cracks or changes in transition temperature for cycling below the endurance limit for 4130.

75S-T6 showed less energy absorption at -320° F than did 24S-T4. The energy for both aluminums decreased as the number of cycles increased. The inferior energy absorption capacity and notch sensitivity (to corrosion) of 75S-T6 when compared to 24S-T4 is due to its higher hardness level.

TN 2821 TORSION TESTS OF ALUMINUM ALLOY STIFFENED CIRCULAR CYLINDERS, J. W. Clark and R. L. Moore, November 1952

The object of this investigation was to obtain information on the shear-buckling resistance and tension-field behavior of aluminum-alloy stiffened circular cylinders loaded in torsion. The specimens were formed of .032- by 36- by 96-inch 24S-T3 sheets, the mean diameter was 30.08 inches and the overall length 36 inches. The ring stiffeners were made of 1/2 by 1/2 inch 24S-T3 and the longitudinal stiffeners were formed of .032-inch 24S-T3 sheet, and the end bulkheads rings were made from 3/8-inch-thick steel plates.

The empirical formula which was found to give agreement with the measured stiffener stresses:

$$\sigma_{ST} = \frac{ht}{A_{ST}} \left(\tau - \frac{H}{D} \tau_{cr}\right)$$

where:

σ_{ST} = average stress in longitudinal stiffener, psi
H = spacing of longitudinal stiffeners, inches
D = spacing of ring stiffeners, inches
A_{ST} = cross-sectional area of longitudinal stiffener, in.^{2}
t = thickness of sheet, in.
τ = average shear stress in sheet, psi
τ_{cr} = shear-buckling stress for panels, psi

The results of these tests agree well with theoretical reports NACA TN's 1344 and 1348. The empirical straight-line relationship gave good results. All of the cylinders having a wall thickness of 0.32 inch and 8 or 16 longitudinal stiffeners failed by the collapse of those stiffeners.

TN 2840 BUCKLING OF LOW ARCHES OR CURVED BEAMS OF SMALL CURVATUVE, U. C. Fung and A. Kaplan, November 1952

Presents method for calculating the critical lateral load, when a low arch is subjected to a lateral loading acting toward the center of curvature, the axial thrust induced by the bending of the arch may cause the arch to buckle so that the curvature becomes suddenly reversed. The buckling load based on the energy criterion of Karman and Tsien was calculated, the experimental critical loads were appreciably below those calculated from the classical criterion, but always above those calculated from the energy criterion.

TN 2872 THE EFFECT OF INITIAL CURVATURE ON THE STRENGTH OF AN INELASTIC COLUMN, Thomas W. Wilder, III, William A. Brooks, Jr., and Eldon E. Mathauser, January 1953

This paper presents a theoretical relation for the effect of initial deflection on the strength of a column.

$$3/14\ (1 + f)^n \left(\frac{\bar{\sigma}}{\sigma_1}\right)^n + f\,\frac{\bar{\sigma}}{\sigma_1} = 3/14\ \left[\left(\frac{\sigma_R}{\sigma_1}\right)_{max}\right]^n + \left[\frac{\sigma_T}{\sigma_1} + \frac{3n}{7}\left(\frac{\sigma_T}{\sigma_1}\right)^n\right](f - e)$$

where:

b = column thickness
d = total lateral deflection of column at midheight after loading
d_o = initial lateral deflection of column at midheight before loading
e = $2d_o/b$
f = $2d/b$
n = Ramsberg-Osgood stress-strain-curve shape parameter
σ_1 = 0.7E secant yield stress
σ_R = compressive stress in right (convex) flange at midheight of column
σ_T = average cross-sectional stress corresponding to tangent-modulus load of column
$\bar{\sigma}$ = average cross-sectional stress of column

TN 2873 THE EFFECT OF LONGITUDINAL STIFFENERS LOCATED ON ONE SIDE OF A PLATE ON THE COMPRESSIVE BUCKLINE STRESS OF THE PLATE STIFFENER COMBINATION, Paul Seide, January 1953

Most useful information is on calculating the moment of inertia of the stiffeners; this information is now available in most structure textbooks.

TN 2874 ON TRAVELING WAVES IN BEAMS, Robert W. Leonard and Bernard Budiansky, January 1953

Presents solutions to the basic equations of Timoshenko for the motion of vibrating non-uniform beams, which allow for effect of transverse shear deformation and rotary inertia.

TN 2875 BEHAVIOR IN PURE BENDING OF A LONG MONOCOQUE BEAM OF CIRCULAR ARC CROSS SECTION, Robert W. Fralich, J. Mayers, and Eric Reissner, January 1953

The pure monocoque beam, with no internal bulkheads, ribs, etc., represents a limiting structure in the design of wings. This report was made in order to determine its favorable or unfavorable characteristics.

The report shows a nonlinear relationship between bending moment and beam curvature that arises from the low chordwise bending stiffness of the covers and ultimately leads to an instability. There was also much profile flexibility which is bad from an aerodynamic point; this could be corrected by additional chordwise bending stiffness in the covers. If no interaction is assumed between local buckling of the compression cover and flattening instability, local buckling should precede flattening instability when the radius-thickness (r/t) ratio exceeds 720 and flattening instability occurs first when r/t is less than 720.

If an average value of 1.3 is assumed for the ratio of the critical stresses, the stress for local buckling in bending becomes

$$\sigma_{x_{cr}} = (0.765 - 0.000563\ r/t)\ Et/r$$

$\sigma_{x_{cr}}$ = local buckling stress of compression cover
r = radius of curvature of circular-arc cross section, in.
t = thickness of cover plate, in.
E = Young's modulus for beam material, $lb/in.^2$

TN 2884 CALCULATION AND MEASUREMENT OF NORMAL MODES OF VIBRATION OF AN ALUMINUM ALLOY BOX BEAM WITH AND WITHOUT LARGE DISCONTINUITIES; Frank C. Smith and Darnley M. Howard, January 1953

This report uses a matrix iteration method; it is very likely that by the use of a computer a more accurate solution has been found.

TN 2886 ANALYSIS OF STATICALLY INDETERMINATE TRUSSES HAVING MEMBERS STRESSED BEYOND THE PROPORTIONAL LIMIT, Thomas W. Wilder, III, February 1953

The method presented in this paper is an application of the principle of minimum complementary energy for the solution of trusses having redundant members.

TN 2915 EFFECT OF PROCESSING VARIABLES ON THE TRANSITION TEMPERATURE, STRENGTH AND DUCTILITY OF HIGH PURITY, SINTERED, WROUGHT MOLYBDENUM METAL, Kenneth C. Dike and Roger A. Long, March 1953

The following results were obtained from an investigation of the effect of processing variables on the properties of sintered, wrought molybdenum.

1. An increase in the swaging of molybdenum progressively lowers the transition temperature.

2. At room temperature, swaging to 99 percent had very little effect (13 percent) upon increasing the ultimate tensile strength over that of molybdenum swaged 35 percent.

3. All the material evaluated in tension, irrespective of the amount of swaging, whether in the as-swaged, stress-relieved, or recrystallized state showed a transgranular fracture at all temperatures.

4. No relation could be established between the grain size of recrystallized metal and strength and ductility, within the transition temperature range, in the grain count of 75 to 825 grains per square millimeter. However, above the transition range, for example, at 200° F, ductility increased with decreasing grain size.

TN 2920 INTERIM REPORT ON A FATIGUE INVESTIGATION OF A FULL SCALE TRANSPORT AIRCRAFT WING STRUCTURE, J. James McGuigan, Jr., April 1953

Constant-level fatigue tests were conducted on several full-scale C-46 wings at a level of $1 \pm 0.625g$ indicated a lifetime at this level of about 200,000 cycles. There were four main types of failure:

1. Corner of inspection cutouts
2. Riveted tension joint
3. Riveted shear joint
4. Discontinuities in section or shape

There were 10 failures of the first type. The second type was a failure of the riveted tension joint near the center line of the aircraft of which there were 6. The 6 failures in type 3 occurred in a riveted shear joint where the shear web of the front spar was riveted to the tension flange of that spar. The 12 failures in type 4 originated at abrupt changes or discontinuities in section or shape.

Fatigue damage had no effect on either the natural frequency or damping until after fatigue failure had originated, and then only very little effect. When a crack did occur, its rate of growth was rather slow until about 5 to 9 percent of the tension material had failed, after which the rate of crack growth increased rapidly.

TN 2930 STRENGTH ANALYSIS OF STIFFENED THICK BEAM WEBS WITH RATIOS OF WEB DEPTH TO WEB THICKNESS OF APPROXIMATELY 60, L. Ross Levin, May 1953

This report (experiment) indicates that the methods of strength analysis presented in NACA TN 2661 are applicable to beams with the flanges symmetrically arranged with respect to the web if the portal-frame effect is taken into account. It was noted during the experiment that beams with unsymmetric flanges failed with a nominal shear stress 18 to 14 percent lower than that in similar beams with flanges symmetrically arranged. However, this detrimental effect resulting from the unsymmetrical arranged flanges was not noted in beams with, depth of beam, thickness of web ratios of 115 or greater. This is the first report to find out that the method of TN 2661 could be used on beams with ratios of web depth to web thickness of 60 if the flanges are symmetrically arranged and if the portal-frame effect is taken into account.

TN 2963 EFFECT OF VARIATION IN RIVET STRENGTH ON THE AVERAGE STRESS AT MAXIMUM LOAD FOR ALUMINUM ALLOY, FLAT Z STIFFENED COMPRESSION PANELS THAT FAIL BY LOCAL BUCKLING, Norris F. Dow, William A. Hickman, and B. Walter Rosen, June 1953

Presents curves and method for choosing the maximum allowable rivet for an average panel stress at maximum load.

TN 2987 CHARTS RELATING THE COMPRESSIVE BUCKLING STRESS OF LONGITUDINALLY SUPPORTED PLATES TO THE EFFECTIVE DEFLECTIONAL AND ROTATIONAL STIFFNESS OF THE SUPPORTS, Roger A. Anderson and Joseph W. Semonian, August 1953

The charts make possible the determination of the compressive buckling stress of plates supported by members whose stiffness may be determined. Examples are used to illustrate the use of the charts in designing wing structures. The data for deflection and rotational stiffness are obtained by analyzing a plate under edge compression.

TN 2994 COLUMN STRENGTH OF H-SECTIONS AND SQUARE TUBES IN POSTBUCKLING RANGE OF COMPONENT PLATES, P. P. Bijlaard and G. P. Fisher, August 1953

Where the component plates have buckled the column buckling stress is calculated by the method of split rigidities. For the elastic region the column buckling stress is calculated by using the Euler buckling stresses. For the plastic region a Johnson parabola which is tangent to the curve for the elastic column buckling stress in the post buckling range.

The postbuckling strength (that is excess strength beyond that indicated by the critical plate buckling stress) increases with decreasing slenderness ratios L/r.

Tests were carried out for a wide range of slenderness ratios. Experimental and theoretical ultimate buckling stresses agree.

TN 3023 RESULTS OF EDGE-COMPRESSION TESTS ON STIFFENED FLAT-SHEET PANELS OF ALCLAD AND NONCLAD 14S-T6, 24S-T3 AND 75S-T6 ALUMINUM ALLOYS, Marshall Holt, April 1954

This was an investigation to obtain data on the compressive strengths of stiffened flat-sheet panels in the range where ultimate strengths approach the compressive yield strengths of the materials. The ultimate strengths of the panels varied from 93.3 to 118.0 percent of the compressive yield strength of the materials. The unsupported width-to-thickness ratio of the sheet is about 11 and that of the flat portion of the stiffener is about 8. U-shaped stiffeners were used.

Failure of the specimens was associated more nearly with column action of the sheet between rivet fastenings than with local buckling of the sheet. The ultimate strengths of the panels was limited by the strength of the rivets.

TN 3039 EXPERIMENTAL STRESS ANALYSIS OF STIFFENED CYLINDERS WITH CUTOUTS, PURE TORSION, Floyd R. Schlechte and Richard Rosecrams, November 1953

Torsion tests were made on a cylindrical semi-monocoque shell. The tests were first made with a cutout and then the cutout was enlarged from 30° to 130° and from 1 to 2 bays in length. Data is presented in six tables for different size cutouts; no attempt was made to analyze the data.

TN 3059 ELASTIC BUCKLING UNDER COMBINED STRESSES OF FLAT PLATES WITH INTEGRAL WAFFLE-LIKE STIFFENING, Norris F. Dow, L. Ross Levin, and John L. Troutman, January 1954

Using: $$N_x = \frac{\pi^2}{W^2}\left[(K_c - 2)\sqrt{D_1 D_2} + 4D_K + 2\mu_y D_1 \right]$$

N_x = longitudinal compressive loading

W = plate width

$D_1 D_2 \mu_y, D_K$ are found in NACA RM L 53E13a

K_c = compressive buckling coefficient

Theory and experiment were found in good agreement for the elastic buckling of long flat plates with waffle-like stiffening under combined stresses. 45° waffle stiffening was found to be the most effective configuration over the widest range of test conditions.

TN 3061 STRESSES AROUND RECTANGULAR CUTOUTS IN TORSION BOXES, Paul Kuhn and James P. Peterson, December 1953

The problem of calculating the stresses produced by cutouts is divided into two parts. The box is treated like a box without a cutout and then "key" stresses are found in the cover by the method of shear lag. The method is unconservative if the cutout is short and narrow, otherwise it gives satisfactory results.

TN 3070 EFFECTS OF PANEL FLEXIBILITY ON NATURAL VIBRATION FREQUENCIES OF BOX BEAMS, Bernard Budiansky and Robert W. Fralich, March 1954

Effects of local panel oscillations on the vibrations of box beams were investigated. The results obtained can be used to guide the estimation of coupling effects in box beams when the uncoupled local frequency is higher than the uncoupled overall frequency. Charts give plate frequencies for a number of configurations.

TN 3073 EXPERIMENTAL STRESS ANALYSIS OF STIFFENED CYLINDERS WITH CUTOUTS PURE BENDING, Floyd R. Schlechte and Richard Rosecrans, March 1954

Bending tests were made on a cylindrical semi-monocoque shell of circular cross section. Tests were first made without a cutout, the cutout was then enlarged from 30° to 130° and from 1 to 2 bays in length. The strains from different parts of the cylinder were measured with strain gages; this data is presented in tables, but no attempt was made to interpret this data.

TN 3077 THE EFFECT OF DYNAMIC LOADING ON THE STRENGTH OF AN INELASTIC COLUMN, William A. Brooks, Jr., and Thomas W. Wilder, III, March 1954

The report presents the maximum loads of an idealized inelastic H-section column whose pinned ends approach each other at a constant rate. As the rate of end displacement becomes smaller the dynamic buckling solutions approach the static solution as a lower limit. Inertia effects are negligible at rates of end displacement comparable to those used in static column tests. For the rates investigated the static maximum may be used as a conservative estimate of the maximum column load.

TN 3082 EXPERIMENTAL INVESTIGATION OF THE PURE-BENDING STRENGTH OF 75S-T6 ALUMINUM-ALLOY MULTI-WEB BEAMS WITH FORMED-CHANNEL WEBS, Richard A. Pride and Nelvin S. Anderson, March 1954

Results are presented for pure-bending tests of 53 multi-web beams of various proportions. The beams had channel-type webs which had been formed with bend radii of four times the web thickness. All failures occurred with the formation of a trough in the compression skin extending across the web attachment flanges. The two modes of buckling that occurred were local buckling of the plate elements and wrinkling of the entire compression skin. The average skin stress at failure can generally be increased by any of the following: decreasing web depth, decreasing web spacing, and increasing web thickness. The most efficient ratio of web thickness to skin thickness $t_w/t_s = 0.63$ and web spacing to skin thickness $b_s/t_s = 25$ was found for the type of beam studied. Three-cell beams gave good indication of multi-web behavior; the use of more than three cells produced insignificant changes in the buckling and failing stresses of the beams.

TN 3090 INVESTIGATION OF SANDWICH CONSTRUCTION UNDER LATERAL AND AXIAL LOADS, Wilhelmina D. Kroll, Leonard Mordfin, and William A. Garland, December 1953

Tests were made on sandwich panels under both axial and lateral loads. The theory that was used is derived from the theory for the buckling of a simply supported sandwich column. Computed and experimental values of the maximum load were within 9%; the computed values were conservative.

TN 3113 ANALYSIS OF STRAIGHT MULTICELL WINGS ON CAL-TECH ANALOG COMPUTER, Stanley U. Benscoter and Richard H. MacNeal, January 1954

The report presents in some detail the method that was used to analyze a wing structurally using an analog computer. Wings with aspect ratios of 2 and 4 with rectangular and biconvex cross sections were considered. The effects of the shearing strains at the ribs and spars were included, due to concentrated loads at the intersections of the ribs and spars. Data is presented for deflections and internal force quantities along with vibration modes and frequencies. It required four weeks of normal working time for the analysis to be made using the analog computer. The results did not agree in all cases with beam theory. The wings of aspect ratio 4 show better agreement than those of ratio 2.

TN 3118 DESIGN DATA FOR MULTIPOST-STIFFENED WINGS IN BENDING, Roger A. Anderson, Aldie E. Johnson, Jr., and Thomas W. Wilder, III, January 1954

This report is a summary of the data and calculations of NACA RM L52K10a and gives numerical values for the stiffnesses required of the various components of a multipost-stiffened wing to achieve the desired buckling-stress values under bending loads, both upright post and posts used as diagonals of a Warren truss are considered.

TN 3136 CREEP BENDING AND BUCKLING OF LINEARLY VISCOELASTIC COLUMNS, Joseph Kempner, January 1954

The following equation was derived for the creep bending of a beam loaded laterally and axially:

$$E_1 I[\partial^2(1/\alpha)/\partial t^2 + (1/\tau_2)\partial(1/\alpha)/\partial t] = \ddot{M} + (K/\tau_2)\dot{M} + (1/\tau_1\tau_2)M$$

This equation was used to obtain the creep deflections due to bending. Deflections increase continuously with time, but large deflections are obtained in short periods of time only if the applied load is near the Euler load of the column.

I	=	moment of inertia
E	=	Young's modulus
M	=	bending moment
t	=	time
K	=	$1 + (\tau_2/\tau_1) + (E_1/E_2)$
τ_1, τ_2	=	relaxation and retardation time, respectively
α	=	ratio of end load and Euler load

TN 3138 CREEP BUCKLING OF COLUMNS, Joseph Kempner and Sharad A. Patel, January 1954

The following formula was derived for the critical time (the time required for infinite deflections to develop). The critical time is plotted for a wide range of parameters.

$$\tau_{cr} = \left(\frac{2^{m-1}}{m}\right) \sum_{n=1,3,\ldots\ldots}^{m-1} (-1)^{(m-n-1)/2} \sin^{m-2}\left(\frac{n\pi}{2m}\right)\left\{\frac{\pi}{2} - \tan^{-1}\left[2f_{t_o} \tan\left(\frac{n\pi}{2m}\right)\right]\right\}$$

τ_{cr} = critical time
f_{t_o} = $f_1/[1 - (\bar{\sigma}/\sigma_E)]$
f_1 = amplitude of initial deviation divided by h
h = distance between flanges of idealized H-section
m = exponent
n = integer
$\bar{\sigma}$ = average axial compressive stress
σ_E = static buckling stress, $\pi^2 E_1 I/AL^2$, $I = Ah^2/4$
L = column length
A = area of idealized H-section
E_1 = effective elastic modulus

TN 3139 TIME-DEPENDENT BUCKLING OF A UNIFORMLY HEATED COLUMN, Nathan Ness, January 1954

This report presents a theoretical investigation of the time-temperature-dependent buckling of a pin-jointed constant-section column, whose initial curvature is defined by a half-sine wave when the material is linearly viscoelastic and is heated uniformly along the column at a prescribed time rate. Deviations from straightness increase with time and become indefinitely large when heating reduces the Young's modulus of the material to the value at which the applied load is the Euler load of the column.

$$W = F_i \left[\frac{e^{C \int_0^t \frac{E}{\lambda(E - C)} dt}}{1 - (P/P_E)} - 1 \right] \sin (\pi x/L)$$

where:

C = constant $E_o P/P_{E_o}$
E = Young's modulus
F_i = maximum deflection of unloaded column
L = length of column
P = constant, compressive end load
$P_E(t)$ = temperature (time) dependent Euler load, $\pi^2 E(t) I/L^2$
t = time
w = additional deflection form initially curved, unloaded column
x = axial coordinate of column
λ = viscosity coefficient

TN 3158 A SUBSTITUTE-STRINGER APPROACH FOR INCLUDING SHEAR-LAG EFFECTS IN BOX-BEAM VIBRATIONS, William W. Davenport and Edwin T. Kruszewski, January 1954

The substitute stringer approach for finding the shear-lag in the calculation of transverse modes and frequencies of box beams is used to idealize thin-walled hollow rectangular beams. Comparison with experimental data indicates that this method may be used to yield accurate representation of the shear-lag effect in dynamic analysis.

TN 3167 THERMAL CONDUCTANCE OF CONTACTS IN AIRCRAFT JOINTS, Martin E. Barzelay, Kin Nee Tong and George Hollo, March 1954

It was found that (1) the thermal conductance of the interface joint increases with mean temperature, but stays constant with heat flow, (2) thin foils of a good conducting material between the interfaces improved the heat transfer and (3) common strength-giving bonding materials provide joints with poor thermal conductivity.

TN 3184 BUCKLING OF LONG SQUARE TUBES IN COMBINED COMPRESSION AND TORSION AND COMPARISON WITH FLAT-PLATE BUCKLING THEORIES, Roger W. Peters, May 1954

Experiments and calculations were made to see if data and theory for flat plates could be used for long square tubes. The following equation from plate theory along with plastic reduction factors from compressive stress-strain data was found to give good results for tubes:

$$\sigma_{cr} = \eta_c \frac{K_c \pi^2 E}{12(1 - \nu^2)(b/t)^2} \qquad \tau_{cr} = \eta_s \frac{K_s \pi^2 E}{12(1 - \nu^2)(b/t)^2}$$

where

σ_{cr} = critical compression stress

τ_{cr} = critical shear stress

η = plasticity reduction factor

K = plate buckling coefficient

R = rate of combined loading stress to individual loading stress

Subscript s denotes shear; c denotes compression. An interaction curve with the following equation was found to be adequate for long square tubes:

$$R_c^2 + R_s^2 = 1$$

The direction of load path has no effect on the shape of the interaction curves.

TN 3192 EXPERIMENTAL STRESS ANALYSIS OF STIFFENED CYLINDERS WITH CUTOUTS, SHEAR LOAD, Floyd R. Schlechte and Richard Rosecrans, July 1954

A cylindrical semi-monocoque shell was mounted as a cantilever and loaded by direct shear at the tip. The cutout was gradually enlarged from 30° to 130° and from one to two bays. Tests were made with the cutout on the neutral axis (one side) and on the tension side of the cylinder. Charts are presented which show how the load varied on each ring.

TN 3200 STRESS ANALYSIS OF CIRCULAR SEMI-MONOCOQUE CYLINDERS WITH CUTOUTS BY A PERTURBATION LOAD TECHNIQUE, Harvey G. McComb, Jr., September 1954

A stress analysis is made of circular semi-monocoque cylinders by applying three unit loads, a concentrated force, a distributed force along a stringer, and a distributed force along the rings and stringers around a panel so as to cause shear in that panel. The method can be used for any loading case for which the structure without the cutout can be analyzed and is sufficiently versatile to account for stringer and shear reinforcement about the cutout. The method is as follows:

1. Find stress distribution without the cutout.

2. Find stress distribution with the perturbation loads placed around the location of the cutout.

3. Write equations for each stringer and panel effected by the cutout.

4. Solve the equations for the stress distribution.

The report presents examples and shows how the equations are changed for different cases.

TN 3231 BENDING TESTS ON BOX BEAMS HAVING SOLID- AND OPEN-CONSTRUCTION WEBS, Aldie E. Johnson, Jr., August 1954

A study was made on the effect of replacing alternate webs in a multiweb beam by open post stringer construction. It was found that post stringers will stabilize the compressive cover of a beam in bending, before and after buckling, as well as a web of the same weight.

TN 3232 AN ANALYSIS OF THE STABILITY AND ULTIMATE BENDING STRENGTH OF MULTIWEB BEAMS WITH FORMED-CHANNEL WEBS, Joseph W. Semonian and Roger A. Anderson, August 1954

Curves are given for finding the stresses at which wrinkling instability and failure occur in multiweb beams. It was found that the method of riveting the web to the cover skin of the beam is very important to the ultimate strength.

TN 3308 AN EXPLORATORY INVESTIGATION OF SOME TYPES OF AEROELASTIC INSTABILITY OF OPEN AND CLOSED BODIES OF REVOLUTION MOUNTED ON SLENDER STRUTS, S. A. Clevenson, E. Widmayer, Jr., and Franklin W.

Diederich, November 1954

An investigation has been conducted in order to gain some insight into the nature of the instability phenomena of isolated bodies of revolution (closed and open). All tests were conducted at Mach No less than 5 and Re (based on body length) from 1.5 to 7.1×10^6. The bodies of revolution are intended to represent such bodies as external fuel tanks. The procedure for each test was to increase the tunnel speed and the angle of yaw of the model to give zero lift and moment on the body until some form of instability occurred.

Several types of aeroelastic instability were encountered. Coupled flutter similar to classical bending-torsion flutter was encountered, except that bending and torsion were lateral motion and yawing.

A combined flutter and divergence instability was observed, not unlike the type of phenomenon which a wing may experience if its flutter occurs in a mode which involves very little bending.

Continuous or intermittent, self-excited, small-amplitude yawing oscillations, usually with fairly well defined frequency were observed.

It was found that:

1. Flutter could not be predicted for the streamlined body by using aerodynamic forces based on potential theory.

2. Closed strut-mounted bodies of revolution appear to be subject to a nonclassical instability which consists in self-excited non-violent oscillations which appear to start, in the case of aerodynamically clean bodies at about 1/3 that at flutter or divergence of a given body.

3. The mechanism which causes these oscillations is as yet unknown.

An Appendix on Calculation of Aeroelastic Instabilities is given.

TN 3368 ANALYSIS OF BEHAVIOR OF SIMPLY SUPPORTED FLAT PLATES COMPRESSED BEYOND THE BUCKLING LOAD INTO THE PLASTIC RANGE, J. Mayers and Bernard Budiansky, February 1955

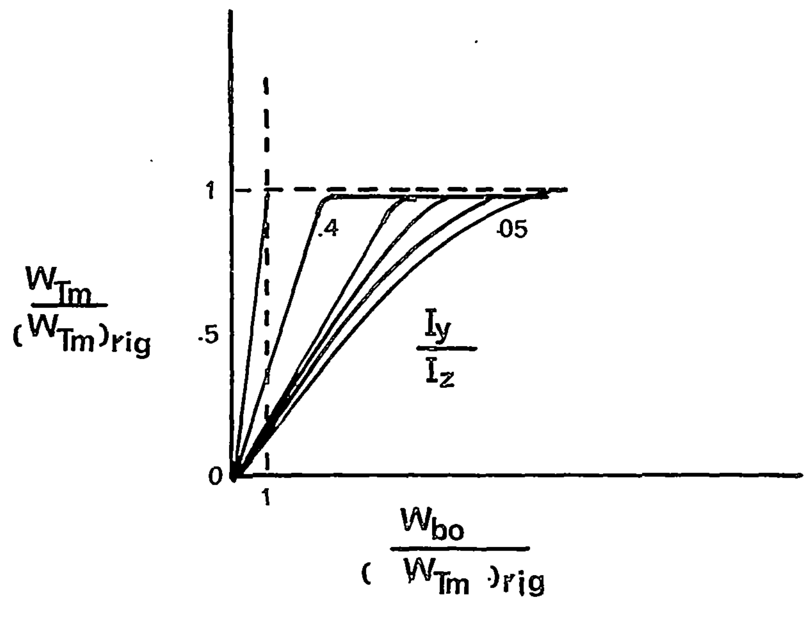
A computer analysis for the postbuckling behavior of a simply supported flat plate. The results that were obtained indicate greater plate strength than found experimentally on plates that do not satisfy straight edge conditions.

TN 3431 AN ANALYSIS OF THE STABILITY AND ULTIMATE COMPRESSIVE STRENGTH OF SHORT SHEET STRINGER PANELS WITH REFERENCE TO THE INFLUENCE OF RIVETED CONNECTIONS BETWEEN SHEET AND STRINGER, Joseph W. Semonian and James P. Peterson, March 1955

Rivet diameter, pitch, and location greatly affect the compressive strength of the panel. The smaller the pitch and the larger the diameter the higher the strength of the panel. The panel strength may be increased by the above method until panel fails in local buckling. The riveting specifications that will cause the panel to fail in the local mode depends on the panel shape and material.

TN 3464 INFLUENCE OF SHEAR DEFORMATION OF THE CROSS SECTION ON TORSIONAL FREQUENCIES OF BOX BEAMS, Edwin T. Kruszewski and William W. Davenport, October 1955

The report investigated the importance of bulkhead shear deformation on torsional frequencies. For conventional constructions, cross-sectional shear deformation generally is negligible. For beams that depend on the bent action of their own walls for most of their cross-sectional stiffness, the effect of cross-sectional shear deformation is considerable.



W_{Tm} = natural torsional frequency of four flange box beam

W_{bo} = frequency of cross sectional uniform shear mode

I_y = mass moment of inertia per unit length about the y-axis

I_z = mass moment of inertia per unit length about the z-axis

SUBSCRIPTS

m = mode number
rig = rigid bulkhead

TN 3618 EXPERIMENTAL INVESTIGATION OF THE VIBRATIONS OF A BUILT-UP RECTANGULAR BOX BEAM, Eldon E. Kordes and Edwin T. Kruszewski, February 1956

Experimental modes and frequencies compared well with those obtained using substitute stringer and elementary or a four-flange beam analysis.

TN 3633 ANALYSIS OF THE ULTIMATE STRENGTH AND OPTIMUM PROPORTIONS OF MULTIWEB WING STRUCTURES, B. Walter Rosen, March 1956

Although the report was done for the design of supersonic aircraft, minimum structural weight is shown as a function of the design variables (bending moment, wing chord, depth and skin thickness) and should be useful in designing a multiweb wing for any type of plane. The charts are for 7075 Al but give the trend that should be the same for other materials. The charts are based on equations developed to relate ultimate bending strength of multiweb beams that fail in the local buckling mode to beam proportions and material properties.

TN 3636 THE ACCURACY OF THE SUBSTITUTE-STRINGER APPROACH FOR DETERMINING THE BENDING FREQUENCIES OF MULTISTRINGER BOX BEAMS, William W. Davenport, April 1956

This report concludes that the substitute stringer method as written up in NACA TN 3158 can yield accurate frequencies for multistringer box beams, but suggests that b_s/b_c be changed from 0.50 to 0.55, since this gives better results.

b_s = distance between web and adjacent substitute stringer
b_c = distance between web and centroid of area of half the cover

TN 3640 A METHOD FOR DEFLECTION ANALYSIS OF THIN LOW-ASPECT-RATIO WINGS, Manuel Stein and J. Lyell Sanders, Jr., June 1956

A method is given for organizing data into matrix form so that it may be used by a computer to give influence coefficients for thin low-aspect-ratio wings of built-up construction.

TN 3684 LARGE DEFLECTION OF CURVED PLATES, H. G. Lew, J. A. Box, and T. T. Loo, October 1956

The effect of initial curvature for a plate under axial compression is to increase its deflection considerably upon the application of load. With increasing loads, the deflection curves merge into one curve regardless of the initial deflection form. The initial curvature affects the average shear strain of a plate under shear load very little. For a circular cylindrical plate with small initial curvature under axial compression the radius R_o is more important than the initial curvature as faras the deflection of the plates is concerned. The effect of an initial deflection is that of reducing the effective width.

TN 3726 COMPRESSIVE AND TORSIONAL BUCKLING OF THIN-WALL CYLINDERS IN YIELD REGION, George Gerard, August 1956

The following equations were derived for the plastic buckling of cylinders based on assumptions for the inelastic buckling of flat plates. Agreement between theory and experimental data was satisfactory.

$$\sigma_{cr} = 0.6\eta_c E(t/R)$$

$$\eta_c = \left(\frac{1 - \nu_e^2}{1 - \nu^2}\right)^{1/2} \frac{E_s}{E} \left(\frac{E_t}{E_s}\right)^{1/2}$$

σ_{cr} = critical stress for plastic buckling
E = modulus of elasticity
E_s = secant modulus
E_t = tangent modulus
R = radius of cylinder
t = thickness
ν = Poisson's ratio
ν_e = elastic value of Poisson's ratio

TN 3735 BENDING TESTS OF RING-STIFFENED CIRCULAR CYLINDERS, James P. Peterson, July 1956

The results of loading twenty-five ring stiffened circular cylinders to failure are presented as design curves applicable to cylinders with heavy rings which fail in local buckling.

TN 3756 STUDY OF SIZE EFFECT IN SHEET-STRINGER PANELS, J. P. Dorman and Edward B. Schwartz, STATISTICAL ANALYSIS, Edward B. Schwartz, July 1956

The object of the report was to determine if the prediction of the strength of large panels by model tests is reliable.

There was no significant size effect in the compressive strength of Z-stiffened panels, therefore the compressive strength of large panels may be predicted from model tests of nondimensional parameters.

TN 3781 HANDBOOK OF STRUCTURAL STABILITY. PART I. BUCKLING OF FLAT PLATES, George Gerard and Herbert Becker, July 1957

Various factors controlling flat plate buckling are reviewed and summarized in charts and tables. Numerical values are given for buckling coefficients for different loadings and boundary conditions. The effects of plastic buckling are presented in a nondimensional buckling chart using a three parameter stress-strain curve.

TN 3782 HANDBOOK OF STRUCTURAL STABILITY. PART II. BUCKLING OF COMPOSITE ELEMENTS, Herbert Becker, July 1957

This part of the handbook summarizes the buckling of stiffened plates and cylinders. Buckling coefficients are given for a number of conditions. Plasticity is discussed. The results of the summary are presented in charts and tables.

TN 3783 HANDBOOK OF STRUCTURAL STABILITY. PART III. BUCKLING OF CURVED PLATES AND SHELLS, George Gerard and Herbert Becker, August 1953

The buckling of curved plates and shells is reviewed for both theory and test data. The cases which presented a disagreement between linear buckling theory (for torsion and external pressure in both the elastic and inelastic ranges) were analyzed using a unified semiempirical method which proves satisfactory for design and analysis purposes.

TN 3784 HANDBOOK OF STRUCTURAL STABILITY. PART IV. FAILURE OF PLATES AND COMPOSITE ELEMENTS, George Gerard, August 1957

The failure of flat plates is reviewed and data on postbuckling behavior, effective width, and failure of flat and curved plates is correlated. Data on the crippling strength of composite shapes is also reviewed with a generalized method of analysis being formulated.

TN 3785 HANDBOOK OF STRUCTURAL STABILITY. PART V. COMPRESSIVE STRENGTH OF FLAT STIFFENED PANELS, George Gerard, August 1957

A generalized crippling analysis for short monolithic panels with stringers was presented. The effect of rivets is analyzed. Failure modes for intermediate and long stiffened panels is covered in the report. Data for optimum stiffened panels is presented.

TN 3786 HANDBOOK OF STRUCTURAL STABILITY. PART VI. STRENGTH OF STIFFENED CURVED PLATES AND SHELLS, Herbert Becker, August 1957

This report reviews the failure of stiffened curved plates and shells. The loadings considered for the plates were axial and shear, while bending, external pressure, torsion, and transverse shear were considered for the cylinders. Test data and theory were correlated and presented in charts. A unified theoretical approach to analysis of general instability of stiffened cylinders was developed.

TN 3801 EXPERIMENTAL INVESTIGATION OF THE STRENGTH OF MULTIWEB BEAMS WITH CORRUGATED WEBS, Allister F. Fraser, October 1956

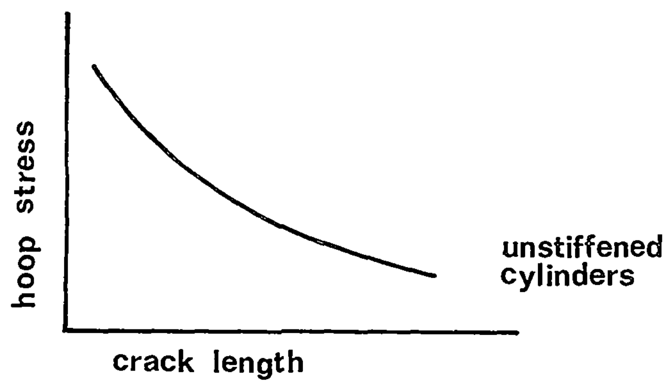
From data obtained from the experimental investigation of multiweb beams with corrugated webs it has been found that:

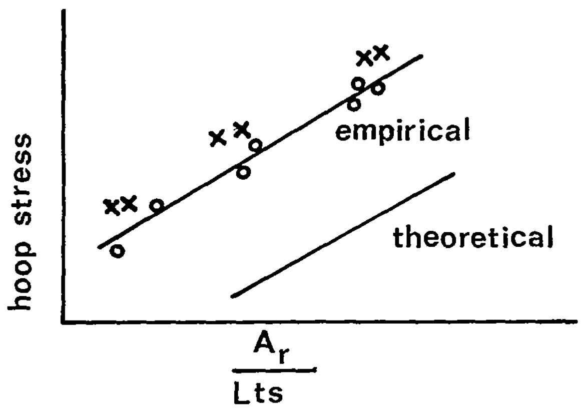
1. The connection between web and skin is very important.

2. Corrugated web beams can be built with better structural efficiency than channel web beams over a wide range of structural index.

TN 4011 SOME ASPECTS OF FAIL-SAFE DESIGN OF PRESSURIZED FUSELAGES, Paul Kuhn and Roger W. Peters, June 1957

How large must the initial damage be, before the pressure causes the shell to rupture? Only longitudinal cracks were considered. The report also includes data on the type of rupture, was it confined to one bay (confined rupture) or did it extend into another bay (unconfined rupture)?





x = unconfined rupture
o = confined rupture
A_r = ring area
L = ring spacing
ts = skin thickness

TN 4012 FATIGUE-CRACK PROPAGATION AND RESIDUAL STATIC STRENGTH OF BUILT-UP STRUCTURES; Herbert F. Hardrath and Richard E. Whaley, May 1957

Summary of crack-propagation and static-strength test in several types of built-up specimens and full scale wings. The rate of crack-propagation is influenced strongly by the mode of connecting the skin and stringers and by the proportions of areas of the skin and stringers.

TN 4114 WEIGHT-STRENGTH STUDIES OF STRUCTURES REPRESENTATIVE OF FUSELAGE CONSTRUCTION, James P. Peterson, October 1957

Weight strength plots for cylindrical shells in bending are presented. Sandwich-type stiffening was found to be the most effective. No advantage was found between waffle-like and longitudinal stiffening for minimum weight design. The ratio of compressive strength to density was found to be most important material parameter for sandwich-type shells. The density of the material is just as important for shells with longitudinal or waffle-like stiffening.

TN 4137 FATIGUE BEHAVIOR OF AIRCRAFT STRUCTURAL BEAMS, W. S. Hyler, H. G. Popp, D. N. Gideon, S. A. Gordon and H. J. Grover, January 1958

The study seeks to correlate composite structural fatigue behavior, basic material, and simple-element behavior. The study indicates that a simulation approach will be useful for those cases where it is possible to assess reasonably factors causing stress-raisers in the structure. High fatigue notch factors were found in composite structures involving stress gradient and biaxial stress distributions at or near rivets. The simulation procedure is presented in detail. The use in design of K_f, fatigue notch factors, obtained from simply notched coupons may be unconservative.

TN 4188 CHARTS RELATING THE COMPRESSIVE AND SHEAR BUCKLING STRESSES OF LONGITUDINALLY SUPPORTED PLATES TO THE EFFECTIVE DEFLECTIONAL STIFFNESS OF THE SUPPORTS, Aldie E. Johnson, Jr., February 1958

Using the results of a stability analysis of long flat rectangular plates, charts are presented for the determination of the buckling load of plates stiffened by stringers or webs.

TN 4207 EFFECT OF A STRINGER ON THE STRESS CONCENTRATION DUE TO A CRACK IN A THIN SHEET, J. Lyell Sanders, Jr., March 1958

In the report a coefficient was obtained for determining the effect of a reinforcing stringer on the stress concentration factor at the tip of the crack in a thin sheet. The crack runs perpendicular to the stringer and extends an equal distance on either side. The results (correction factor for stress concentration for a crack) are presented in graphical and tabular form for the case where the stringer is intact and the case where it is broken.

TN 4237 GENERAL INSTABILITY OF STIFFENED CYLINDERS, Herbert Becker, July 1958

Theoretical buckling stresses were determined in explicit form using a derivation of Donnell's equation by Taylor. The derivation is presented in the report.

For isotropic cylinders:

$$\sigma_y = \frac{K_y \pi^2 E t^2}{12\,(1 - \nu^2) L^2}$$

$$K_y = 1.033\, Z_L^{\frac{1}{2}} \qquad Z_L = \frac{L^2}{RT}$$

For long cylinders under radial pressure:

$$\sigma_y = 3E(\alpha_f/R)^2$$

σ_y = circumferential-compressive-buckling stress
E = elastic modulus
α_f = radius of gyration of frame section
R = radius of cylinder
t = thickness of cylinder wall
T = torque loading on cylinder wall
ν = Poisson's ratio
L = length of cylinder

TN 4244 ON SOLUTIONS FOR THE TRANSIENT RESPONSE OF BEAMS, Robert W. Leonard, June 1958

Williams type modal solutions are presented for elementary and Timoshenko beam equations for the response of several uniform beams with a general load applied. Examples are included.

TN 4246 FURTHER INVESTIGATION OF FATIGUE-CRACK PROPAGATION IN ALUMINUM-ALLOY BOX BEAMS, Herbert F. Hardrath and Herbert A. Leybold, June 1958

Twenty-one box beams of nine designs were tested at one load level to study fatigue-crack propagation. The rate of crack propagation was faster in 7075 Al than in 2024 Al. Specimens with bonded stringers had the lowest crack growth rate, while those specimens with small total stringer area or integrally stiffened covers had high growth rates.

TN 4292 LOCAL INSTABILITY OF THE ELEMENTS OF A TRUSS-CORE SANDWICH PLATE, Melvin S. Anderson, July 1958

Charts covering a wide range of sandwich proportions give the compressive buckling coefficient.

TN 4398 ANALYSIS OF THE CREEP BEHAVIOR OF A SQUARE PLATE LOADED IN EDGE COMPRESSION, Harvey G. McComb, Jr., September 1958

A simply supported square plate loaded in edge compression and subjected to creep was analyzed theoretically. A material that obeys a nonlinear creep law was assumed. The theory did not yield a finite collapse time, but did indicate lateral deflections and unit shortening due to creep. Creep can cause significant redistribution of the middle-surface stresses in a plate. Applied load has a stronger influence on creep deflections. Along the loaded edges the stresses increase at the ends and decrease in the center. Provided the unloaded edges remain straight, significant stresses can grow along these edges. The effective width of the plates is reduced as the creep progresses.

TN 4403 TESTS OF RING-STIFFENED CIRCULAR CYLINDERS SUBJECTED TO A TRANSVERSE SHEAR LOAD, James P. Peterson and Richard G. Updegraff, September 1958

Interaction curves are used to present the data obtained when 34 ring stiffened cylinders were loaded in combined bending and transverse shear to failure. Charts are applicable to design of cylinders that fail in local buckling.

NACA Technical Notes Dealing with Structural Analysis or Design But Not Judged Applicable to Light Aircraft

TN	744	THE DEVELOPMENT OF ELECTRICAL STRAIN GAGES, A. V. DeForest and H. Leaderman, January 1940
TN	854	DESIGN OF TOOLS FOR PRESS COUNTERSINKING OR DIMPLING 0.040-INCH THICK 24S-T SHEET, R. L. Templin and J. W. Fogwell, August 1942
TN	860	THE CRITICAL COMPRESSION LOAD FOR A UNIVERSAL TESTING MACHINE WHEN THE SPECIMEN IS LOADED THROUGH KNIFE EDGES, Eugene E. Lundquist and Edward B. Schwartz, September 1942
TN	870-1	STRESS ANALYSIS OF MONOCOQUE FUSELAGE BULKHEADS BY THE PHOTO-ELASTIC METHOD, Benjamin F. Ruffner, December 1942
TN	874	CURING OF RESIN WOOD COMBINATIONS BY HIGH FREQUENCY HEATING, Arthur R. Von Hippel and A. G. H. Dietz, December 1942
TN	878	EFFECT OF FILTERS AND OF MIXING PROCEDURE ON THE STRENGTH OF PLASTIC MATERIALS, William Kynoch and L. A. Patronsky, January 1943
TN	887	A PORTABLE CALIBRATOR FOR DYNAMIC STRAIN GAGES, Albert E. McPherson, February 1943
TN	940	CHARTS FOR RAPID ANALYSIS OF 45° STRAIN-ROSETTE DATA, S. S. Manson, May 1944
TN	941	AN AUTOMATIC ELECTRICAL ANALYZER FOR 45° STRAIN-ROSETTE DATA, S. S. Manson, May 1944
TN	954	PERFORMANCE TESTS OF WIRE STRAIN GAGES. I - CALIBRATION FACTORS IN TENSION, William R. Campbell, November 1944
TN	978	PERFORMANCE TESTS OF WIRE STRAIN GAGES, William R. Campbell, September 1945
TN	989	SURVEY OF ADHESIVES AND ADHESION, R. C. Rinker and G. M. Kline, August 1945
TN	997	PERFORMANCE TESTS OF WIRE STRAIN GAGES, William R. Campbell, December 1945
TN	1000	TABLE OF INTERPLANAR SPACINGS FOR CRYSTAL STRUCTURE DETERMINATIONS BY X-RAY DIFFRACTION WITH MOLYBDENUM, COPPER, COBALT, IRON, AND CHROMIUM RADIATIONS, Howard Kittel, October 1945

TN 1011 ERRORS IN INDICATED STRAIN FOR A TYPICAL WIRE STRAIN GAGE CAUSED BY PRESTRAINING, TEMPERATURE CHANGES, AND WEATHERING, William R. Campbell, April 1946

TN 1019 THE SYNTHESIS AND PURIFICATION OF AROMATIC HYDROCARBONS: I - BUTYLBENZENE, Joseph V. Karabinos and Joseph M. Lambert, January 1946

TN 1020 THE SYNTHESIS AND PURIFICATION OF AROMATIC HYDROCARBONS: II - 1, 2, 4, TRIMETHYLBENZENE, Earl R. Ebersole, January 1946

TN 1021 THE SYNTHESIS AND PURIFICATION OF AROMATIC HYDROCARBONS: III - ISOBUTYLBENZENE, SEC-BUTYLBENZENE, AND TERT-BUTYLBENZENE, C. M. Guess, J. V. Karabinos, P. V. Kunz, and L. C. Gibbons, June 1946

TN 1022 A FIXTURE FOR COMPRESSIVE TESTS OF THIN SHEET METAL BETWEEN LUBRICATED STEEL GUIDES, James A. Miller, April 1946

TN 1028 EXTENSION OF THE CHAPLYGIN PROOFS ON THE EXISTENCE OF COMPRESSIBLE-FLOW SOLUTIONS TO THE SUPERSONIC REGION, Theodore Theodorsen, March 1946

TN 1042 PERFORMANCE TESTS OF WIRE STRAIN GAGES. IV - AXIAL AND TRANSVERSE SENSITIVITIES, William R. Campbell, 1942

TN 1133 EFFECT OF MISALIGNMENT OF STRAIN-GAGE COMPONENTS OF STRAIN ROSETTES, S. S. Manson and W. C. Morgan, September 1946

TN 1165 TENSILE PROPERTIES OF A SILLIMANTITE REFRACTORY AT ELEVATED TEMPERATURES, Alfred E. Kunen, Frederick J. Hartwig, and Joseph R. Bressman, November 1946

TN 1182 A COLLECTION OF THE COLLAPSED RESULTS OF GENERAL TANK TESTS OF MISCELLANEOUS FLYING-BOAT-HULL MODELS, F. W. S. Locke, Jr., March 1947

TN 1240 EFFECT OF SIMULATED SERVICE CONDITIONS ON PLASTICS, W. A. Crouse, D. C. Caudill and F. W. Reinhart, July 1947

TN 1279 THE DETERMINATION OF ELASTIC STRESSES IN GAS-TURBINE DISKS, S. S. Manson, May 1947

TN 1281 AN ELECTRICAL COMPUTER FOR THE SOLUTION OF SHEAR LAG AND BOLTED JOINT PROBLEMS, Robert D. Ross, May 1947

TN 1318 PERFORMANCE TESTS OF WIRE STRAIN GAGES, W. R. Campbell and A. F. Medbery, July 1947

TN 1346 CRITICAL SHEAR STRESS OF LONG PLATES WITH TRANSVERSE CURVATURE, S. B. Batdorf, Murray Schildcrout, and Manuel Stein, June 1947

TN 1355 A STUDY OF METAL TRANSFER BETWEEN SLIDING SURFACES, B. S. Wakmann, N. Grossman, and John W. Irvine, Jr., September 1947

TN 1456 PERFORMANCE TESTS OF WIRE STRAIN GAGES (PART VI), William R. Campbell, January 1948

TN 1461 INFLUENCE OF CRYSTAL PLANE AND SURROUNDING ATMOSPHERE OF SOME TYPES OF FRICTION AND WEAR BETWEEN METALS, Allan T. Gwathmey, Henry Leidheiser, Jr., and G. Pedro Smith, June 1948

TN 1486 STRESS DISTRIBUTION IN A BEAM OF ORTHOTROPIC MATERIAL SUBJECTED TO A CONCENTRATED LOAD, C. B. Smith and A. W. Voss, March 1948

TN 1488 COMPARISON OF CRYSTAL STRUCTURES OF 10 WROUGHT HEAT RESISTING ALLOYS AT ELEVATED TEMPERATURES WITH THEIR CRYSTAL STRUCTURES AT ROOM TEMPERATURE, J. Howard Kittel, November 1947

TN 1501 ON THE INTERPRETATION OF COMBINED TORSION AND TENSION TESTS OF THIN WALL TUBES, W. Paager, January 1948

TN 1531 A METALLURGICAL INVESTIGATION OF FIVE FORGED GAS TURBINE DISCS OF TIMKEN ALLOY, J. W. Freeman, E. E. Reynolds, and A. E. White, June 1948

TN 1532 A METALLURGICAL INVESTIGATION OF TWO CONTOUR FORCED GAS TURBINE DISCS OF 19-9DL ALLOY, J. W. Freeman, E. E. Reynolds, and A. E. White, September 1948

TN 1533 A METALLURGICAL INVESTIGATION OF TWO LARGE DISCS OF CSA ALLOY, E. E. Reynolds, J. W. Freeman, and A. E. White, September 1948

TN 1534 A METALLURGICAL INVESTIGATION OF A CONTOUR FORGED DISC OF EME ALLOY, E. E. Reynolds, J. W. Freeman, and A. E. White, November 1948

TN 1535 A METALLURGICAL INVESTIGATION OF TWO TURBOSUPERCHARGER DISCS OF 19-9DL ALLOY, E. E. Reynolds, J. W. Freeman, and A. E. White, November 1948

TN 1550 TENSILE AND COMPRESSIVE PROPERTIES OF LAMINATED PLASTICS AT HIGH AND LOW TEMPERATURES, J. J. Lamb, Isabelle Boswell, and B. M. Axilrod, July 1948

TN 1560 MECHANICAL PROPERTIES OF FIVE LAMINATED PLASTICS, William N. Findley and Will J. Worley, August 1948

TN 1561 STRENGTH AND CREEP CHARACTERISTICS OF CERAMIC BODIES AT ELEVATED TEMPERATURES, M. D. Burdick, R. E. Moreland, and R. F. Geller, April 1949

TN 1564 METHODS OF CONSTRUCTING CHARTS FOR ADJUSTING TEST RESULTS FOR THE COMPRESSIVE STRENGTH OF PLATES FOR DIFFERENCES IN MATERIAL PROPERTIES, George J. Heimerl, April 1948

TN 1578 FRICTION OF SOLID FILMS ON STEEL AT HIGH SLIDING VELOCITIES, Robert L. Johnson, Douglas Godfrey, and Edmond E. Bisson, April 1948

TN 1580 X-RAY DIFFRACTION INVESTIGATION OF MINOR PHASES OF 20 HIGH TEMPERATURE ALLOYS, B. M. Rosenbaum, July 1948

TN 1626 A STUDY OF CERAMIC COATINGS FOR HIGH-TEMPERATURE PROTECTION OF MOLYBDENUM, D. G. Moore, L. H. Bolz, and W. N. Harrison, July 1948

TN 1636 DETERMINATION OF STRESSES IN GAS-TURBINE DISKS SUBJECTED TO PLASTIC FLOW AND CREEP, M. B. Millenson and S. S. Manson, June 1948

TN 1656 TEST OF SIX TYPES OF BAKERLITE BONDED WIRE STRAIN GAGES, William R. Campbell, July 1948

TN 1667 EFFECT OF STRENGTH AND DUCTILITY ON BURST CHARACTERISTICS OF ROTATING DISCS, Arthur G. Holms and Joseph E. Jenkins, July 1948

TN 1720 FRICTION AT HIGH SLIDING VELOCITIES OF SURFACES LUBRICATED WITH SULFUR AS AN ADDITIVE, Robert L. Johnson, Max A. Swikert, and Edmond E. Bisson, October 1948

TN 1760 NACA AND OFFICE OF NAVAL RESEARCH METALLURGICAL INVESTIGATION OF TWO LARGE FORCED DISCS OF S-590 ALLOY, J. W. Freeman and Howard C. Cross, February 1949

TN 1765 OFFICE OF NAVAL RESEARCH AND NACA METALLURGICAL INVESTIGATION OF LARGE FORCED DISC OF S-816 ALLOY, Howard C. Cross and J. W. Freeman, February 1949

TN 1770 OFFICE OF NAVAL RESEARCH AND NACA METALLURGICAL INVESTIGATION OF A LARGE FORCED DISC OF INCONEL X ALLOY, Howard C. Cross and J. W. Freeman, April 1949

TN 1836 INITIAL INVESTIGATION OF CARBIDE-TYPE CERAMAL OF 80-PERCENT TITANIUM CARBIDE PLUS 20-PERCENT COBALT FOR USE AS GAS-TURBINE-BLADE MATERIAL, Charles A. Hoffman, G. Mervin Ault, and James J. Gangler, March 1949

TN 1856 THEORETICAL STUDY OF THE DIFFUSION CONSTANT FOR SELF-DIFFUSION IN METALS, M. Leichter, April 1949

TN 1863 COMPARATIVE STRENGTHS OF SOME ADHESIVE-ADHERENT SYSTEMS, N. J. DeLollis, Nancy Rucker, and J. E. Wier, March 1949

TN 1911 PHYSICAL PROPERTIES AT ELEVATED TEMPERATURE OF SEVEN HOT-PRESSED CERAMICS, James J. Gangler, Chester F. Robards, and James E. McNutt, July 1949

TN 1914 OXIDATION OF TITANIUM CARBIDE BASE CERMALS CONTAINING MOLYBDENUM, TUNGSTEN, AND COBALT, M. J. Whitman and A. J. Repko, July 1949

TN 1915 ELEVATED TEMPERATURE PROPERTIES OF SEVERAL TITANIUM CARBIDE BASE CERAMALS, George C. Deutsch, Andrew J. Repko, and William G. Lidman, July 1949

TN 1918 CORRELATION OF PHYSICAL PROPERTIES OF CERAMIC MATERIALS WITH RESISTANCE TO FRACTURE BY THERMAL SHOCK, W. G. Lidman and A. R. Bobrowsky, July 1949

TN 1920 PRELIMINARY INVESTIGATION OF NEEDLE BEARINGS OF L-1/8-INCH PITCH DIAMETER AT SPEEDS TO 17,000 RPM, E. Fred Macks, August 1949

TN 1928 CRITICAL COMBINATIONS OF SHEAR AND DIRECT AXIAL STRESS FOR CURVED RECTANGULAR PANELS, Murry Schildcrout and Manuel Stein, August 1949

TN 1938 MECHANISMS OF FAILURE OF HIGH NICKEL-ALLOY TURBOJET COMBUSTION LINERS, John W. Weeton, October 1949

TN 1945 INVESTIGATION OF BONDING BETWEEN METALS AND CERAMICS, H. J. Hamjian and W. G. Lidman, September 1949

TN 1957 DIRECT METHOD OF DESIGN AND STRESS ANALYSIS OF ROTATING DISCS WITH TEMPERATURE-GRADIENT, S. S. Manson, October 1949

TN 1962 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS. VII - EXPERIMENTAL INVESTIGATION OF CYLINDERS HAVING EITHER LONG BOTTOM CUTOUTS OR SERIES OF SIDE CUTOUTS, N. J. Hoff, Bruno A. Boley, and Joseph J. Mele, October 1949

TN 1963 STRESSES IN AND GENERAL INSTABILITY OF MONOCOQUE CYLINDERS WITH CUTOUTS. VIII - CALCULATION OF THE BUCKLING LOAD OF CYLINDERS WITH LONG SYMMETRIC CUTOUT SUBJECTED TO PURE BENDING, N. J. Hoff, Bruno A. Boley, and Merven W. Mandel, October 1949

TN 2003 INVESTIGATION OF A NACA HIGH-SPEED STRAIN-GAGE TORQUEMETER, John J. Rebeske, Jr., January 1950

TN 2052 EFFECTS OF AN AGING TREATMENT ON LIFE OF SMALL CAST VITALLIUM GAS-TURBINE BLADES, Charles A. Hoffman and Charles Yaker, March 1950

TN 2128 INVESTIGATION OF 75-MILLIMETER-BORE CYLINDRICAL ROLLER BEARINGS AT HIGH SPEEDS. I - INITIAL STUDIES, E. Fred Macks and Zolton N. Nemeth, July 1950

TN 2162 INVESTIGATION OF PROPERTIES OF AISI TYPE 310B ALLOY SHEET AT HIGH TEMPERATURES, E. E. Reynolds, J. W. Freeman, and A. E. White, August 1950

TN 2180 EFFECTIVENESS OF MOLYBDENUM DISULFIDE AS A FRETTING-CORROSION INHIBITOR, Douglas Godfrey and Edmond E. Bisson, September 1950

TN 2187 BONDING INVESTIGATION OF TITANIUM CARBIDE WITH VARIOUS ELEMENTS, Walter J. Engel, September 1950

TN 2198 SINTERING MECHANISM BETWEEN ZIRCONIUM CARBIDE AND COLUMBIUM, H. J. Hamjian and W. G. Lidman, October 1950

TN 2218 DIFFUSION OF CHROMIUM IN A COBALT-CHROMIUM SOLID SOLUTIONS, John W. Weeton, November 1950

TN 2224 MULTIPLE-FILM BACK-REFLECTION CAMERA FOR ATOMIC STRAIN STUDIES, Anthony B. Marmo, November 1950

TN 2232 STRESS AND DISTORTION ANALYSIS OF A SWEPT BOX BEAM HAVING BULKHEADS PERPENDICULAR TO THE SPARS, Richard R. Heldenfels, George W. Zender, and Charles Libove, November 1950

TN 2240 THE EFFECT OF NONUNIFORM TEMPERATURE DISTRIBUTIONS ON THE STRESSES AND DISTORTIONS OF STIFFENED-SHELL STRUCTURES, Richard R. Heldenfels, November 1950

TN 2241 A NUMERICAL METHOD FOR THE STRESS ANALYSIS OF STIFFENED-SHELL STRUCTURES UNDER NONUNIFORM TEMPERATURE DISTRIBUTIONS, Richard R. Heldenfels, November 1950

TN 2269 A STRUCTURAL-EFFICIENCY EVALUATION OF TITANIUM AT NORMAL AND ELEVATED TEMPERATURES, George J. Heimerl and Paul F. Barrett, January 1951

TN 2320 EFFECTS OF SOME SOLUTION TREATMENTS FOLLOWED BY AN AGING TREATMENT ON THE LIFE OF SMALL CASE GAS-TURBINE BLADES OF A COBALT-CHROMIIM-BASE ALLOY. I - EFFECT OF SOLUTION-TREATING TEMPERATURE, C. Yaker and C. A. Hoffman, March 1951

TN 2327 FATIGUE TESTING MACHINE FOR APPLYING A SEQUENCE OF LOADS OF TWO AMPLITUDES, Frank C. Smith, Darnley M. Howard, Ira Smith, and Richard Harwell, March 1951

TN 2329 HIGH-TEMPERATURE PROTECTION OF A TITANIUM-CARBIDE CERAMAL WITH A CERAMIC-METAL COATING HAVING A HIGH CHROMIUM CONTENT, Dwight G. Moore, Stanley G. Benner, and William N. Harrison, March 1951

TN 2342 EVALUATION OF PACKED DISTILLATION COLUMNS. I - ATMOSPHERIC PRESSURE, Thaine W. Reynolds and George H. Sugimura, April 1951

TN 2354 A NUMERICAL APPROACH TO THE INSTABILITY PROBLEMS OF MONOCOQUE CYLINDERS, Bruno A. Boley, Joseph Kempner, and J. Mayers, April 1951

TN 2366 FRICTION AT HIGH SLIDING VELOCITIES OF OXIDE FILMS ON STEEL SURFACES BOUNDARY-LUBRICATED WITH STEARIC-ACID SOLUTIONS, Robert L. Johnson, Marshall B. Peterson and Max A. Swikert, May 1951

TN 2367 GENERAL PLASTIC BEHAVIOR AND APPROXIMATE SOLUTIONS OF ROTATING DISK IN STRAIN-HARDENING RANGE, M. H. Lee Wu, May 1951

TN 2369 TORSION AND TRANSVERSE BENDING OF CANTILEVER PLATES, Eric Reissner and Manuel Stein, June 1951

TN 2376 METHOD FOR ANALYZING INDETERMINATE STRUCTURES STRESSED ABOVE PROPORTIONAL LIMIT, F. R. Steinbacher, C. N. Gaylord and W. K. Rey, June 1951

TN 2377 EFFECT OF FUEL IMMERSION ON LAMINATED PLASTICS, W. A. Crouse, Margie Carickhoff and Margaret A. Fisher, June 1951

TN 2380 EFFECTIVENESS OF CERAMIC COATINGS IN REDUCING CORROSION OF FIVE HEAT-RESISTANT ALLOYS BY LEAD-BROMIDE VAPORS, Dwight G. Moore and Mary W. Mason, June 1951

TN 2385 FUNDAMENTAL AGING EFFECTS INFLUENCING HIGH-TEMPERATURE PROPERTIES OF SOLUTION-TREATED INCONEL X, D. N. Frey, J. W. Freeman, and A. E. White, June 1951

TN 2386 STUDIES OF HIGH-TEMPERATURE PROTECTION OF A TITANIUM-CARBIDE CERAMAL BY CHROMIUM-TYPE CERAMIC-METAL COATINGS, Dwight G. Moore, Stanley G. Benner, and William N. Harrison, June 1951

TN 2397 INFLUENCE OF TENSILE STRENGTH AND DUCTILITY ON STRENGTHS OF ROTATING DISKS IN PRESENCE OF MATERIAL AND FABRICATION DEFECTS OF SEVERAL TYPES, Arthur G. Holms, Joseph E. Jenkins, and Andrew J. Repko, June 1951

TN 2420 INVESTIGATION OF 75 MILLIMETER-BORE CYLINDRICAL-ROLLER BEARINGS AT HIGH SPEEDS. III - LUBRICATION AND COOLING STUDIES - OIL INLET DISTRIBUTION, OIL INLET TEMPERATURE, AND GENERALIZED SINGLE-OIL-JET COOLING-CORRELATION ANALYSIS, E. Fred Macks and Zolton N. Nemeth, July 1951

TN 2422 STUDY OF CHROMIUM-FRIT-TYPE COATINGS FOR HIGH-TEMPERATURE PROTECTION OF MOLYBDENUM, D. G. Moore, L. H. Bolz, J. W. Pitts, and W. N. Harrison, July 1951

TN 2433 A CRITICAL REVIEW OF NOTCH SENSITIVITY IN STRESS-RUPTURE TESTS, W. F. Brown, Jr., and George Sachs, August 1951

TN 2434 A BIHARMONIC RELAXATION METHOD FOR CALCULATING THERMAL STRESS IN COOLED IRREGULAR CYLINDERS, Arthur G. Holms, August 1951

TN 2439 A THEORY OF CONDUCTIVITY OF COLD-WORKED COPPER, Rolf Landaner, September 1951

TN 2442 A PHOTOELASTIC INVESTIGATION OF STRESS CONCENTRATIONS DUE TO SMALL FILLETS AND GROOVES IN TENSION, M. M. Frocht, August 1951

TN 2444 EFFECT OF STRESS-SOLVENT CRAZING ON TENSILE STRENGTH OF POLY-METHYL METHACRYLATE, B. M. Axilrod and Martha A. Sherman, August 1951

TN 2447 STATISTICAL FLUCTUATION OF INTENSITY IN DEBYE-SCHERRER LINES DUE TO RANDOM ORIENTATION OF CRYSTAL GRAINS, Hans Ekstein, August 1951

TN 2448 X-RAY DIFFRACTION BY BENT CRYSTAL LAMELLAE, Hans Ekstein, September 1951

TN 2449 INVESTIGATION OF INFLUENCE OF CHEMICAL COMPOSITION OF FORGED MODIFIED LOW-CARBON N-155 ALLOYS IN SOLUTION-TREATED AND AGED CONDITION AS RELATED TO RUPTURE PROPERTIES AT 1200° F, E. E. Reynolds, J. W. Freeman, and A. E. White, September 1951

TN 2460 FORMATION OF SULFIDE FILMS ON STEEL AND EFFECT OF SUCH FILMS ON STATIC FRICTION, Erva C. Levine and Marshall B. Peterson, September 1951

TN 2469 RUPTURE PROPERTIES OF LOW-CARBON N-155 TYPE ALLOYS MADE WITH A COLUMBIUM-TANTALUM FERRO-ALLOY, J. W. Freeman, E. E. Reynolds, and A. E. White, October 1951

TN 2472 FUNDAMENTAL EFFECTS OF COLD-WORKING ON CREEP PROPERTIES OF LOW-CARBON N-155 ALLOY, D. N. Frey, J. W. Freeman, and A. E. White, October 1951

TN 2491 KINETICS OF SINTERING CHROMIIM CARBIDE, W. G. Lidman and H. J. Hamjian, August 1951

TN 2507 EXPERIMENTAL INVESTIGATION OF OIL FILM PRESSURE DISTRIBUTION FOR MISALINED PLAIN BEARINGS, G. B. DuBois, H. H. Mabie, and F. W. Ocvirk, October 1951

TN 2513 EFFECTS OF SOME SOLUTION TREATMENTS FOLLOWED BY AN AGING TREATMENT ON THE LIFE OF SMALL CAST GAS-TURBINE BLADES OF A COBALT-CHROMIUM-BASE ALLOY. II - EFFECT OF SELECTED COMBINATIONS OF SOAKING TIME, TEMPERATURE, AND COOLING RATE, C. A. Hoffman and C. F. Robards, October 1951

TN 2523 RETROGENERATIVE DETECTION OF CORROSION CURRENTS, Joseph P. McAndrew, William H. Colner, and Howard T. Francis, November 1951

TN 2532 X-RAY DIFFRACTION STUDY OF THE INTERNAL STRUCTURE OF SUPER-COOLED WATER, Robert G. Dorsch and Bemrose Boyd, October 1951

TN 2544 GYRODYNAMIC LUBRICATION OF CYCLICALLY LOADED BEARINGS, R. W. Dayton and E. M. Simons, November 1951

TN 2545 DISCREPANCIES BETWEEN THEORETICAL AND OBSERVED BEHAVIOR OF CYCLICALLY LOADED BEARINGS, R. W. Dayton, E. M. Simons, and F. A. Fend, November 1951

TN 2561 A STUDY OF POISSON'S RATIO IN THE YIELD REGION, George Gerard and Sorrel Wildhorn, January 1952

TN 2574 THEORETICAL ANALYSIS OF SOME SIMPLE TYPES OF ACCELERATION RESTRICTORS, William H. Phillips, December 1951

TN 2586 FUNDAMENTAL EFFECTS OF COLL-WORK ON SOME COBALT CHROMIUM NICKEL IRON BASE CREEP RESISTANT ALLOYS, D. N. Frey, J. W. Freeman, and A. E. White, January 1952

TN 2602 SURVEY OF THE CHROMIUM COBALT NICKEL PHASE DIAGRAM AT 1200° C, W. D. Manly and Paul A. Beck, February 1952

TN 2603 SURVEY OF PORTIONS OF THE COBALT CHROMIUM IRON NICKEL QUATERNARY SYSTEM, E. L. Kamen and Paul A. Beck, February 1952

TN 2617 RELATIVE IMPORTANCE OF VARIOUS SOURCES OF DEFECT PRODUCING HYDROGEN INTRODUCED INTO STEEL DURING APPLICATION OF VITREOUS COATINGS, Dwight G. Moore, Mary A. Mason, and William N. Harrison, February 1952

TN 2618 CREEP IN METALS, A. D. Schwope, F. R. Shaber and L. R. Jackson, February 1952

TN 2628 BONDING OF MOLYBDENUM DISULFIDE TO VARIOUS MATERIALS TO FORM A SOLID LUBRICATING FILM. I - THE BONDING MECHANISM, Douglas Godfrey and Edmond E. Bisson, February 1952

TN 2632 CORROSION OF MAGNESIUM ALLOY ZK60A IN MARINE ATMOSPHERE AND TIDE-WATER, Fred M. Reinhart, February 1952

TN 2636 INFLUENCE OF LUBRICANT VISCOSITY ON OPERATING TEMPERATURES OF 75-MM BORE CYLINDRICAL ROLLER BEARING AT HIGH SPEEDS, E. Fred Macks, William J. Anderson, and Zolton N. Nemeth, February 1952

TN 2639 FATIGUE STRENGTHS OF AIRCRAFT MATERIALS AXIAL LOAD FATIGUE TESTS ON NOTCHED SHEET SPECIMENS OF 24S-T3 AND 75S-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL WITH STRESS CONCENTRATION FACTOR OF 1.5, H. J. Grover, W. A. Hyler, and L. R. Jackson, February 1952

TN 2678 ABNORMAL GRAIN GROWTH IN S-816 ALLOY, A. I. Rush, J. W. Freeman, and A. E. White, April 1952

TN 2683 SURVEY OF PORTIONS OF THE CHROMIUM COBALT NICKEL MOLYBDENUM QUATERNARY SYSTEM AT 1200° C, Sheldon Paul Rideout and Paul A. Beck, April 1952

TN 2695 MIGRATION OF COBALT DURING FIRING OF GROUND COAT ENAMELS ON IRON, William N. Harrison, Joseph C. Richmond, Joseph W. Pitts, and Stanley G. Benner, June 1952

TN 2696 A FUNDAMENTAL STUDY OF THE MECHANISM BY WHICH HYDROGEN ENTERS METALS DURING CHEMICAL AND ELECTROCHEMICAL PROCESSING, L. D. McGraw, C. A. Snavely, H. L. Moore, P. T. Woodberry, and C. L. Fraust, April 1952

TN 2704 FATIGUE STRENGTHS OF 14S-T4 ALUMINUM ALLOY SUBJECTED TO BIAXIAL TENSILE STRESSES, Joseph Marin and W. P. Hughes, June 1952

TN 2709 FATIGUE AND STATIC TESTS OF FLUSH RIVETED JOINTS, Darnley M. Howard and Frank C. Smith, June 1952

TN 2716 EFFECT OF OPEN CIRCULAR HOLES ON TENSILE STRENGTH AND ELONGATION OF SHEET SPECIMENS OF A MAGNESIUM ALLOY, R. S. Barker, June 1952

TN 2717 EFFECT OF TEMPERATURES FROM -70° TO 600° F ON STRENGTH OF ADHESIVE BONDED LAP SHEAR SPECIMENS OF CLAD 24S-T3 ALUMINUM ALLOY AND OF COTTON AND GLASS FABRIC PLASTIC LAMINATES, H. W. Eicner, W. Z. Olson, and R. F. Blomquist, June 1952

TN 2719 INVESTIGATION OF STATISTICAL NATURE OF FATIGUE PROPERTIES, E. Epremian and R. F. Mehl, June 1952

TN 2731 INFLUENCE OF STRUCTURE ON PROPERTIES OF SINTERED CHROMIUM CARBIDE, H. J. Hamjian and W. G. Lidman, June 1952

TN 2745 INFLUENCE OF CHEMICAL COMPOSITION ON RUPTURE TEST PROPERTIES AT 1500° F OF FORCED CHROMIUM COBALT NICKEL IRON BASE ALLOYS, J. W. Frèeman, J. F. Ewing, and A. E. White, July 1952

TN 2746 PREVIEW OF BEHAVIOR OF GRAIN BOUNDARIES IN CREEP OF ALUMINUM BICRYSTALS, F. N. Rhines and A. W. Cochardt, July 1952

TN 2754 A METHOD OF SELECTING THE THICKNESS, HOLLOWNESS, AND SIZE OF A SUPERSONIC WING FOR LEAST DRAG AND SUFFICIENT BENDING STRENGTH AT SPECIFIED FLIGHT CONDITIONS, James L. Amick, July 1952

TN 2758 WEAR AND SLIDING FRICTION PROPERTIES OF NICKEL ALLOYS SUITED FOR GAGES OF HIGH TEMPERATURE ROLLING CONTACT BEARINGS. I - ALLOYS RETAINING MECHANICAL PROPERTIES TO 600° F, Robert L. Johnson, Max A. Swikert, and Edmond E. Bisson, August 1952

TN 2759 WEAR AND SLIDING FRICTION PROPERTIES OF NICKEL ALLOYS SUITED FOR GAGES OF HIGH TEMPERATURE ROLLING CONTACT BEARINGS. II - ALLOYS RETAINING MECHANICAL PROPERTIES ABOVE 600° F, Robert L. Johnson, Max. A. Swikert, and Edmond E. Bisson, August 1952

TN 2769 EXPERIMENTAL AND THEORETICAL DETERMINATION OF THERMAL STRESSES IN A FLAT PLATE, Richard R. Heldenfels and William M. Roberts, August 1952

TN 2771 THERMAL BUCKLING OF PLATES, Myron L. Gossard, Paul Seide, and William M. Roberts, August 1952

TN 2777 THEORETICAL DISTRIBUTION OF SLIP ANGLES IN AN AGGREGATE OF FACE-CENTERED CUBIC CRYSTALS, John M. Hedgepeth, August 1952

TN 2778 STRESS AND STRAIN AT ONSET OF CRAZING OF POLYMETHYL METHACYLATE AT VARIOUS TEMPERATURES, M. A. Sherman and B. M. Axilrod, September 1952

TN 2779 EFFECTS OF MODERATE BIAXIAL STRETCH FORMING ON TENSILE AND CRAZING PROPERTIES OF ACRYLIC PLASTIC GLAZING, B. M. Axilrod, M. A. Sherman, V. Cohen, and I. Wolock, October 1952

TN 2788 EFFECT OF SOLVENTS IN IMPROVING BOUNDARY LUBRICATION OF STEEL BY SILICONES, S. F. Murray and Robert L. Johnson, September 1952

TN 2791 CORRELATION OF TENSILE STRENGTH, TENSILE DUCTILITY, AND NOTCH TENSILE STRENGTH OF ROTATING DISKS OF SEVERAL DESIGNS IN THE RANGE OF LOW AND INTERMEDIATE DUCTILITY, Arthur G. Holms and Andrew J. Repko, September 1952

TN 2798 AN EXPERIMENTAL INVESTIGATION OF THE BEHAVIOR OF 24S-T4 ALUMINUM ALLOY SUBJECTED TO REPEATED STRESSES OF CONSTANT AND VARYING AMPLITUDES, Herbert F. Hardrath and Elmer C. Utley, Jr., October 1952

TN 2802 BONDING OF MOLYBDENUM DISULFIDE TO VARIOUS MATERIALS TO FORM A SOLID LUBRICATING FILM. II - FRICTION AND ENDURANCE CHARACTERISTICS OF FILMS BONDED BY PRACTICAL METHODS, Douglas Godfrey and Edmond E. Bisson, October 1952

TN 2803 A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF TEMPERATURE GRADIENTS ON THE DEFORMATION AND BURST SPEEDS OF ROTATING DISCS, P. J. Wilterdink, A. G. Holms, and S. S. Mason, October 1952

TN 2805 AN ENGINEERING METHOD FOR ESTIMATING NOTCH SIZE EFFECT IN FATIGUE TESTS ON STEEL, Paul Kuhn and Herbert F. Hardrath, October 1952

TN 2808 SHORT BEARING APPROXIMATION FOR FULL JOURNAL BEARINGS, F. W. Ocvirk, October 1952

TN 2809 EXPERIMENTAL INVESTIGATION OF ECCENTRICITY RATIO, FRICTION, AND OIL FLOW OF SHORT JOURNAL BEARINGS, G. B. DuBois and F. W. Ocvirk, November 1952

TN 2822 A SPECIAL INVESTIGATION TO DEVELOP A GENERAL METHOD FOR THREE DIMENSIONAL PHOTOELASTIC STRESS ANALYSIS, M. M. Frocht and R. Guernsey, Jr., December 1952

TN 2838 CALORIMETIC DETERMINATION OF CONSTANT PRESSURE SPECIFIC HEATS OF CARBON DIOXIDE AT ELEVATED PRESSURES AND TEMPERATURES, Virgil E. Schrock, December 1952

TN 2841 INVESTIGATION OF 75-MILLIMETER BORE DEEP GROOVE BALL BEARINGS UNDER RADIAL LOAD AT HIGH SPEEDS. I - OIL-FLOW STUDIES, Zolton N. Nemeth, E. Fred Machs, and William J. Anderson, December 1952

TN 2842 THE PLANNING CHARACTERISTICS OF SURFACE HAVING A BASIC ANGLE OF DEAD RISE OF 40^{o} AND HORIZONTAL CHINE FLARE, Ulysse J. Blanchard, December 1952

TN 2846 EFFECTIVE LUBRICATION RANGE FOR STEEL SURFACES BOUNDARY LUBRICATED AT HIGH SLIDING VELOCITIES BY VARIOUS CLASSES OF SYNTHETIC FLUIDS, Robert L. Johnson, Max A. Swikert, and Edmond E. Bisson, December 1952

TN 2862 INFLUENCE OF NONMARTENSITIC TRANSFORMATION PRODUCTS ON MECHANICAL PROPERTIES OF TEMPERED NARTENSITE, J. M. Hodge and W. T. Lankford, December 1952

TN 2865 INVESTIGATION OF GASES EVOLVED DURING FIRING OF VITREOUS COATING ON STEEL, Dwight G. Moore and Mary A. Mason, January 1953

TN 2876 THE PLANING CHARACTERISTICS OF TWO V-SHAPED PRISMATIC SURFACES HAVING ANGLES OF DEAD RISE OF 20^{o} AND 40^{o}, Derrill B. Chambliss and George M. Boyd, Jr., January 1953

TN 2883 BEARING STRENGTHS OF SOME 75S-T6 AND 14S-T6 ALUMINUM ALLOY HAND FORGINGS, E. M. Finley, January 1953

TN 2890 A LINEAR TIME TEMPERATURE RELATION FOR EXTRAPOLATION OF CREEP AND STRESS RUPTURE DATA, S. S. Manson and A. M. Haferd, March 1953

TN 2896 SURVEY OF PORTIONS OF THE IRON-NICKEL-MOLYBDENUM AND COBALT-IRON-MOLYBDENUM TERNARY SYSTEMS AT 1200^{o} C, Dilip K. Das and Paul A. Beck, February 1953

TN 2924 COMBINED STRESS FATIGUE STRENGTH OF 76S-T61 ALUMINUM ALLOY WITH SUPERIMPOSED MEAN STRESSES AND CORRECTIONS FOR YIELDING, William N. Findley, May 1953

TN 2928 AXIAL LOAD FATIGUE PROPERTIES OF 24S-T AND 75S-T ALUMINUM ALLOY AS DETERMINED IN SEVERAL LABORATORIES, H. J. Grover, W. S. Hyler, Paul Kuhn, Charles B. Landers, May 1953

TN 2933 BEHAVIOR OF MATERIALS UNDER CONDITIONS OF THERMAL STRESS, S. S. Manson, July 1953

TN 2934 RELATION BETWEEN ROUGHNESS OF INTERFACE AND ADHERENCE OF PORCELAIN ENAMEL TO STEEL, J. C. Richmond, D. G. Moore, H. B. Kirkpatrick, and W. N. Harrison, April 1953

TN 2935 THE GALVANIC CORROSION THEORY FOR ADHERENCE OF PORCELAIN ENAMEL GROUND COATS TO STEEL, D. G. Moore, J. W. Pitts, J. C. Richmond, and W. N. Harrison, June 1953

TN 2945 THE CREEP OF SINGLE CRYSTALS OF ALUMINUM, R. D. Johnson, F. R. Shober, and A. D. Schwope, May 1953

TN 2973 EFFECT OF PRESTRAINING ON RECRYSTALLIZATION TEMPERATURE AND MECHANICAL PROPERTIES OF COMMERCIAL, SINTERED, WROUGHT MOLYBDENUM, Kenneth C. Dike and Roger A. Long, July 1953

TN 3001 COMPARISON OF OPERATING CHARACTERISTICS OF FOUR EXPERIMENTAL AND TWO CONVENTIONAL 75-MILLIMETER-BORE CYLINDRICAL-ROLLER BEARINGS AT HIGH SPEEDS, William J. Anderson, E. Fred Macks and Zolton N. Nemeth, September 1953

TN 3002 EFFECT OF BRONZE AND NODULAR IRON GAGE MATERIALS ON GAGE SLIP AND OTHER PERFORMANCE CHARACTERISTICS OF 75-MILLIMETER-BORE CYLINDRICAL ROLLER BEARINGS AT DN VALUES TO 2×10^6, William J. Anderson, E. Fred Macks and Zolton N. Nemeth, September 1953

TN 3003 INVESTIGATION OF 75-MILLIMETER-BORE DEEP-GROOVE BALL BEARINGS UNDER RADIAL LOAD AT HIGH SPEEDS. II - OIL INLET TEMPERATURE, VISCOSITY, AND GENERALIZED COOLING CORRELATION, William J. Anderson, E. Fred Macks and Zolton N. Nemeth, September 1953

TN 3006 CORRELATION OF CALCULATION AND FLIGHT STUDIES OF THE EFFECT OF WING FLEXIBILITY ON STRUCTURAL RESPONSE DUE TO GUSTS, John C. Houbolt, August 1953

TN 3011 COEFFICIENT OF FRICTION AND DAMAGE TO CONTACT AREA DURING THE EARLY STAGES OF FRETTING. I - GLASS, COPPER, OR STEEL AGAINST COPPER, Douglas Godfrey and John M. Bailey, September 1953

TN 3017 AXIAL-LOAD FATIGUE TESTS ON NOTCHED AND UNNOTCHED SHEET SPECIMENS OF 61S-T6 ALUMINUM ALLOY, ANNEALED 347 STAINLESS STEEL AND HEAT-TREATED 403 STAINLESS STEEL, Herbert F. Hardrath, Charles B. Landers and Elmer C. Utley, Jr., October 1953

TN 3043 APPLICATION OF SILVER CHLORIDE IN INVESTIGATIONS OF ELASTO-PLASTIC STATES OF STRESS, L. E. Goodman and J. G. Sutherland, November 1953

TN 3055 FRICTION AND WEAR INVESTIGATION OF MOLYBDENUM DISULFIDE. I - EFFECT OF MOISTURE, Marshal B. Peterson and Robert L. Johnson, December 1953

TN 3074 A PRELIMINARY INVESTIGATION OF THE EFFECTS OF GUSTY AIR ON HELICOPTER-BLADE BENDING MOMENTS, Joseph W. Jewel, Jr. and Paul J. Carpenter, March 1954

TN 3084 A METHOD FOR MEASURING THE PRODUCT OF INERTIA AND THE INCLINATION OF THE PRINCIPAL LONGITUDINAL AXIS OF INERTIA OF AN AIRPLANE, Robert W. Boucher, Drexel A. Rich, Harold L. Crane and Cloyce E. Matheny, April 1954

TN 3085 AN EXPERIMENTAL STUDY OF POROSITY CHARACTERISTICS OF PERFORATED MATERIALS IN NORMAL AND PARALLEL FLOW, George M. Stokes, Don D. Davis, Jr. and Thomas B. Sellers, April 1954

TN 3107 EFFECT OF HEAT TREATMENT UPON THE MICROSTRUCTURE AND HARDNESS OF A WROUGHT COBALT-BASE ALLOY STELLITE 21 (AMS5385), F. J. Clauss and J. W. Weeton, March 1954

TN 3108 RELATION OF MICROSTRUCTURE TO HIGH-TEMPERATURE PROPERTIES OF A WROUGHT COBALT-BASE ALLOY STELLITE 21 (AMS 5385), F. J. Clauss and J. W. Weeton, March 1954

TN 3109 AN INVESTIGATION OF LAMELLAR STRUCTURES AND MINOR PHASES IN ELEVEN COBALT-BASE ALLOYS BEFORE AND AFTER HEAT TREATMENT, J. W. Weeton and R. A. Signorelli, March 1954

TN 3110 TRENDS OF ROLLING-CONTACT BEARINGS AS APPLIED TO AIRCRAFT GAS-TURBINE ENGINES, Daniel Gurney, C. M. Michaels, Stephen Drabek, Frank W. Wellons, Robert L. Johnson, Max A. Swikert, Edmond E. Bisson, E. F. Macks, April 1954

TN 3111 FRICTION AND WEAR INVESTIGATION OF MOLYBDENUM DISULFIDE. II - EFFECTS OF CONTAMINANTS AND METHOD OF APPLICATION, Marshal B. Peterson and Robert L. Johnson, March 1954

TN 3114 ANALYSIS OF MULTICELL DELTA WINGS ON CAL-TECH ANALOG COMPUTER, Richard H. MacNeal and Stanley V. Benscoter, December 1953

TN 3115 ANALYSIS OF SWEPTBACK WINGS ON CAL-TECH ANALOG COMPUTER, Richard H. MacNeal and Stanley V. Benscoter, January 1954

TN 3117 LUBRICANTS OF REDUCED FLAMMABILITY, Charles E. Frank, Donald E. Swarts and Kenneth T. Mecklenborg, January 1954

TN 3119 STATIC PROPERTIES AND RESISTANCE CHARACTERISTICS OF A FAMILY OF SEAPLANE HULLS HAVING VARYING LENGTH-BEAM RATIO, Arthur W. Carter and David R. Woodward, January 1954

TN 3132 FATIGUE STRESSES PRODUCING FAILURE IN 2 TO 10,000 CYCLES 24S-T3 AND 75S-T6 ALUMINUM-ALLOY SHEET SPECIMENS WITH A THEORETICAL STRESS-CONCENTRATION FACTOR OF 4.0 SUBJECTED TO COMPLETELY REVERSED AXIAL LOAD, Herbert F. Hardrath and Walter Illg, January 1954

TN 3154 INFRARED SPECTRA OF 47 DICYCLIC HYDROCARBONS, John F. Lamneck, Jr., Harold F. Hipsher and Virginia O. Fenn, June 1954

TN 3164 FURTHER STUDIES OF THE MECHANISM BY WHICH HYDROGEN ENTERS METALS DURING CHEMICAL AND ELECTROCHEMICAL PROCESSING, L. D. McGraw, W. E. Ditmars, C. A. Snavely and C. L. Faust, March 1954

TN 3195 TIME-TEMPERATURE PARAMETERS AND AN APPLICATION TO RUPTURE AND CREEP OF ALUMINUM ALLOYS, George J. Heimerl, June 1954

TN 3197 MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF FOUR CERMETS OF TITANIUM CARBIDE WITH NICKEL BINDER, Aldie E. Johnson, Jr., August 1954

TN 3203 CONSIDERATIONS ON A LARGE HYDRAULIC JET CATAPULT, Upshur T. Joyner and Walter B. Horne, July 1954

TN 3204 AN INVESTIGATION OF THE CREEP LIFETIME OF 75S-T6 ALUMINUM-ALLOY COLUMNS, Eldon E. Mathauser and William A. Brooks, Jr., July 1954

TN 3206 TORSIONAL VIBRATIONS OF HOLLOW THIN-WALLED CYLINDRICAL BEAMS, Edwin T. Kruszewski and Eldon E. Kordes, August 1954

TN 3207 ROLE OF NICKEL DIP IN ENAMELING OF SHEET STEEL, D. G. Moore, J. W. Pitts and W. N. Harrison, June 1954

TN 3209 HIGH-RESOLUTION AUTORADIOGRAPHY, George C. Towe, Henry J. Gomberg and J. W. Freeman, July 1954

TN 3211 STATISTICAL STUDY OF OVERSTRESSING IN STEEL, G. E. Dieter, G. T. Horne and R. F. Mehl, April 1954

TN 3212 A NONLINEAR THEORY OF BENDING AND BUCKLING OF THIN ELASTIC SHALLOW SPHERICAL SHELLS, A. Kaplan and Y. C. Fung, August 1954

TN 3214 FUNDAMENTAL STUDY OF EROSION CAUSED BY STEEP PRESSURE WAVES, B. G. Rightmire and J. M. Bonneville, June 1954

TN 3216 COOPERATIVE INVESTIGATION OF RELATIONSHIP BETWEEN STATIC AND FATIGUE PROPERTIES OF WROUGHT N-155 ALLOY AT ELEVATED TEMPERATURES, NASA Subcommittee on Heat-Resisting Materials, April 1955

TN 3221 STUDY OF THE SUBSONIC FORCES AND MOMENTS ON AN INCLINED PLATE OF INFINITE SPAN, Bradford H. Wick, June 1954

TN 3233 A REVIEW OF PLANING THEORY AND EXPERIMENT WITH A THEORETICAL STUDY OF PURE-PLANING LIFT OF RECTANGULAR FLAT PLATES, Charles L. Shuford, Jr., August 1954

TN 3257 EFFECTS OF CHEMICALLY ACTIVE ADDITIVES ON BOUNDARY LUBRICATION OF STEEL BY SILICONES, S. F. Murray and Robert L. Johnson, August 1954

TN 3259 INVESTIGATION OF NICKEL-ALUMINUM ALLOYS CONTAINING FROM 14 TO 34 PERCENT ALUMINUM, W. A. Maxwell and E. M. Grala, August 1954

TN 3268 SHEARING-STRESS MEASUREMENTS BY USE OF A HEATED ELEMENT, H. W. Liepmann and G. T. Skinner, November 1954

TN 3279 EFFECT OF PHOSPHATE COATINGS ON TEMPERATURE OF METAL PARTS EXPOSED TO FLAME ENVIRONMENTS, George C. Fryburg, Norman H. Katz, and Sidney L. Simon, July 1956

TN 3280 ELECTRICAL ANALOGIES FOR STIFFENED SHELLS WITH FLEXIBLE RINGS, R. H. MacNeal, December 1954

TN 3281 INTERGRANULAR CORROSION OF HIGH-PURITY ALUMINUM IN HYDROCHLORIC ACID. I - EFFECTS OF HEAT TREATMENT, IRON CONTENT, AND ACID COMPOSITION, M. Metzger and J. Intratter, February 1955

TN 3282 INTERGRANULAR CORROSION OF HIGH-PURITY ALUMINUM IN HYDROCHLORIC ACID. II - GRAIN-BOUNDARY SEGREGATION OF IMPURITY ATOMS, M. Metzger and J. Intrater, April 1955

TN 3286 GENERALIZED INDICIAL FORCES ON DEFORMING RECTANGULAR WINGS IN SUPERSONIC FLIGHT, Harvard Lomax, Franklyn B. Fuller and Loma Sluder, November 1954

TN 3291 EXPERIMENTAL INVESTIGATION OF NOTCH-SIZE EFFECTS ON ROTATING-BEAM FATIGUE BEHAVIOR OF 75S-T6 ALUMINUM ALLOY, W. S. Hyler, R. A. Lewis and H. J. Grover, November 1954

TN 3292 INFLUENCE OF EXPOSED AREA ON STRESS-CORROSION CRACKING OF 24S ALUMINUM ALLOY, William H. Colner and Howard T. Francis, November 1954

TN 3293 CUMULATIVE FATIGUE DAMAGE OF AXIALLY LOADED ALCLAD 75S-T6 AND ALCLAD 24S-T3 ALUMINUM-ALLOY SHEET, Ira Smith, Darnley M. Howard, and Frank C. Smith, September 1955

TN 3295 EFFECT OF PRESSURE ON THERMAL CONDUCTANCE OF CONTACT JOINTS, Martin E. Barzelay, Kin Tee Tong and George F. Holloway, May 1955

TN 3297 EFFECT OF OXYGEN CONTENT OF THE ATMOSPHERE ON ADHERENCE OF VITREOUS COATINGS TO IRON, A. G. Eubanks and D. G. Moore, May 1955

TN 3305 SOME MEASUREMENTS AND POWER SPECTRA RUNWAY ROUGHNESS, James H. Walls, John C. Houbolt and Harry Press, November 1954

TN 3309 MECHANICAL PROPERTIES AT ROOM TEMPERATURE OF FOUR CERMETS OF TUNGSTEN CARBIDE WITH COBALT BINDER, Aldie E. Johnson, Jr., December 1954

TN 3310 INVESTIGATION OF STATIC STRENGTH AND CREEP BEHAVIOR OF AN ALUMINUM - ALLOY MULTIWEB BOX BEAM AT ELEVATED TEMPERATURES, Eldon E. Mathauser, November 1954

TN 3315 TENSILE AND COMPRESSIVE STRESS-STRAIN PROPERTIES OF SOME HIGH-STRENGTH SHEET ALLOYS AT ELEVATED TEMPERATURES, Philip J. Huges, John E. Inge and Stanley B. Prosser, November 1954

TN 3333 CORROSION OF METALS OF CONSTRUCTION BY ALTERNATE EXPOSURE TO LIQUID AND GASEOUS FLUORINE, Richard M. Gundzik and Charles E. Feiler, December 1954

TN 3351 PLASTIC DEFORMATION OF ALUMINUM SINGLE CRYSTALS AT ELEVATED TEMPERATURES, R. D. Johnson, A. P. Young, and A. D. Schwope, April 1955

TN 3352 EXPERIMENTAL INVESTIGATION OF MISALINING COUPLES AND ECCENTRICITY AT ENDS OF MISALINED PLAIN BEARINGS, G. B. DuBois, F. W. Ocvirk and R. L. Wehe, February 1955

TN 3380 STUDY OF EFFECTS OF MICROSTRUCTURE AND ANISOTROPY ON FATIGUE OF 24S-T4 ALUMINUM ALLOY, H. A. Lipsitt, G. E. Dieter, G. T. Horne and R. F. Mehl, March 1955

TN 3386 SOME CONSIDERATIONS ON TWO-DIMENSIONAL THIN AIRFOILS DEFORMING IN SUPERSONIC FLOW, Eugene Migotsky, January 1955

TN 3402 BOUNDARY LUBRICATION OF STEEL WITH FLUORINE- AND CHLORINE-SUBSTITUTED METHANE AND ETHANE GASES, S. F. Murray, Robert L. Johnson, and Max A. Swikert, February 1955

TN 3409 CHAIN BREAKING AND BRANCHING IN THE ACTIVE-PARTICLE DIFFUSION CONCEPT OF QUENCHING, Frank E. Belles and A. L. Berlad, February 1955

TN 3412 CREEP AND CREEP-RUPTURE CHARACTERISTICS OF SOME RIVETED AND SPOT-WELDED LAP JOINTS OF AIRCRAFT MATERIALS, Leonard Mordfin, June 1955

TN 3413 INVESTIGATION OF THE USE OF A RUBBER ANALOG IN THE STUDY OF STRESS DISTRIBUTION IN RIVETED AND CEMENTED JOINTS, Louis R. Demarkles, November 1955

TN 3414 INFLUENCE OF TEMPERATURE ON CREEP, STRESS-RUPTURE, AND STATIC PROPERTIES OF MELAMINE-RESIN AND SILICONE-RESIN GLASS-FABRIC LAMINATES, William N. Findley, Harlan W. Peithman, and Will J. Worley, January 1956

TN 3415 A UNIVERSAL COLUMN FORMULA FOR LOAD AT WHICH YIELDING STARTS, L. H. Donnell and V. C. Tsien, October 1955

TN 3423 METHOD OF CONTROLLING STIFFNESS PROPERTIES OF A SOLID-CONSTRUCTION MODEL WING, Norman S. Land and Frank T. Abbott, Jr., April 1955

TN 3443 SHEARING EFFECTIVENESS OF INTEGRAL STIFFENING, Robert F. Crawford and Charles Libove, June 1955

TN 3444 FRICTION, WEAR, AND SURFACE DAMAGE OF METALS AS AFFECTED BY SOLID SURFACE FILMS, Edmond E. Bisson, Robert L. Johnson, Max A. Swikert and Douglas Godfrey, May 1955

TN 3450 PRELIMINARY INVESTIGATION OF PROPERTIES OF HIGH-TEMPERATURE BRAZED JOINTS PROCESSED IN VACUUM OR IN MOLTEN SALT, C. A. Gyorgak and A. C. Francisco, May 1955

TN 3459 SIMPLIFIED PROCEDURES AND CHARTS FOR THE RAPID ESTIMATION OF BENDING FREQUENCIES OF ROTATING BEAMS, Robert T. Yntema, June 1955

TN 3462 TENSILE PROPERTIES OF 7075-T6 AND 2024-T3 ALUMINUM-ALLOY SHEET HEATED AT UNIFORM TEMPERATURE RATES UNDER CONSTANT LOAD, George J. Heimerl and John E. Inge, July 1955

TN 3463 INVESTIGATION OF THE VIBRATIONS OF A HOLLOW THIN-WALLED RECTANGULAR BEAM, Eldon E. Kordes and Edwin T. Kruzewski, October 1955

TN 3473 RAPID RADIANT-HEATING TESTS OF MULTIWEB BEAMS, Joseph N. Kotanchik, Adie E. Johnson, Jr., and Robert D. Ross, September 1955

TN 3493 DEVELOPMENT OF EQUIPMENT AND OF EXPERIMENTAL TECHNIQUES FOR COLUMN CREEP TESTS, Sharad A. Patel, Martin Bloom, Burton Erickson, Alexander Chwick and Nicholas John Hoff, September 1955

TN 3514 RESPONSE OF HOMOGENEOUS AND TWO-MATERIAL LAMINATED CYLINDERS TO SINUSOIDAL ENVIRONMENTAL TEMPERATURE CHANGE, WITH APPLICATIONS TO HOT-WIRE ANEMOMETRY AND THERMOCOUPLE PYROMETRY, Herman H. Lowell and Norman A. Patton, September 1955

TN 3542 ANALYSIS OF STRESSES IN THE PLASTIC RANGE AROUND A CIRCULAR HOLE IN A PLATE SUBJECTED TO UNIAXIAL TENSION, Bernard Budiansky and Robert J. Vidensek, October 1955

TN 3544 COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL STRESSES IN CIRCULAR SEMI-MONOCOQUE CYLINDERS WITH RECTANGULAR CUTOUTS, Harvey G. McComb, Jr., and Emmet F. Low, Jr., October 1955

TN 3552 INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP LIFETIME OF 2024-T3 ALUMINUM-ALLOY PLATES AT ELEVATED TEMPERATURES, Eldon E. Mathauser and William D. Deveikis, January 1956

TN 3553 COMPRESSIVE CRIPPLING OF STRUCTURAL SECTIONS, Melvin S. Anderson, January 1956

TN 3556 GRAIN-BOUNDARY BEHAVIOR IN CREEP OF ALUMINUM BICRYSTALS, F. N. Rhines, W. E. Bond, and M. A. Kissel, December 1955

TN 3577 THE NICKEL DIP: A RADIOISOTOPE STUDY OF METALLIC DEPOSITS IN PORCELAIN ENAMELING, Joseph C. Richmond, Harry B. Kirkpatrick and William N. Harrison, February 1956

TN 3578 INFLUENCE OF LARGE AMPLITUDES ON FLEXURAL MOTIONS OF ELASTIC PLATES, George Herman, May 1956

TN 3595 WEAR OF TYPICAL CARBON-BASE SLIDING SEAL MATERIALS AT TEMPERATURES TO 700° F, Robert L. Johnson, Max A. Swikert and John M. Bailey, February 1956

TN 3596 ON THE PERMEABILITY OF POROUS MATERIALS, E. Carson Yates, Jr., January 1956

TN 3600 CORRELATION OF CRIPPLING STRENGTH OF PLATE STRUCTURES WITH MATERIAL PROPERTIES, Roger A. Anderson and Melvin S. Anderson, January 1956

TN 3631 RESULTS OF AXIAL-LOAD FATIGUE TESTS ON ELECTRO-POLISHED 2024-T3 AND 7075-T6 ALUMINUM-ALLOY-SHEET SPECIMENS WITH CENTRAL HOLES, Charles B. Landers and Herbert F. Hardrath, March 1956

TN 3638 ON PANEL FLUTTER AND DIVERGENCE OF INFINITELY LONG UNSTIFFENED AND RING-STIFFENED THIN-WALLED CIRCULAR CYLINDERS, Robert W. Leonard and John M. Hedgepeth, April 1956

TN 3646 A THEORY FOR THE ELASTIC DEFLECTIONS OF PLATES INTEGRALLY STIFFENED ON ONE SIDE, Robert F. Crawford, April 1956

TN 3647 INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP LIFETIME OF 2024-T ALUMINUM-ALLOY SKIN-STRINGER PANELS AT ELEVATED TEMPERATURES, Eldon E. Mathauser and William D. Deveikis, May 1956

TN 3657 FRICTION STUDIES OF GRAPHITE AND MIXTURES OF GRAPHITE WITH SEVERAL METALLIC OXIDES AND SALTS AT TEMPERATURES TO 1000° F, Marshal B. Peterson and Robert L. Johnson, February 1956

TN 3660 INVESTIGATION OF THE Ni_3Al PHASE OF NICKEL-ALUMINUM ALLOYS, Edward M. Grala, April 1956

TN 3669 PERFORATED SHEETS AS A POROUS MATERIAL FOR DISTRIBUTED SUCTION AND INJECTION, Robert F. Dannenberg, Bruno J. Gambucci and James A. Weinberg, April 1956

TN 3678 INFLUENCE OF ALLOYING UPON GRAIN-BOUNDARY CREEP, F. N. Rhines, W. E. Bond and M. A. Kissel, April 1956

TN 3679 INFLUENCE OF COPPER IONS ON ADHERENCE OF VITREOUS COATINGS TO STAINLESS STEEL, D. G. Moore and A. G. Eubanks, February 1956

TN 3681 INVESTIGATION OF PLASTIC BEHAVIOR OF BINARY ALUMINUM ALLOYS BY INTERNAL-FRICTION METHODS, R. E. Maringer, L. L. Marsh, and G. K. Manning, June 1956

TN 3699 SOME EFFECTS OF JOINT CONDUCTIVITY ON THE TEMPERATURES AND THERMAL STRESSES IN AERODYNAMICALLY HEATED SKIN-STIFFENER COMBINATIONS, George E. Griffith and Georgene H. Miltonberger, June 1956

TN 3727 INFLUENCE OF HOT-WORKING CONDITIONS ON HIGH-TEMPERATURE PROPERTIES OF A HEAT-RESISTANT ALLOY, John F. Ewing and J. W. Freeman, August 1956

TN 3728 STUDY OF ALUMINUM DEFORMATION BY ELECTRON MICROSCOPY, A. P. Young, C. W. Melton, and C. M. Schwartz, August 1956

TN 3731 TENSILE PROPERTIES OF INCONEL AND RS-120 TITANIUM-ALLOY SHEET UNDER RAPID-HEATING AND CONSTANT-TEMPERATURE CONDITIONS, George J. Meimerl, Ivo M. Kurg, and John E. Inge, July 1956

TN 3732 AN INVESTIGATION OF VERTICAL-WIND-SHEAR INTENSITIES FROM BALLOON SOUNDINGS FOR APPLICATION TO AIRPLANE- AND MISSILE-RESPONSE PROBLEMS, H. B. Tolefson, July 1956

TN 3736 POISSON'S RATIOS AND VOLUME CHANGES FOR PLASTICALLY ORTHOTROPIC MATERIAL, Elbridge Z. Stowell and Richard A. Pride, August 1956

TN 3742 TENSILE PROPERTIES OF HK31XA-H24 MAGNESIUM-ALLOY SHEET UNDER RAPID-HEATING CONDITIONS AND CONSTANT ELEVATED TEMPERATURES, Thomas W. Gibbs, August 1956

TN 3749 TORSIONAL STIFFNESS OF THIN-WALLED SHELLS HAVING REINFORCING CORES AND RECTANGULAR, TRIANGULAR, OR DIAMOND CROSS SECTION, Harvey G. McComb, Jr., October 1956

TN 3752 TENSILE PROPERTIES OF AZ31A-0 MAGNESIUM-ALLOY SHEET UNDER RAPID-HEATING AND CONSTANT-TEMPERATURE CONDITIONS, Ivo M. Kurg, August 1956

TN 3755 SOME OBSERVATIONS ON THE RELATIONSHIP BETWEEN FATIGUE AND INTERNAL FRICTION, S. R. Valluri, September 1956

TN 3757 TORSIONAL INSTABILITY OF HINGED FLANGES STIFFENED BY LIPS AND BULBS, George Gerard, August 1956

TN 3758 INTERACTION OF BEARING AND TENSILE LOADS ON CREEP PROPERTIES OF JOINTS, E. G. Bodine, R. L. Carlson, and G. K. Manning, October 1956

TN 3769 FURTHER INVESTIGATION OF THE FEASIBILITY OF THE FREEZE-CASTING METHOD FOR FORMING FULL-SIZE INFILTRATED TITANIUM CARBIDE TURBINE BLADES, E. M. Grala, October 1956

TN 3772 EFFECT OF THREE DESIGN PARAMETERS ON THE OPERATING CHARACTERISTICS OF 75-MILLIMETER-BORE CYLINDRICAL ROLLER BEARINGS AT HIGH SPEEDS, William J. Anderson, October 1956

TN 3773 THE DESIGN OF BRITTLE-MATERIAL BLADE ROOTS BASED ON THEORY AND RUPTURE TESTS OF PLASTIC MODELS, Andre J. Meyer, Jr., Albert Kaufman and William C. Caywood, September 1956

TN 3778 ANALYSIS OF ELASTIC THERMAL STRESSES IN THIN PLATE WITH SPANWISE AND CHORDWISE VARIATIONS OF TEMPERATURE AND THICKNESS, Alexander Mendelson and Marvin Hirschberg, November 1956

TN 3787 HEAT-CAPACITY MEASUREMENTS OF TITANIUM AND OF A HYDRIDE OF TITANIUM FOR TEMPERATURES FROM 4° TO 15° K INCLUDING A DETAILED DESCRIPTION OF A SPECIAL ADIABATIC SPECIFIC-HEAT CALORIMETER, M. H. Aven, R. S. Craig, and W. E. Wallace, October 1956

TN 3813 COMPARISON OF THEORETICAL STRESSES AND DEFLECTIONS OF MULTICELL WINGS WITH EXPERIMENTAL RESULTS OBTAINED FROM PLASTIC MODELS, George W. Zender, November 1956

TN 3824 EFFECT OF AN INTERFACE ON TRANSIENT TEMPERATURE DISTRIBUTION IN COMPOSITE AIRCRAFT JOINTS, Martin E. Barzelay and George F. Holloway, April 1957

TN 3828 INVESTIGATION OF THE NiAl PHASE OF NICKEL-ALUMINUM ALLOYS, Edward M. Grala, January 1957

TN 3851 FAILURE CHARACTERISTICS OF PRESSURIZED STIFFENED CYLINDERS, Roger W. Peters and Norris F. Dow, December 1956

TN 3853 COMPRESSIVE STRESS-STRAIN PROPERTIES OF 2025-T3 ALUMINUM-ALLOY SHEET AT ELEVATED TEMPERATURES, Eldon E. Mathauser, November 1956

TN 3854 COMPRESSIVE STRESS-STRAIN PROPERTIES OF 7075-T6 ALUMINUM-ALLOY SHEET AT ELEVATED TEMPERATURES, Eldon E. Mathauser, November 1956

TN 3866 FATIGUE TESTS ON NOTCHED AND UNNOTCHED SHEET SPECIMENS OF 2024-T3 AND 7075-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL WITH SPECIAL CONSIDERATION OF THE LIFE RANGE FROM 2 TO 10,000 CYCLES, Walter Illg, December 1956

TN 3889 PRESSURE LOSSES OF TITANIA AND MAGNESIUM SLURRIES IN PIPES AND PIPELINE TRANSITIONS, Ruth N. Weltmann and Thomas A. Keller, January 1957

TN 3892 PERFORMANCE OF 110-MILLIMETER-BORE M-1 TOOL STEEL BALL BEARINGS AT HIGH SPEEDS, LOADS, AND TEMPERATURES, William J. Anderson, January 1957

TN 3894 A STUDY OF THE IMPACT BEHAVIOR OF HIGH-TEMPERATURE MATERIALS, H. B. Probst and Howard T. McHenry, March 1957

TN 3901 SHEAR STRENGTH AT 75° F TO 500° F OF FOURTEEN ADHESIVES USED TO BOND A GLASS-FABRIC-REINFORCED PHENOLIC RESIN LAMINATE TO STEEL, John R. Davidson, December 1956

TN 3925 PRELIMINARY METALLOGRAPHIC STUDIES OF BALL FATIGUE UNDER ROLLING-CONTACT CONDITIONS, H. Robert Bear and Robert H. Butler, March 1957

TN 3927 PRELIMINARY INVESTIGATION OF THE EFFECT OF SURFACE TREATMENT ON THE STRENGTH OF A TITANIUM CARBIDE - 30 PERCENT NICKEL BASE CERMET, Leonard Robins and Edward M. Grala, February 1957

TN 3930 STRESS-LIFE RELATION OF THE ROLLING-CONTACT FATIGUE SPIN RIG, Robert H. Butler and Thomas L. Carter, March 1957

TN 3931 A STUDY OF THE "TOSS FACTOR" IN THE IMPACT TESTING OF CERMETS BY THE IZOD PENDULUM TEST, H. B. Probst and Howard T. McHenry, February 1957

TN 3932 AN INVESTIGATION OF HIGH-TEMPERATURE VACUUM AND HYDROGEN FURNACE BRAZING, Walter E. Russell and John P. Wisner, March 1957

TN 3933 EFFECT OF FIBER ORIENTATION ON BALL FAILURES UNDER ROLLING-CONTACT CONDITIONS, Robert H. Butler, H. Robert Bear, and Thomas L. Carter, February 1957

TN 3939 A THEORETICAL AND EXPERIMENTAL STUDY OF PLANING SURFACES INCLUDING EFFECTS OF CROSS SECTION AND PLAN FORM, Charles L. Shuford, Jr., March 1957

TN 3949 EXPERIMENTAL INVESTIGATION OF THE OSCILLATING FORCES AND MOMENTS ON A TWO-DIMENSIONAL WING EQUIPPED WITH AN OSCILLATING CIRCULAR-ARC SPOILER, Sherman A. Clevenson and John E. Tomassoni, March 1957

TN 3972 EFFECT OF FREQUENCY AND TEMPERATURE ON FATIGUE OF METALS, S. R. Valluri, February 1957

TN 3976 RUPTURE STRENGTH OF SEVERAL NICKEL-BASE ALLOYS IN SHEET FORM, James H. Dance and Francis J. Clauss, April 1957

TN 3987 EFFECT OF ENVIRONMENTS OF SODIUM HYDROXIDE, AIR, AND ARGON ON THE STRESS-RUPTURE PROPERTIES OF NICKEL AT 1500° F, Howard T. McHenry and H. B. Probst, January 1958

TN 3989 STRENGTH AND DUCTILITY OF BAINITIC STEELS, Donald H. Desy, J. O. Brittain, and M. Gensamer, August 1957

TN 3990 EFFECT OF CRYSTAL ORIENTATION ON FATIGUE-CRACK INITIATION IN POLYCRYSTALLINE ALUMINUM ALLOYS, J. G. Weinberg and J. A. Bennett, August 1957

TN 3991 INTERFACE THERMAL CONDUCTANCE OF TWENTY-SEVEN RIVETED AIRCRAFT JOINTS, Martin E. Barzelay and George F. Holloway, July 1957

TN 3993 BURSTING STRENGTH OF UNSTIFFENED PRESSURE CYLINDERS WITH SLITS, Roger W. Peters and Paul Kuhn, April 1957

TN 3994 STATIC STRENGTH OF CROSS-GRAIN 7075-T6 ALUMINUM-ALLOY EXTRUDED BAR CONTAINING FATIGUE CRACKS, Walter Illg and Arthur J. McEvily, Jr., April 1957

TN 4000 A PHENOMENOLOGICAL RELATION BETWEEN STRESS, STRAIN RATE, AND TEMPERATURE FOR METALS AT ELEVATED TEMPERATURES, Elbridge Z. Stowell, May 1957

TN 4003 A VARIATIONAL THEOREM FOR CREEP WITH APPLICATIONS TO PLATES AND COLUMNS, J. Lyell Sanders, Jr., Harvey G. McComb, Jr., and Floyd R. Schlechte, May 1957

TN 4019 SOME OBSERVATIONS ON STRESS-CORROSION CRACKING OF SINGLE CRYSTALS OF AZ61X MAGNESIUM ALLOY, F. Meller and M. Metzger, July 1957

TN 4026 EFFECTS OF THERMAL RELAXATION AND SPECIFIC-HEAT CHANGES ON MEASUREMENTS WITH A PNEUMATIC-PROBE PYROMETER, P. W. Kuhns, July 1957

TN 4027 APPLICATION OF OBLIQUELY MOUNTED STRAIN GAGE TO MEASUREMENT OF RESIDUAL STRESSES IN DISKS, M. H. Hirschberg, R. H. Kemp, and S. S. Manson, September 1957

TN 4032 REDUCTION OF OXIDIZED NICHROME V POWDERS AND SINTERING OF NICHROME V BODIES, Paul Sikora and Philip Clarkin, September 1957

TN 4036 CREEP OF ALUMINUM-COPPER ALLOYS DURING AGE HARDENING, E. E. Underwood, L. L. Marsh, and G. K. Manning, February 1958

TN 4049 INFLUENCE OF CRUCIBLE MATERIALS ON HIGH-TEMPERATURE PROPERTIES OF VACUUM-MELTED NICKEL-CHROMIUM-COBALT ALLOY, R. F. Decker, John P. Rowe, and J. W. Freeman, June 1957

TN 4050 STUDIES OF STRUCTURAL FAILURE DUE TO ACOUSTIC LOADING, Robert W. Hess, Robert W. Fralich, and Harvey H. Hubbard, July 1957

TN 4051 EFFECTS OF RAPID HEATING ON STRENGTH OF AIRFRAME COMPONENTS, Richard A. Pride, John B. Hall, Jr., and Melvin S. Anderson, June 1957

TN 4052 TWO FACTORS INFLUENCING TEMPERATURE DISTRIBUTIONS AND THERMAL STRESSES IN STRUCTURES, William A. Brooks, Jr., George E. Griffith, and H. Kurt Strass, June 1957

TN 4053 THE COMBINATIONS OF THERMAL AND LOAD STRESSES FOR THE ONSET OF PERMANENT BUCKLING IN PLATES, George W. Zender and Richard A. Pride, June 1957

TN 4054 EFFECT OF TRANSIENT HEATING ON VIBRATION FREQUENCIES OF SOME SIMPLE WING STRUCTURES, Louis F. Vosteen, Robert R. McWithey, and Robert G. Thomson, June 1957

TN 4065 TENSILE PROPERTIES OF INCONEL X SHEET UNDER RAPID-HEATING AND CONSTANT-TEMPERATURE CONDITIONS, Ivo M. Kurg, August 1957

TN 4067 APPROXIMATE ANALYSIS OF EFFECTS OF LARGE DEFLECTIONS AND INITIAL TWIST ON TORSIONAL STIFFNESS OF A CANTILEVER PLATE SUBJECTED TO THERMAL STRESSES, Richard R. Heldenfels and Louis F. Vosteen, August 1957

TN 4074 COMPRESSIVE STRESS-STRAIN PROPERTIES OF 17-7 PH AND AM 350 STAINLESS-STEEL SHEET AT ELEVATED TEMPERATURES, Bland A. Stein, August 1957

TN 4075 TENSILE STRESS-STRAIN PROPERTIES OF 17-7 PH AND AM 350 STAINLESS-STEEL SHEET AT ELEVATED TEMPERATURES, Ivo M. Kurg, September 1957

TN 4076 CALCULATED AND MEASURED STRESSES IN SIMPLE PANELS SUBJECT TO INTENSE RANDOM ACOUSTIC LOADING INCLUDING THE NEAR NOISE FIELD OF A TURBOJET ENGINE, Leslie W. Lassiter and Robert W. Hess, September 1957

TN 4081 EFFECT OF OVERHEATING ON CREEP-RUPTURE PROPERTIES OF S-816 ALLOY AT 1,500° F, John P. Rowe and J. W. Freeman, December 1957

TN 4082 ABNORMAL GRAIN GROWTH IN NICKEL-BASE HEAT-RESISTANT ALLOYS, R. F. Decker, A. I. Rush, A. G. Dano, and J. W. Freeman, December 1957

TN 4083 EFFECT OF OVERHEATING ON CREEP-RUPTURE PROPERTIES OF HS-31 ALLOY AT 1,500° F, John P. Rowe and J. W. Freeman, December 1957

TN 4084 ABNORMAL GRAIN GROWTH IN M-252 AND S-816 ALLOYS, R. F. Decker, A. I. Rush, A. G. Dano, and J. W. Freeman, November 1957

TN 4088 PRACTICAL SOLUTION OF PLASTIC DEFORMATION PROBLEMS IN ELASTIC-PLASTIC RANGE, A. Mendelson and S. S. Manson, September 1957

TN 4089 THE MECHANISM OF THERMAL-GRADIENT MASS TRANSFER IN THE SODIUM HYDROXIDE-NICKEL SYSTEM, Charles E. May, September 1957

TN 4101 EFFECT OF LUBRICANT VISCOSITY ON ROLLED CONTACT FATIGUE LIFE, Thomas L. Carter, October 1957

TN 4111 INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP OF 7075-T6 ALUMINUM ALLOY PLATES AT ELEVATED TEMPERATURES, William D. Deveikis, November 1957

TN 4112 GENERALIZED MASTER CURVES FOR CREEP AND RUPTURE, George J. Heimerl and Arthur J. McEvily, Jr., October 1957

TN 4115 THEORY OF AIRCRAFT STRUCTURAL MODELS SUBJECT TO AERODYNAMIC HEATING AND EXTERNAL LOADS, William J. O'Sullivan, Jr., September 1957

TN 4138 CREEP DEFORMATION PATTERNS OF JOINTS UNDER BEARING AND TENSILE LOADS, E. G. Bodine, R. L. Carlson, and G. K. Manning, December 1957

TN 4141 THE USEFUL HEAT CAPACITY OF SEVERAL MATERIALS FOR BALLISTIC NOSE-CONE CONSTRUCTION, Jackson R. Stalder, November 1957

TN 4157 CORROSION RESISTANCE OF NICKEL ALLOYS IN MOLTEN SODIUM HYDROXIDE, H. B. Probst, C. E. May, and Howard T. McHenry, January 1958

TN 4160 THERMAL FATIGUE OF DUCTILE MATERIALS. I - EFFECT OF VARIATIONS IN THE TEMPERATURE CYCLE ON THE THERMAL-FATIGUE LIFE OF S-816 AND INCONEL 550, Francis J. Clauss and James W. Freeman, September 1958

TN 4161 EFFECT OF LUBRICANT BASE STOCK ON ROLLING-CONTACT FATIGUE LIFE, Thomas L. Carter, February 1958

TN 4163 EFFECT OF TEMPERATURE ON ROLLING-CONTACT FATIGUE LIFE WITH LIQUID AND DRY POWDER LUBRICANTS, Thomas L. Carter, January 1958

TN 4165 THERMAL FATIGUE OF DUCTILE MATERIALS. II - EFFECT OF CYCLIC THERMAL STRESSING ON THE STRESS-RUPTURE LIFE AND DUCTILITY OF S-816 AND INCONEL 550, Francis J. Clauss and James W. Freeman, September 1958

TN 4205 TRANSIENT HEATING EFFECTS ON THE BENDING STRENGTH OF INTEGRAL ALUMINUM-ALLOY BOX BEAMS, Richard A. Pride and John B. Hall, Jr., March 1958

TN 4206 MEASUREMENTS OF TOTAL HEMISPHERICAL EMISSIVITY OF VARIOUS OXIDIZED METALS AT HIGH TEMPERATURE, William R. Wade, March 1958

TN 4209 EXPERIMENTAL THERMAL CONDUCTIVITIES OF THE $N_2O_4 \rightleftharpoons 2NO_2$ SYSTEM, Cleveland O'Neal, Jr., February 1958

TN 4216 EFFECT OF FIBER ORIENTATION IN RACES AND BALLS UNDER ROLLING-CONTACT FATIGUE CONDITIONS, Thomas L. Carter, February 1958

TN 4218 ANALYSIS OF STRESSES AND DEFLECTIONS IN A DISK SUBJECTED TO GYROSCOPIC FORCES, M. H. Hirschberg and A. Mendelson, March 1958

TN 4223 RELATION OF JOURNAL BEARING PERFORMANCE TO MINIMUM OIL-FILM THICKNESS, F. W. Ocvirk and G. B. DuBois, April 1958

TN 4224 EFFECT OF OVERHEATING ON CREEP-RUPTURE PROPERTIES OF M-252 ALLOY, John P. Rowe and J. W. Freeman, March 1958

TN 4225 INTERNAL-FRICTION STUDY OF ALUMINUM ALLOY CONTAINING 4 WEIGHT PERCENT COPPER, B. S. Berry and A. S. Nowick, August 1958

TN 4250 EFFECT OF THE PROXIMITY OF THE WING FIRST-BENDING FREQUENCY AND THE SHORT-PERIOD FREQUENCY ON THE AIRPLANE DYNAMIC-RESPONSE FACTOR, Carl R. Huss and James J. Donegan, June 1958

TN 4285 TRANSGRANULAR AND INTERGRANULAR FRACTURE OF INGOT IRON DURING CREEP, L. A. Shepard and W. H. Giedt, August 1958

TN 4286 MECHANISM OF BENEFICIAL EFFECTS OF BORON AND ZIRCONIUM ON CREEP-RUPTURE PROPERTIES OF A COMPLEX HEAT-RESISTANT ALLOY, R. F. Decker and J. W. Freeman, August 1958

TN 4287 RELATIONSHIP OF METAL SURFACES TO HEAT-AGING PROPERTIES OF ADHESIVE BONDS, J. M. Black and R. F. Blomquist, September 1958

TN 4296 COMPRESSIVE STRENGTH AND CREEP OF 17-7 PH STAINLESS-STEEL PLATES AT ELEVATED TEMPERATURES, Bland A. Stein, July 1958

TN 4306 TEMPERATURE AND THERMAL-STRESS DISTRIBUTIONS IN SOME STRUCTURAL ELEMENTS HEATED AT A CONSTANT RATE, William A. Brooks, Jr., August 1958

TN 4328 STUDY OF HYDROGEN EMBRITTLEMENT OF IRON BY INTERNAL-FRICTION METHODS, R. E. Maringer, E. B. Swetnam, L. L. Marsh, and G. K. Manning, September 1958

TN 4329 INFLUENCE OF HEAT TREATMENT ON MICRO-STRUCTURE AND HIGH-TEMPERATURE PROPERTIES OF A NICKEL-BASE PRECIPITATION-HARDENING ALLOY, R. F. Decker, John P. Rowe, W. C. Bigelow, and J. W. Freeman, July 1958

TN 4331 AN INVESTIGATION OF THE EFFECTS OF ATMOSPHERIC CORROSION ON THE FATIGUE LIFE OF ALUMINUM ALLOYS, Herbert A. Leybold, Herbert F. Hardrath, and Robert L. Moore, September 1958

TN 4348 EFFECT OF TEMPERATURE ON DYNAMIC MODULUS OF ELASTICITY OF SOME STRUCTURAL ALLOYS, Louis F. Vosteen, August 1958

TN 4349 HEAT TRANSFER AND THERMAL STRESSES IN SANDWICH PANELS, Robert T. Swann, September 1958

TN 4371 SOME OBSERVATIONS RELATING TO RECOVERY OF INTERNAL FRICTION DURING FATIGUE OF ALUMINUM, S. R. Valluri, September 1958

TN 4372 EFFECT OF PRECIPITATE PARTICLES ON CREEP OF ALUMINUM-COPPER ALLOYS DURING AGE HARDENING, E. E. Underwood, L. L. Marsh and G. K. Manning, September 1958

Applicable NASA Memoranda

MEMO 5-3-59L INVESTIGATION OF THE STRUCTURAL BEHAVIOR AND MAXIMUM BENDING STRENGTH OF SIX MULTIWEB BEAMS WITH THREE TYPES OF WEBS, James P. Peterson and Walter E. Bruce, Jr., May 1959

It was decided to test 6 seven-web beams of optimum weight-strength design in bending and compare the experimental results with the results obtained by weight-strength diagrams. The computations necessary to construct such a diagram make use of assumptions that may affect the validity of the computations in regions of optimum design. The beams tested were of near optimum design for a given ratio of beam depth to face-sheet thickness as there were two types of full-depth solid webs and combinations of webs and post-stringer webs fabricated from 7075-T6 aluminum.

Existing methods (weight-strength diagrams) were found to be adequate for predicting structural behavior, local buckling, and failures of the beams. Post-stringer webs were found in certain cases to be at least as efficient as the solid-web beams.

Not Applicable NASA Memoranda

MEMO 10-5-58E STRUCTURAL DESIGN AND PRELIMINARY EVALUATION OF A LIGHTWEIGHT, BRAZED, AIR-COOLED TURBINE ROTOR ASSEMBLY, André J. Meyer, Jr., and William C. Morgan, December 1958

MEMO 10-18-58L EFFECT OF TRAGET THICKNESS ON CRATERING AND PENETRATION OF PROJECTILES IMPACTING AT VELOCITIES TO 13,000 FEET PER SECOND, William H. Kinard, C. H. Lambert, Jr., David R. Schryer, and Francis W. Casey, Jr., December 1958

MEMO 11-21-58W EFFECT OF REST PERIODS ON FATIGUE OF HIGH-PURITY ALUMINUM, J. W. Berry, J. Lemaitre, and S. R. Valluri, 1958

MEMO 12-3-58L AN ANALYSIS OF FLIGHT-TEST MEASUREMENTS OF THE WING STRUCTURAL DEFORMATIONS IN ROUGH AIR OF A LARGE FLEXIBLE SWEPT-WING AIRPLANE, Harold N. Murrow, January 1959

MEMO 12-29-58A EFFECTS OF LARGE WING-TIP MASSES ON OSCILLATORY STABILITY OF WING BENDING COUPLED WITH AIRPLANE PITCH, Donald T. Higdon, January 1959

MEMO 1-5-59L THE EFFECT OF BEAM LOADING ON WATER IMPACT LOADS AND MOTIONS, John S. Mixson, February 1959

MEMO 1-30-59L EFFECTS OF CROSS-SECTIONAL SHAPE, SOLIDITY, AND DISTRIBUTION OF HEAT-TRANSFER COEFFICIENT ON THE TORSIONAL STIFFNESS OF THIN WINGS SUBJECTED TO AERODYNAMIC HEATING, Robert G. Thomson, February 1959

MEMO 2-12-59L COMPRESSION TESTS ON CIRCULAR CYLINDERS STIFFENED LONGITUDINALLY BY CLOSELY SPACED Z-SECTION STRINGERS, James P. Peterson and Marvin B. Dow, March 1959

MEMO 2-18-59L EVALUATION OF SEVERAL APPROXIMATE METHODS FOR CALCULATING THE SYMMETRICAL BENDING-MOMENT RESPONSE OF FLEXIBLE AIRPLANES TO ISOTROPIC ATMOSPHERIC TURBULENCE, Floyd V. Bennett and Robert T. Yntema, March 1959

MEMO 2-24-59W THEORETICAL DETERMINATION OF LIFETIME OF COMPRESSED PLATES AT ELEVATED TEMPERATURES, George Herrmann and Hu-Nan Chu, March 1959

MEMO 2-25-59E HALOGEN-CONTAINING GASES AS BOUNDARY LUBRICANTS FOR CORROSION-RESISTANT ALLOYS AT 1200° F, Donald H. Buckley and Robert L. Johnson, March 1959

MEMO 2-28-59L COMPARISON OF MEASURED FLAPWISE STRUCTURAL BENDING MOMENTS ON A TEETERING ROTOR BLADE WITH RESULTS CALCULATED FROM THE MEASURED PRESSURE DISTRIBUTION, Alton P. Mayo, March 1959

MEMO 3-2-59E LUBRICATING PROPERTIES OF LEAD-MONOXIDE-BASE COATINGS OF VARIOUS COMPOSITIONS AT TEMPERATURES TO 1250° F, Harold E. Sliney, February 1959

MEMO 3-3-59L WIND-TUNNEL INVESTIGATION OF THE EFFECT OF ANGLE OF ATTACK AND FLAPPING-HINGE OFFSET ON PERIODIC BENDING MOMENTS AND FLAPPING OF A SMALL ROTOR, John Locke McCarty, George W. Brooks, and Domenic J. Maglieri, March 1959

MEMO 3-3-59W STUDY OF PLASTIC DEFORMATION IN BINARY ALUMINUM ALLOYS BY INTERNAL-FRICTION METHODS, E. C. Olson, R. E. Maringer, L. L. Marsh, and G. K. Manning, March 1959

MEMO 3-9-59E TENSILE PROPERTIES OF MOLYBDENUM AND TUNGSTEN FROM 2500° TO 3700° F, Robert W. Hall and Paul F. Sikora, February 1959

MEMO 3-10-59E OPTIMIZATION OF PARAMETRIC CONSTANTS FOR CREEP-RUPTURE DATA BY MEANS OF LEAST SQUARES, S. S. Manson and A. Mendelson, March 1959

MEMO 4-12-59L EXPERIMENTAL INVESTIGATION OF EFFECTS OF RANDOM LOADING ON THE FATIGUE LIFE OF NOTCHED CANTILEVER-BEAM SPECIMENS OF 7075-T6 ALUMINUM ALLOY, Robert W. Fralich, June 1959

MEMO 4-13-59E EXPLORATORY INVESTIGATION OF ADVANCED-TEMPERATURE NICKEL-BASE ALLOYS, John C. Freche and William J. Waters, May 1959

MEMO 6-2-59L COMPRESSIVE STRENGTH OF STAINLESS-STEEL SANDWICHES AT ELEVATED TEMPERATURES, Eldon E. Mathauser and Richard A. Pride, June 1959

MEMO 6-14-59L DETERMINATION OF STATIC STRENGTH AND CREEP BUCKLING OF UNSTIFFENED CIRCULAR CYLINDERS SUBJECTED TO BENDING AT ELEVATED TEMPERATURES, Eldon E. Mathauser and Avraham Berkovits, June 1959

Applicable Technical Notes, D-Series

TN D 98 OPTIMUM PROPORTIONS OF TRUSS CORE AND WEB CORE SANDWICH PLATES LOADED IN COMPRESSION, Melvin S. Anderson, September 1959

The proportions of truss-core and web core sandwiches which give the minimum weight for carrying inplane compressive loads are presented. For lightly loaded sandwich plates, the truss-core sandwich is less efficient than a honeycomb sandwich, but for higher loading intensities the truss-core sandwich is more efficient. The web-core sandwich is not as efficient as either the truss-core or honeycomb sandwich.

TN D 104 MINIMUM WEIGHT ANALYSIS OF SYMMETRICAL MULTI WEB BEAMS STRUCTURES SUBJECTED TO THERMAL STRESS, Robert R. McWithey, October 1959

A study is presented to determine beams of optimum weight based upon buckling and yielding stress criteria. Curves of minimum structural weight and optimum values of the beam parameters are shown as a function of the bending moment for various temperature differences between skin and web.

TN D 158 LIMITED INVESTIGATION OF CRUSHABLE STRUCTURES FOR ACCELERATION PROTECTION OF OCCUPANTS OF VEHICLES AT LOW IMPACT SPEEDS, Thomas C. O'Bryan and Howard G. Hatch, October 1958

"A LIMITED investigation has been made to determine the characteristics of three materials to see how they can be applied for human protection against accelerations encountered at low impact speeds."

TN D 162 HANDBOOK OF STRUCTURAL STABILITY. PART VII, George Gerard and Herbert Becker, September 1959

The stability of various forms of stiffened and sandwich plates which have been considered for the compression covers of thin wings is presented in terms of orthotropic plate theory. Design charts are given and methods of evaluating the plate elastic constants are reviewed. Buckling and failure of multiweb, multipost, and multipost-stiffened forms of beams construction are considered in terms of available theoretical and experimental results. The pertinent findings of minimum-weight analyses are presented.

TN D 163 HANDBOOK OF STRUCTURAL STABILITY. PART III - BUCKLING OF CURVED PLATES AND SHELLS, George Gerard, September 1959

Recent experimental data on buckling of cylinders under pressure is correlated with existing theories as of September 1959.

TN D 171 CALCULATED EFFECTIVE THERMAL CONDUCTIVITIES OF HONEYCOMB SANDWICH PANELS, R. T. Swann, December 1959

The steady-state temperature distribution through honeycomb type sandwich panels is calculated with simultaneous radiation and conduction.

TN D 178 FLUTTER INVESTIGATION OF A TRUE SPEED DYNAMIC MODEL WITH VARIOUS TIP TANK CONFIGURATIONS, J. L. Sewall, R. W. Herr and W. G. Igoe, March 1960

A 1/6 scale wing tip tank model, representative of an unswept wing airplane, was flutter tested. The wing was dynamically scaled to flutter at the same speed as a typical full scale configuration. Experimental flutter results indicating the effects of external stores are compared with the results of conventional Rayleigh-Ritz type of flutter analysis which predicted flutter speeds that were excessively conservative with respect to experiment as the tip tank center of gravity approached the elastic axis.

TN D 208 AN INVESTIGATION OF NONPROPAGATING FATIGUE CRACKS, A. J. McEvily, December 1959

Through consideration of the stresses existing at the tip of a fatigue crack an attempt is made to account for nonpropagating fatigue cracks. It is concluded that such cracks may form under constant-amplitude cyclic loading if the crack closes during compression or if the effective radius of the crack is larger than that of the initial note. The results of experimental work on steel and aluminum alloys compare favorably with predictions.

TN D 256 FATIGUE DAMAGE DURING COMPLEX STRESS HISTORIES, H. W. Liu, November 1959

The relation between fatigue life and the relative number and amplitude of imposed cycles of stress was determined in wire specimens of 2024-T4 and 7075-T6 aluminum alloys and hard drawn steel. Agreement was excellent between the hypothesis that the fatigue life was adequately described by a two parameter expression involving the percent of cycles at high stress and a stress interaction factor and the experimentally determined fatigue life.

TN D 360 BENDING AND COMPRESSION TESTS OF PRESSURIZED RING STIFFENED CYLINDERS, Marvin B. Dow and James P. Peterson, April 1960

The results of tests on pressurized ring stiffened cylinders subjected to compression and bending are presented and discussed. The results obtained at high values of internal pressure differ from those obtained by previous investigators in that the theoretical small deflection compressive buckling coefficient of 0.6 was nearly achieved in each test. Small amounts of internal pressure had a greater stabilizing effect in the bending test than in the compression tests.

TN D 400
TN D 401
TN D 402

ANALYSIS OF FRAME REINFORCED CYLINDRICAL SHELLS, Richard H. Mac Neal and John A. Bailie, May 1960

The state of stress in and near a reinforced frame subjected to concentrated loads and moments and supported in a circular cylindrical shell is investigated and shown to be mainly dependent upon a single parameter. The theoretical approach is new and enables tables of coefficients for the calculation of loads per inch in the shell as well as loads and deflections in the frame to be evaluated using a digital computer. The tables are presented in part III. A comparison of this work and two existing theories is made to show relationships between parameters developed in the three methods of analysis. The usefulness of these two theories is thereby extended.

TN D 424

INVESTIGATION OF THE BUCKLING STRENGTH OF CORRUGATED WEBS IN SHEAR, James P. Peterson and Michael F. Card, June 1960

Design charts are presented from which the buckling strength of corrugated shear webs can be determined. The charts are applicable to webs with supported edges in which the edge rotations of the web along lines of support may range from unrestrained (simply supported edges) to completely restrained (clamped edges). In addition, the results of shear tests on seven beams with corrugated webs are presented and discussed.

TN D 429

CREEP BENDING AND BUCKLING OF THIN CIRCULAR CYLINDRICAL SHELLS, Burton Erickson, Francis W. French, Sharad A. Patel, N. J. Hoff, and Joseph Kempner, June 1960

A number of circular cylindrical shells manufactured of 5052-0 aluminum alloy were tested in pure bending, most at 500° F. Some specimens were reinforced, some had longitudinal, some had circumferential, and some had longitudinal and circumferential reinforcing elements. All the specimens not subjected to static tests failed by creep buckling. The results of the experiments are presented in tables and diagrams.

TN D 451

FLUTTER RESEARCH AND SKIN PANELS, Eldon E. Kordes, Weimer J. Tuovila and Lawrence D. Guy, September 1960

Results are presented for unstiffened rectangular panels and for rectangular panels stiffened by corrugated backing. Flutter boundaries are established for all types of panels when considered on the basis of equivalent isotropic plates. A flutter analysis of orthotropic panels is presented in the appendix.

TN D 506 STRUCTURAL BEHAVIOR OF PRESSURIZED, RING-STIFFENED, THIN-WALL CYLINDERS SUBJECTED TO AXIAL COMPRESSION, James P. Peterson and Marvin B. Dow, October 1960

Although not directly applicable to most light aircraft because it deals with pressurized cylinders, this report is a contribution to the development of more exact methods to analyze cylindrical structures. See TN D 3089 for more recent related work.

TN D 526 CORRELATION OF THE BUCKLING STRENGTH OF PRESSURIZED CYLINDERS IN COMPRESSION OR BENDING WITH STRUCTURAL PARAMETERS, James P. Peterson, October 1960

The data on nonpressurized cylinders in bending of NACA TN 3735 and the data on pressurized cylinders in compression and bending of NASA TN D 360 are correlated with structural parameters by using small deflection buckling theory and reduced values for the extensional stiffness of the cylinder wall.

TN D 536 APPLICATIONS OF A GENERAL FINITE DIFFERENCE METHOD FOR CALCULATING BENDING DEFORMATIONS OF SOLID PLATES, William C. Walton, Jr., November 1960

A finite difference technique for calculating small static or simple harmonic flexures of plates and beams is reported. On the basis of comparisons with experiments and exact theory it is concluded that the method is accurate and general. An appendix is devoted to computing procedures which facilitate application of the technique in conjunction with high speed computing equipment.

TN D 543 FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOY TENSION PANELS, Richard E. Whaley and Peter R. Kurzhals, November 1960

Results are presented of fatigue-crack propagation and stress redistribution in built up tension panels for which the ratio of skin area to stiffener area was varied over a wide range.

TN D 547 FATIGUE INVESTIGATION OF FULL SCALE TRANSPORT AIRPLANE WINGS, Lee R. Foster and Richard E. Whaley, October 1960

Six fatigue tests were conducted on C-46 airplane wings: Two tests at high constant amplitude load, two tests with loading schedules based on gust frequency statistics, and two tests with loading schedules developed from maneuver-loads statistics. The results are presented, discussed, and compared with previously published data from other tests in this series.

TN D 635 FATIGUE INVESTIGATION OF FULL SCALE WING PANELS OF 7075 ALUMINUM ALLOY, Claude B. Castle and John F. Ward, April 1961

Results are presented of a fatigue investigation conducted using 18 outer wing panels of a T-29A airplane. Constant-amplitude tests were performed by using the resonant frequency method at three different alternating load levels superposed on a 1 g, or level flight mean load.

TN D 647 FATIGUE DAMAGE UNDER VARYING STRESS AMPLITUDES, H. W. Liu and H. T. Corten, November 1960

The influence of complex stress histories on the fatigue life of members was investigated to determine the relationship between fatigue life and the relative number and amplitude of imposed cycles of stress. A physical model of fatigue damage was formulated in terms of the number of damaged nuclei initiated by the highest applied stress and the propagation of damage by all subsequent cycles of stress. Based on this physical model, a mathematical equation was derived that related the fatigue life to stress history. Further interpretation of this equation was made by an alternative hypothesis. Aluminum-alloy, hard-drawn-steel, and high-strength-steel music wire were tested and the data statistically analyzed to obtain a measure of mean fatigue life and scatter.

TN D 661 ANALYTICAL STUDY OF CREEP DEFLECTION OF STRUCTURAL BEAMS, Leonard Mordfin, December 1960

A study was made of existing methods of analyzing the creep deflections of beams. Using Popov's elastic followup technique, the stress and strain distributions are determined for the creep bending of beams of nonrectangular cross section having unequal creep properties in tension and compression.

TN D 662 EXPERIMENTAL INVESTIGATION OF CREEP DEFLECTION OF EXTRUDED AND RIVETED I BEAMS, Leonard Mordfin and Nixon Halsey, December 1960

Tests of 2024-T4 aluminum beams in creep bending at 450° F are reported. The creep deflections were compared with theoretical values calculated by the methods presented in another report.

TN D 725 FACTORS IN EVALUATING FATIGUE LIFE OF STRUCTURAL PARTS, Walter Illg, April 1961

Three facets of fatigue testing are discussed in relation to problems involved in evaluating the fatigue life of structural parts. These facets are variable amplitude loading, fatigue-crack propagation, and equivalent fatigue loading. Experimental tests results are included to support conclusions.

TN D 796 RESIDUAL STATIC STRENGTH OF ALUMINUM ALLOY BOX BEAMS CONTAINING FATIGUE CRACKS IN THE TENSION COVERS, Herbert A. Leybold, April 1961

Static tests were performed on 31 box beams to determine their residual static strengths. The beams were constructed of 7075 and 2024 aluminum according to several designs and employed stringers that were either bonded, riveted, or an integral part of the skin. Beams with stringers bonded to the skin (both materials) had the highest residual static strengths, whereas 7075 beams with integrally stiffened covers had the lowest residual strengths. The test results are compared with predictions of the residual static strength. Fair agreement between predicted strength and actual strength was obtained for all beams tested.

TN D 826 GENERAL THEORY OF LARGE DEFLECTIONS OF THIN SHELLS, E. H. Dill, March 1961

A general theory is developed for large deflections of thin shells but with rotations of the elements negligible compared to unity. The derivation is carried out in tensor form and any coordinate system on the surface of the shell can be used. It is shown that for shallow shells and developable surfaces the problem can be reduced to the solution of two fourth-order partial differential equations in a stress function and the deflection normal to the shell. For shells forming a surface of revolution the results are indicated in terms of the equation of the generating curve. The differential equations for the conical shell are listed.

TN D 987 CROSS-SECTION DEFORMATIONS OF MONOCOQUE BEAMS AND THEIR EFFECTS ON THE NATURAL VIBRATION FREQUENCIES, Robert G. Thompson and Edwin T. Kruszewski, December 1961

The variational principle, differential equations, and boundary conditions governing the cross-sectional distortions due to inertia loading of a two-dimensional model of a thin monocoque wing are shown. A theoretical analysis of this simplified model is made in order to determine the nature of the coupling between the cross sectional modes and the spanwise deformation modes. General solutions are obtained in finite difference form for arbitrary cross sections and an exact solution is presented for a parabolic arc cross section of constant cover thickness.

TN D 1008 CALCULATED MODE SHAPES AND PRESSURE DISTRIBUTIONS AT FLUTTER FOR A HIGHLY TAPERED HORIZONTAL TAIL IN SUBSONIC FLOW, Gerald L. Hunt and Gerald D. Walberg, April 1962

The kernel-function method is used for calculating unsteady aerodynamic loads.

TN D 1101 INVESTIGATION OF TAPERED CIRCULAR REINFORCEMENTS AROUND CENTRAL HOLES IN FLAT SHEET UNDER BIAXIAL LOADS IN THE ELASTIC RANGE, Albert Kaufman, Peter T. Bizon and William C. Morgan, February 1962

Nine configurations of plastic reinforcing rings were centered on each side of plastic sheet specimens. Stress concentration factors were determined from strain gage measurements. Design curves are given and the best geometries determined. The results were compared with those from an investigation of rectangular cross section reinforcements, and with predictions from an analytical media.

TN D 1156 THEORETICAL FLUTTER ANALYSIS OF FLAT RECTANGULAR PANELS IN UNIFORM COPLANAR FLOW WITH ARBITRARY DIRECTION, Eldon E. Kordez and Richard B. Noll, January 1962

Numerical calculations show that small variations in flow direction have a marked effect on the flutter of simply supported rectangular panels. The results of the calculations also show that the critical flutter mode changes at small flow angles when the length-width ratio is less than 1. Flutter conditions for a given panel at different flow angles can be compared on a common basis by use of a dynamic-pressure parameter ratio referenced to flow conditions of an alined panel.

TN D 1195 INVESTIGATION OF CIRCULAR REINFORCEMENTS OF RECTANGULAR CROSS SECTION AROUND CENTRAL HOLES IN FLAP SHEETS UNDER BIAXIAL LOADS IN THE ELASTIC RANGE, Albert Kaufman, Peter T. Bizon, and William C. Morgan, February 1962

Twenty-five different configurations of plastic reinforcing rings were cemented on each side of plastic sheet specimens. Design curves were constructed and the best reinforcements were determined. The results were compared with predictions of a two-dimensional analytical method.

TN D 1200 EXPERIMENTAL INVESTIGATION OF STRESS DISTRIBUTIONS NEAR ABRUPT CHANGES IN WALL THICKNESS IN THIN WALLED PRESSURIZED CYLINDERS, William C. Morgan and Peter T. Bizon, June 1962

Stress distributions were compared with those predicted by a previously published theoretical method of analysis. This method was developed to include consideration of stresses attributable to differences between average radii in cylindrical sections as well as to thickness changes. Typical cases of radically symmetric abrupt changes in cylinder wall thickness were investigated for ratios of diameter to larger wall thickness of 117 and 28. The degree of correlation between predicted and experimental stress distributions established the validity of the theoretical method. The significance of additional stresses caused by change in wall thickness was evaluated.

TN D 1251 STRUCTURAL BEHAVIOR AND COMPRESSIVE STRENGTH OF CIRCULAR CYLINDERS WITH LONGITUDINAL STIFFENERS, James P. Peterson, Ralph O. Whitley and Jerry N. Deaton, May 1962

Results of tests on 17 circular cylinders with longitudinal stiffening are presented and discussed. In addition, studies of the compressive load-shortening characteristics of plates with large width-thickness ratios and of the strength of columns consisting of longitudinally stiffened sheet which buckled prior to column failure are given and employed in analyses of the cylinder tests. Correlation between experiment and analysis was achieved in predicting local buckling of the skin, in predicting shortening of the cylinders, and in predicting the panel instability load on the longer cylinders. Shorter cylinders fail with loads considerably less than those predicted.

TN D 1258 INVESTIGATION OF THE RESPONSE OF MULTIWEB BEAMS TO STATIC AND DYNAMIC LOADING, Wilbur B. Fichter and Eldon E. Kordes, May 1962

Measured cover stresses are presented for four multiweb beams subjected to transient uniform loading. Elementary beam theory more accurately predicted the bending stresses due to static loading than those due to transient loading. Timoshenko beam theory offered no improvement over elementary theory for the one beam considered. Results for one specimen indicate that dynamic effects on the strength of multiweb beams can be appreciable.

TN D 1510 COLLECTED PAPERS ON INSTABILITY OF SHELL STRUCTURES, 1962

This is in effect a status report on methods for determining the instability of shell structures.

TN D 1522 VARIABLE AMPLITUDE FATIGUE TESTS WITH PARTICULAR ATTENTION TO THE EFFECTS OF HIGH AND LOW LOADS, Eugene C. Naumann, December 1962

Load schedules were designed to approximate gust load statistics and maneuver load statistics. The test data were analyzed by assuming linear cumulative damage, and a limited statistical analysis was used to strengthen conclusions.

TN D 1666 A GENERAL DIGITAL COMPUTER ANALYSIS OF STATICALLY INDETERMINATE STRUCTURES, Paul H. Denke, Douglas Aircraft Co., Inc., December 1962

A procedure for structural analysis, comprising a matrix formulation of the equilibrium and Maxwell-Mohr continuity equations, and an associated digital computer program, has been developed. This procedure is applicable, in its basic form, to any linear discrete structure. The method has been fully verified by comparison with test results, both in the lab and in proof tests, and it has been shown to be a practical analysis tool in 5 numerous applications.

TN D 1803 INVESTIGATION OF THE EFFECTS OF VARIABLE AMPLITUDE LOADINGS ON FATIGUE CRACKS PROPAGATION PATTERNS, C. Michael Hudson and Herbert F. Hardrath, August 1963

Axial load variable amplitude fatigue tests were conducted on 2024-T4 aluminum specimens. Both gust and ground-air-ground cycles were simulated in these tests, and the resulting fracture patterns were carefully inspected to determine which loadings produced the various markings. The effects of loading order and load magnitude on the size and texture of the markings were also investigated.

TN D 1872 OBSERVATIONS ON THE ROLE OF NONLINEARITY IN RANDOM VIBRATIONS OF STRUCTURES, Richard H. Lyon, Bolt Beraner and Newman Inc., March 1963

The effect of nonlinearity in several clamped-clamped beam vibration problems are reviewed. Studies of prototype panel-frame structures show similar behavior. The necessity for extending these efforts to built-up structures is emphasized. Also, estimates for the onset of nonlinearity based on two simple models are made to show how one can be guided in experimental design by quantitative-empirical considerations.

TN D 1948 APPLICATION OF THE TRANSTABILITY CONCEPT TO FLUTTER OF FINITE PANELS AND EXPERIMENTAL RESULTS, Sidney C. Dixon, September 1963

The governing differential equation was solved by the Galerkin method. Numerical results obtained from four term solutions are presented for both clamped and simply supported panels with various length width ratios and various ratios of lateral to longitudinal midplane stress. Experimental data are presented for essentially clamped panels with a length-width ratio of 4. The results revealed that the flutter characteristics are very sensitive to the local buckling characteristics. Both theory and experiment indicated that existing experimental panel-flutter envelopes can be inadequate as flutter criteria for stresses panels.

TN D 1967 AN ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF THE NATURAL FREQUENCIES OF UNIFORM RECTANGULAR CROSS SECTION FREE-FREE SANDWICH BEAMS, Robert R. Clary and Sumner A. Leadbetter, October 1963

Natural frequencies of the first six lateral bending modes were measured. Correlation with values calculated from the Timoshenko beam theory was excellent when the secondary effect of transverse shear was included. The shear effect was increasingly important for the higher modes. For one beam the natural frequencies corresponding to the first five modes were measured and were found to increase as the density of the surrounding air was reduced from a sea level value to that of a near vacuum.

TN D 2051 COMPARATIVE EVALUATION OF METHODS FOR PREDICTING FLUTTER AND DIVERGENCE OF UNSWEPT WINGS OF FINITE SPAN, E. Carson Yates, Jr., and Samuel R. Bland, December 1963

Subsonic and supersonic flutter and divergence calculations have been made for five unswept wings by several analytical methods. The results have been compared with experimental flutter data in order to evaluate each method of predicting aeroelastic instabilities, particularly in the high subsonic and low supersonic to hypersonic ranges.

TN D 2200 BENDING TESTS OF LARGE DIAMETER STIFFENED CYLINDERS SUSCEPTIBLE TO GENERAL INSTABILITY, Michael F. Card, April 1964

7 ring and stringer stiffened, circular cylinders were loaded to failure in bending. At low loadings, portions of the skin in each of the cylinders buckled locally; the overall load distribution in the cylinders, however, could be predicted analytically up to failure. Failure of all but one of the cylinders is believed to have been precipitated by general instability. Correlation between orthotropic buckling theory and experiment was found to be fairly good, discrepancies being attributed mainly to uncertainties in two of the orthotropic stiffnesses.

TN D 2206 ANALYSIS OF PLASTIC THERMAL STRESS AND STRAINS IN FINITE THIN PLATE OF STRAIN HARDENING MATERIAL, Ernest Roberts, Jr., and Alexander Mendelson, October 1964

A practical method for obtaining the plastic deformations in a biaxial stress field is presented. The method is numerical, utilizing a system of successive approximations. There are no limitations regarding boundaries, loading history, stress-strain curves, or temp dependence of material properties. The incremental theory of plasticity is used. Two examples are presented for strain-hardening materials: a thermally loaded square plate and a thermally loaded long rectangular plate. Where possible, comparisons are made with existing solutions. The validity of certain approximations of the solution is also investigated.

TN D 2227 RESEARCH ON PANEL FLUTTER, D. R. Kobett and E. F. E. Zeydel, November 1963

A theoretical parametric study is conducted of the flutter characteristics of simply supported flat panel arrays extending to infinity in the spanwise direction and to one panel in the chordwise direction. Small deflection plate theory and exact linearized, three dimensional aerodynamic theory are used.

TN D 2260 ELASTIC STRESS DISTRIBUTION IN A FINITE WIDTH ORTHOTROPIC PLATE CONTAINING A CRACK, Alexander Mendelson and Samuel W. Spero, March 1964

The elastic stress distribution in a thin-finite-width orthotropic plate containing a central crack under tension is presented. The solution is not exact in the sense that the normal stress distribution in the sides of the plate is not zero, but it has a zero resultant. For an isotropic plate, the solution agrees with Westergaard's semi-inverse solution for a set of colinear cracks, and as the ratio of crack length to plate width approaches zero, the solution reduces to the well known solution for the infinite plate. It is shown that the stress intensity factor is independent of the orthotropy of the material.

TN D 2266 REVIEW OF SOME RECENT RESEARCH ON NOISE AND STRUCTURAL VIBRATION, R. H. Lyon and G. Maidanik, Bolt, Beranek and Newman Inc., April 1964

A series of studies in the response of structures to sound and energy transfer between attached structures is discussed. The procedure for computing radiation loss factor, which measures the coupling between sound and structure, and measurements of this parameter are described.

TN D 2297 COMPARISONS OF SOME WING FLUTTER CHARACTERISTICS OBTAINED BY MODIFIED STRIP ANALYSIS, SUBSONIC KERNEL FUNCTION, AND EXPERIMENT, E. Carson Yates and Robert N. Desmarais, May 1964

All flutter speeds calculated for seven swept and unswept wings by both modified strip method and kernel-function method are in good agreement with subsonic experimental values with the exception of kernel-function results for two swept wings that had ballast weight distributed along leading or trailing edges. The kernel function calculations included variations in the number and type of vibration modes and in the number and location of the downwash collocation points.

TN D 2395 STRESS INTENSITY FACTORS FOR A SINGLE EDGE NOTCH TENSION SPECIMEN BY BOUNDARY COLLOCATION OF A STRESS FUNCTION, Bernard Gross, John E. Srawley and William F. Brown, Jr., August 1964

A boundary value collocation procedure applied to the Williams stress function was employed to determine the elastic stress distribution in the immediate vicinity of the tip of an edge crack in a finite-width specimen subjected to uniform tensile loading. The analytical results are expressed in such a way that the stress-intensity factor may be determined from known conditions of specimen geometry and loading. As the crack length decreased, the results obtained by the collocation procedure approached those derived from the solution for an edge crack in a semi-infinite plate.

TN D 2396 EXPERIMENTAL DETERMINATION OF THE DEPENDENCE OF CRACK EXTENSION FORCE ON CRACK LENGTH FOR A SINGLE EDGE NOTCH TENSION SPECIMEN, John E. Srawley, Melvin H. Jones and Bernard Gross, August 1964

The single-edge-notch form of a plane strain crack toughness specimen is particularly economical in regard to available test material and testing machine capacity. The necessary calibration relation for a particular design of a single-edge-notch specimen, centrally loaded in tension, was determined from a series of compliance measurements at crack lengths ranging from zero to one half the specimen width. The accuracy of the calibration is estimated to be $\pm$ 1/2 percent in the range of interest. Agreement with results obtained by boundary collocation of an appropriate stress function is excellent.

TN D 2482 INFLUENCE OF RING STIFFENERS ON INSTABILITY OF ORTHOTROPIC CYLINDERS IN AXIAL COMPRESSION, David L. Block, October 1964

Calculations are presented from analytical investigation on the influence of ring stiffeners on the instability modes of orthotropic cylinders subject to compressive or bending loads. The analysis is performed by employing small deflection theory and by modifying the equilibrium equation to include the effects of discrete ring stiffeners characterized by a bending stiffness that restrains radial deformation of the shell. These calculations indicate that the ring bending stiffness necessary to cause panel instability can be adequately determined by use of an analysis which does not include the discreteness of the rings. Comparison of the results of the calculations with an empirical ring design criterion in common use indicated that the empirical formula can be either very conservative or very nonconservative depending on the cylinder geometry.

TN D 2505 PLANE-STRESS ANALYSIS OF AN EDGE-STIFFENED RECTANGULAR PLATE SUBJECTED TO LOADS AND TEMPERATURE GRADIENTS, Charles Libove, Dalpat Panchal, and Frank Donn, December 1964

TN D 2537 THE EFFECTS OF END SLOPE ON THE BUCKLING STRESS OF CYLINDRICAL SHELLS, C. D. Babcock and E. E. Sechler, December 1964

Seamless cylindrical shells with a ratio of cylinder radius to shell thickness of approximately 800 were loaded with a uniform axial load to failure. The radial displacement of the boundary was controlled and the boundary slope was measured. With these values known, the maximum slope of the shell near the boundary could be calculated. If the maximum slope is plotted against the degradation of buckling stress from the classical value a definite correlation appears.

TN D 2578 THE AUTOCORRELATION FUNCTION OF STRUCTURAL RESPONSE MEASUREMENTS, Richard D. Rechtien, January 1965

The autocorrelation function of the response of a multi-degree-of-freedom system is formally derived and analyzed to determine those factors which significantly influence its characteristics. The form of the autocorrelation function is primarily governed by the joint and cross-joint acceptance function from the viewpoint of coincidence as well as the geometric distribution of pressure cross-power spectral density. Modal cross-coupling by damping also influences the response for some structures. Autocorrelation function of response measurements will generally be complex in nature and will consist of a superposition of damped sine and cosine functions of many frequencies. Narrow band filtering of the response measurements may yield autocorrelation functions possessing single-degree-of-freedom characteristics depending on the spatial homogeneity of the pressure correlation functions.

TN D 2603 STRESS INTENSITY FACTORS FOR SINGLE-EDGE-NOTCH SPECIMENS IN BENDING OR COMBINED BENDING AND TENSION BY BOUNDARY COLLOCATION OF A STRESS FUNCTION, Bernard Gross and John E. Srawley, January 1965

TN D 2672 INVESTIGATION OF THE ELASTIC-PLASTIC STRESS STATE AROUND A REINFORCED OPENING IN A SPHERICAL SHELL, Albert Kaufman and David A. Spera, February 1965

TN D 2783 EFFECT OF FACE-SHEET STIFFNESS ON BUCKLING OF CURVED PLATES AND CYLINDRICAL SHELLS OF SANDWICH CONSTRUCTION IN AXIAL COMPRESSION, Robert E. Fulton, April 1965

TN D 2799 ANALYSIS OF PRESSURIZED AND AXIALLY LOADED ORTHOTROPIC MULTICELL TANKS, Robert E. Blum, May 1965

TN D 2814 COLLAPSE TESTS OF PRESSURIZED MEMBRANE-LIKE CIRCULAR CYLINDERS FOR COMBINED COMPRESSION AND BENDING, Waltor J. Leaumont, Jr., May 1965

TN D 2926 STRUCTURAL BEHAVIOR AND BUCKLING STRENGTH OF HONEYCOMB SANDWICH CYLINDERS SUBJECTED TO BENDING, James P. Peterson and James Kent Anderson, August 1965

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TN D-1094 EFFECT OF STRAIN RATE ON MECHANICAL PROPERTIES OF WROUGHT SINTERED TUNGSTEN AT TEMPERATURES ABOVE 2500° F, Paul F. Sikora and Robert W. Hall, October 1961

TN D-1100 THE DESIGN OF VARIOUS TYPES OF AIR BEARINGS FOR SIMULATING FRICTIONLESS ENVIRONMENTS, Kenneth W. Stack, May 1962

TN D-1102 CONSISTENT P1 ANALYSIS OF AQUEOUS URANIUM-235 CRITICAL ASSEMBLIES, Daniel Fieno, November 1961

TN D-1103 EFFECT OF INERT, REDUCING, AND OXIDIZING ATMOSPHERES ON FRICTION AND WEAR OF METALS TO 1000° F, Donald H. Buckley and Robert L. Johnson, October 1961

TN D-1120 SERVO LOOP DESIGN FOR AIR BEARING INERTIAL COMPONENTS, Herman E. Thomason, May 1962

TN D-1158 STRUCTURAL DYNAMIC EXPERIENCES OF THE X-15 AIRPLANE, Gareth H. Jordan, Norman J. McLeod, and Lawrence D. Guy, March 1962

TN D-1161 ELECTRON AND LIGHT MICROSCOPY TECHNIQUES SUITABLE FOR STUDYING FATIGUE DAMAGE IN A CRYSTALLIZED GLASS CERAMIC, Shelley Harrell and Erwin V. Zaretsky, November 1961

TN D-1167 SOME EFFECTS OF VARIATION OF HOT-PRESSING TEMPERATURE UPON THE AGGLOMERATION OF MgO IN A DISPERSION STRENGTHENED NICKEL-MgO ALLOY, Robert J. Schafer, Max Quatinetz, and John W. Weeton, March 1962

TN D-1175 THE STRUCTURE OF THE EXPLORER X MAGNETOMETER SPACE PROBE, E. D. Angulo and R. K. Browning, April 1962

TN D-1182 ELASTIC DESIGN CHARTS FOR THIN PLATES WITH SPANWISE AND CHORDWISE VARIATIONS IN TEMPERATURE, Ernest Roberts, Jr., March 1962

TN D-1190 LUBRICATING PROPERTIES OF CERAMIC-BONDED CALCIUM FLUORIDE COATINGS ON NICKEL-BASE ALLOYS FROM 75° TO 1900° F, Harold E. Sliney, February 1962

TN D-1191 MICROWAVE INTERFEROMETER MEASUREMENTS OF ELECTRON-ION RECOMBINATION IN NITROGEN, AIR, AND ARGON, Perry Kuhns, February 1962

TN D-1194 AN ANALYTICAL STUDY OF THE CONTINUOUS CHEMICAL REGENERATION OF SURFACES, Leonard K. Tower, February 1962

TN D-1198 EXPERIMENTAL INVESTIGATION OF LITHIUM HYDRIDE AS A HEAT-SINK MATERIAL, C. Robert Morse and Robert O. Hickel, May 1962

TN D-1217 HIGH-VACUUM CONDENSER DESIGN: EXPERIMENTAL EFFECTS FROM CESIUM AND MERCURY ION BEAMS, Edward A. Richley and Ronald J. Cybulski, August 1962

TN D-1221 INFLUENCE OF CERTAIN COMPOSITION AND FABRICATION VARIABLES ON THE STRESS-RUPTURE PROPERTIES OF A COBALT-BASE ALLOY CONSOLIDATED BY POWDER METALLURGY, Philip A. Clarkin, John W. Weeton, and Paul F. Sikora, August 1962

TN D-1224 COMBINATIONS OF TEMPERATURE AND AXIAL COMPRESSION REQUIRED FOR BUCKLING OF A RING-STIFFENED CYLINDER, Melvin S. Anderson, April 1962

TN D-1243 DESIGN OF THE NASA LIGHTWEIGHT INFLATABLE SATELLITES FOR THE DETERMINATION OF ATMOSPHERIC DENSITY AT EXTREME ALTITUDES, Claude W. Coffee, Jr., Walter E. Bressette, and Gerald M. Keating, April 1962

TN D-1247 A MATRIX METHOD FOR THE DETERMINATION OF THE NATURAL VIBRATIONS OF FREE-FREE UNSYMMETRICAL BEAMS WITH APPLICATION TO LAUNCH VEHICLES, Vernon L. Alley, Jr., and A. Harper Gerringer, April 1962

TN D-1253 AXIAL-LOAD FATIGUE TESTS USING LOADING SCHEDULES BASED ON MANEUVER-LOAD STATISTICS, Eugene C. Naumann and Russell L. Schott, May 1962

TN D-1259 UNIFIED NOTCH-STRENGTH ANALYSIS FOR WROUGHT ALUMINUM ALLOYS, Paul Kuhn and I. E. Figge, May 1962

TN D-1265 DETERMINATION OF THE CREEP DEFLECTION AND LIFETIME OF ALUMINUM-ALLOY MULTIWEB BOX BEAMS SUBJECTED TO VARIED LOADS AT CONSTANT TEMPERATURE, Avraham Berkovits, June 1962

TN D-1268 MEASUREMENT OF TOTAL NORMAL EMITTANCE OF BORON NITRIDE FROM 1,200° F TO 1,900° F WITH NORMAL SPECTRAL EMITTANCE DATA AT 1,400° F, Gilbert H. Walker and Francis W. Casey, Jr., July 1962

TN D-1269 IMPACT CHARACTERISTICS OF VARIOUS MATERIALS OBTAINED BY AN ACCELERATION-TIME-HISTORY TECHNIQUE APPLICABLE TO EVALUATING REMOTE TARGETS, John Locke McCarty and Huey D. Carden, June 1962

TN D-1275 LAUNCH DEFLECTOR DESIGN CRITERIA AND THEIR APPLICATION TO THE SATURN C-1 DEFLECTOR, R. L. Evans and O. L. Sparks, March 1963

TN D-1282 SMOOTH AND SHARP-NOTCH PROPERTY VARIATIONS FOR SEVERAL HEATS OF Ti-6Al-4V SHEET AT ROOM AND CRYOGENIC TEMPERATURES, Morgan P. Hanson and Hadley T. Richards, May 1962

TN D-1284 COMPATIBILITY OF SEVERAL PLASTICS AND ELASTOMERS WITH SODIUM, POTASSIUM, AND RUBIDIUM, Louis Rosenblum and Henry Putre, April 1962

TN D-1286 AN ANALYTICAL DETERMINATION OF TEMPERATURE OSCILLATIONS IN A WALL HEATED BY ALTERNATING CURRENT, Frank A. Jeglic, July 1962

TN D-1296 IMPORTANT RESEARCH PROBLEMS IN MISSILE AND SPACECRAFT STRUCTURAL DYNAMICS, 1961, M. V. Barton in collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structures, May 1962

TN D-1310 OBSERVATIONS OF PROPERTIES OF SINTERED WROUGHT TUNGSTEN SHEET AT VERY HIGH TEMPERATURES, E. C. Sutherland and William D. Klopp, February 1963

TN D-1322 CRITICALITY EFFECTS OF CENTRALLY LOCATED TUBES AND RODS OF ALUMINUM, IRON, AND TUNGSTEN IN A HOMOGENEOUS REACTOR, Daniel Fieno, Eugene Gunn, Clayton Barber, Thomas Fox, Donald Alger, and Robert Mueller, August 1962

TN D-1325 RELATIONS BETWEEN MICROSTRUCTURE AND CREEP-RUPTURE PROPERTIES OF NICKEL-BASE ALLOYS AS REVEALED BY OVERTEMPERATURE EXPOSURES, John P. Rowe and J. W. Freeman, September 1962

TN D-1329 INITIAL WEIGHT LOSS OF PLASTICS IN A VACUUM AT TEMPERATURES FROM 80° TO 500° F, Hermilo R. Gloria, W. James Steward, and Raymond C. Savin, December 1962

TN D-1339 BEARINGS FOR VACUUM OPERATION. PHASE I. Harold E. Evans and Thomas W. Flatley, May 1962

TN D-1342 THE COMPOSITION OF GASES IN A TEKTITE BUBBLE, John A. O'Keefe, Kenneth L. Dunning, and Paul D. Lowman, Jr., July 1962

TN D-1373 A USE OF CONFORMAL MAPPING TO DETERMINE THE APPARENT ADDITIONAL MASS OF SCALLOPED AND/OR CLUSTERED CYLINDER CONFIGURATIONS WITH EXPERIMENTAL EVALUATIONS OF RESULTS, Charles E. Watkins, Donald L. Lansing, and Frederick W. Gibson, September 1962

TN D-1386 EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF COMPRESSIVE STRESS ON THE FLUTTER OF A CURVED PANEL AND A FLAT PANEL AT SUPERSONIC MACH NUMBERS, Robert W. Hess and Frederick W. Gibson, October 1962

TN D-1404 EFFECT OF NINE LUBRICANTS ON ROLLING-CONTACT FATIGUE LIFE, Erwin V. Zaretsky, William J. Anderson, and Richard J. Parker, October 1962

TN D-1407 REACTOR-WEIGHT STUDY OF BERYLLIUM OXIDE, BERYLLIUM, LITHIUM-7 HYDRIDE, AND WATER AS MODERATORS WITH TUNGSTEN 184 STRUCTURAL MATERIAL AND URANIUM DIOXIDE FUEL, Robert E. Hyland, September 1962

TN D-1429 THERMODYNAMIC AND TRANSPORT PROPERTY CORRELATION FORMULAS FOR EQUILIBRIUM AIR FROM 1,000° K TO 15,000° K, John R. Viegas and John T. Howe, October 1962

TN D-1431 AN EXPERIMENTAL INVESTIGATION OF THE IMPACT RESISTANCE OF DOUBLE-SHEET STRUCTURES AT VELOCITIES TO 24,000 FEET PER SECOND, C. Robert Nysmith and James L. Summers, October 1962

TN D-1438 EFFECT OF OXIDIZER PARTICLE SIZE ON ADDITIVE AGGLOMERATION, Louis A. Povinelli, November 1962

TN D-1442 COMPATIBILITY OF MOLTEN URANIUM DIOXIDE WITH FIVE REFRACTORY MATERIALS, William A. Sanders and Isadore L. Drell, January 1963

TN D-1458 PRELIMINARY INVESTIGATION OF EFFECT OF HYDROGEN ON STRESS-RUPTURE AND FATIGUE PROPERTIES OF AN IRON-, A NICKEL-, AND A COBALT-BASE ALLOY, Stanley J. Klima, Alfred J. Nachtigall, and Charles A. Hoffman, December 1962

TN D-1493 ENVIRONMENTAL PROBLEMS OF SPACE FLIGHT STRUCTURES. II. METEOROID HAZARD, John R. Davidson and Paul E. Sandorff (in collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structures), January 1963

TN D-1496 LANDING CHARACTERISTICS OF A WINGED REENTRY VEHICLE WITH ALL-SKID LANDING GEAR HAVING YIELDING-METAL SHOCK ABSORBERS, Ulysse J. Blanchard, December 1962

TN D-1499 ROOM-TEMPERATURE SHEAR AND COMPRESSION TESTS OF STIFFENED PANELS WITH INTEGRAL OR ATTACHED COOLING CIRCUITS, Marvin B. Dow and Ralph O. Whitley, March 1963

TN D-1513 BUCKLING OF RING-STIFFENED CYLINDERS UNDER A PURE BENDING MOMENT AND A NON-UNIFORM TEMPERATURE DISTRIBUTION, Melvin S. Anderson and Michael F. Card, November 1962

TN D-1520 AN EXPERIMENTAL INVESTIGATION OF SEVERAL ABLATION MATERIALS IN AN ELECTRIC-ARC-HEATED AIR JET, Andrew J. Chapman, April 1963

TN D-1523 OPTICAL PROPERTIES OF SATELLITE MATERIALS - THE THEORY OF OPTICAL AND INFRARED PROPERTIES OF METALS, Research Projects Division, March 1963

TN D-1531 CONTINUED INVESTIGATION OF AN ADVANCED TEMPERATURE, TANTALUM-MODIFIED, NICKEL-BASE ALLOY, John C. Freche and William J. Waters, April 1963

TN D-1565 EXPERIMENTAL EVALUATION OF THEORETICAL ELASTIC STRESS DISTRIBUTIONS FOR CYLINDER-TO-HEMISPHERE AND CONT-TO-SPHERE JUNCTIONS IN PRESSURIZED SHELL STRUCTURES, William C. Morgan and Peter T. Bizon, February 1963

TN D-1568 ALLOYING EFFECTS OF TUNGSTEN-FIBER-REINFORCED COPPER-ALLOY OR HIGH-TEMPERATURE-ALLOY MATRIX COMPOSITES, Donald W. Petrasek and John W. Weeton, October 1963

TN D-1574 FATIGUE BEHAVIOR OF MATERIALS UNDER STRAIN CYCLING IN LOW AND INTERMEDIATE LIFE RANGE, Robert W. Smith, Marvin H. Hirschberg, and S. S. Manson, April 1963

TN D-1577 EFFECT OF THE ACCELERATION DISTURBANCES ENCOUNTERED IN THE MA-7 SPACECRAFT ON THE LIQUID-VAPOR INTERFACE IN A BAFFLED TANK DURING WEIGHTLESSNESS, Donald A. Petrash, Ralph C. Nussle, and Edward W. Otto, January 1963

TN D-1581 EFFECT OF OXYGEN ON MECHANICAL PROPERTIES OF TUNGSTEN, Joseph R. Stephens, April 1963

TN D-1592 TENSILE PROPERTIES AND SHEET-BENDING FATIGUE PROPERTIES OF SOME REFRACTORY METALS AT ROOM TEMPERATURE, Lee R. Foster, Jr., and Bland A. Stein, January 1963

TN D-1609 STRENGTH OF FILAMENTARY SHEETS WITH ONE OR MORE FIBERS BROKEN, George W. Zender and Jerry W. Deaton, March 1963

TN D-1646 EFFECTS OF SPUTTERING WITH HYDROGEN IONS ON TOTAL HEMISPHERICAL EMITTANCE OF SEVERAL METALLIC SURFACES, Donald L. Anderson and George J. Nothwang, January 1963

TN D-1658 EROSION RESISTANCE AND FAILURE MECHANISMS OF SEVERAL NOZZLE MATERIALS IN A SMALL SOLID-PROPELLANT ROCKET ENGINE, Robert A. Signorelli and James R. Johnston, February 1963

TN D-1690 A CONTRIBUTION TO THE THEORY OF FOLDING DEFORMATIONS IN EXPANDABLE STRUCTURES WITH A PARTICULAR APPLICATION TO TOROIDAL SHELLS, H. U. Schuerch and G. M. Schindler, December 1962

TN D-1691 STRUCTURAL SYNTHESIS OF SYMMETRIC WAFFLE PLATE, Lucien A. Schmit and Thomas P. Kicher, December 1962

TN D-1692 A THEORY AND APPLICATIONS OF FILAMENTARY STRUCTURES, H. U. Schuerch, O. R. Burggraf and A. C. Kyser, December 1962

TN D-1706 INFLUENCE OF FLUORINE ENVIRONMENT ON THE MECHANICAL PROPERTIES OF SEVERAL SHEET ALLOYS, Hadley T. Richards and Morgan P. Hanson, April 1963

TN D-1707 PRELIMINARY INVESTIGATION OF MELTING, EXTRUDING, AND MECHANICAL PROPERTIES OF ELECTRON-BEAM-MELTED TUNGSTEN, Walter R. Witzke, Earl C. Sutherland, and Gordon K. Watson, May 1963

TN D-1708 INFLUENCE OF MICROSTRUCTURAL INCLUSIONS ON FRICTION AND WEAR OF NICKEL AND IRON IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY, Donald H. Buckley and Robert L. Johnson, May 1963

TN D-1784 AN EXPERIMENTAL INVESTIGATION OF THE EFFECTIVENESS OF SINGLE ALUMINUM METEOROID BUMPERS, Donald H. Humes, May 1963

TN D-1785 INVESTIGATION OF MECHANICAL PROPERTIES AND METALLURGICAL CHARACTERISTICS OF A METALLIC CHROMIUM AND MAGNESIUM OXIDE COMPOSITE, Charles R. Manning, Jr., and Dick M. Royster, June 1963

TN D-1798 PROGRESS REPORT OF THE NASA SPECIAL COMMITTEE ON MATERIALS RESEARCH FOR SUPERSONIC TRANSPORTS, Richard H. Raring, J. W. Freeman, J. W. Schultz, and H. R. Voorhees, May 1963

TN D-1880 EFFECT OF TWO BRAZE COATINGS, PROCESSING VARIABLES, AND HEAT TREATMENTS ON 1200° F STRESS-RUPTURE STRENGTH OF L-605, A-286, AND INCONEL 700 SHEET, John H. Sinclair and Charles A. Gyorgak, November 1963

TN D-1881 STRESS STRAIN BEHAVIOR OF TUNGSTEN-FIBER-REINFORCED COPPER COMPOSITES, David L. McDanels, Robert W. Jech, and John W. Weeton, October 1963

TN D-1903 ARIEL I - EVOLUTION OF ITS STRUCTURE, Carl L. Wagner, Jr., September 1963

TN D-1918 ON ISOMETRIC DEFORMATION OF SCREW SURFACES, G. W. Schindler, May 1963

TN D-1919 A CONTRIBUTION TO THE THEORY OF PRESSURE STABILIZED STRUCTURES, A. C. Kyser, May 1963

TN D-1920 ANALYSIS OF AXISYMMETRIC, ROTATING PRESSURIZED FILAMENTARY STRUCTURES, O. R. Burggraf and H. U. Schuerch, May 1963

TN D-1943 A METHOD FOR PREDICTING THE STATIC STRENGTH OF A STIFFENED SHEET CONTAINING A SHARP CENTRAL NOTCH, Herbert A. Leybold, August 1963

TN D-1944 AN INVESTIGATION OF A NEW NICKEL ALLOY STRENGTHENED BY DISPERSED THORIA, Charles R. Manning, Jr., Dick M. Royster, and David N. Braski, July 1963

TN D-2005 THE EFFECT OF INITIAL IMPERFECTIONS ON THE BUCKLING STRESS OF CYLINDRICAL SHELLS, C. D. Babcock and E. E. Sechler, July 1963

TN D-2007 MEASUREMENT OF TORSIONAL RIGIDITY OF STIFFENED PLATES, Herbert Becker and George Gerard, July 1963

TN D-2039 DIFFUSION STUDIES OF SEVERAL OXIDATION RESISTANT COATINGS ON Mo-0.5Ti MOLYBDENUM ALLOY AT 2,500° F, Bland A. Stein and W. Barry Lisagor, August 1964

TN D-2040 A STUDY OF SEVERAL OXIDATION-RESISTANT COATINGS ON Mo-0.5Ti ALLOY SHEET AT 2,500° F, Donald R. Rummler, Bland A. Stein, and Richard A. Pride, August 1964

TN D-2045 RESIDUAL STATIC STRENGTH OF SEVERAL TITANIUM AND STAINLESS-STEEL ALLOYS AND ONE SUPERALLOY AT -109° F, 70° F, AND 550° F, I. E. Figge, December 1963

TN D-2059 IMPORTANT STRUCTURAL RESEARCH PROBLEMS FOR THE SUPPORT OF FUTURE SPACE MISSIONS, Lewis H. Abraham in collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structures, August 1963

TN D-2082 AN EXAMINATION OF THE ROLLING-CONTACT FATIGUE PROCESS IN A CRYSTALLIZED-GLASS CERAMIC, Shelley Harrell and Erwin V. Zaretsky, December 1963

TN D-2125 RECOMMENDATIONS AND EVALUATIONS OF MATERIALS-RESEARCH AREAS OF IMPORTANCE TO MISSILE AND SPACE VEHICLE STRUCTURES, Jack B. Esgar, Norris F. Dow, and William R. Micks in collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structures, October 1963

TN D-2153 DETERMINATION OF LESS THAN 10 PARTS PER MILLION CARBON IN TUNGSTEN, William A. Gordon, Judson W. Graab, and Zita T. Tumney, October 1964

TN D-2186 DESIGN, TESTS, AND ANALYSIS OF A HOT STRUCTURE FOR LIFTING RE-ENTRY VEHICLES, Richard A. Pride, Dick M. Royster, and Bobbie F. Helms, April 1964

TN D-2196 EFFECT OF WEIGHT, DENSITY, AND HEAT LOAD ON THERMAL-SHIELDING PERFORMANCE OF PHENOLIC NYLON, Andrew J. Chapman, June 1964

TN D-2202 TENSILE COUPON TESTS OF CRYOFORMED AISI 301 STAINLESS-STEEL PRESSURE VESSELS AT CRYOGENIC TEMPERATURES, Thomas W. Orange, October 1964

TN D-2245 FREQUENCIES AND MODES OF VIBRATION OF BUCKLED CIRCULAR PLATES, B. Herzog and E. F. Masur, February 1964

TN D-2258 PROPOSED MECHANISM FOR THERMOPHOTOTROPIC BEHAVIOR IN PEROVSKITE-STRUCTURED TITANATES, Stanley M. Neuder, March 1964

TN D-2287 EFFECTS OF INTERSTITIAL IMPURITIES ON THE LOW-TEMPERATURE TENSILE PROPERTIES OF TUNGSTEN, Joseph R. Stephens, June 1964

TN D-2300 EFFECTS OF PREOXIDATION TREATMENTS ON SPECTRAL NORMAL AND TOTAL NORMAL EMITTANCE OF INCONEL, INCONEL-X, AND TYPE 347 STAINLESS STEEL, Wayne S. Slemp, July 1964

TN D-2306 THERMOPHOTOTROPISM IN CORTICATED ALKALINE EARTH TITANATES, J. B. Schutt, J. A. Colony, and D. R. Lepp, June 1964

TN D-2307 FRICTION AND WEAR OF NICKEL-ALUMINUM ALLOYS AND SOME SULFUR-MODIFIED STEELS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY, Donald H. Buckley and Robert L. Johnson, May 1964

TN D-2321 WELDED ELECTRONIC MODULE FABRICATION, John C. Lyons and David R. Dargo, June 1964

TN D-2331 FATIGUE-CRACK PROPAGATION IN SEVERAL TITANIUM AND STAINLESS-STEEL ALLOYS AND ONE SUPERALLOY, C. Michael Hudson, October 1964

TN D-2345 EXPERIMENTAL EVIDENCE OF DEGRADATION EFFECTS IN SHORT SAMPLES OF HARD SUPERCONDUCTORS, John C. Fakan and Edward R. Schrader, June 1964

TN D-2353 BUCKLING OF THE ECHO A-12 PASSIVE COMMUNICATIONS SATELLITE, Wilbur B. Fichter, Harvey G. McComb, Jr., and Robert W. Leonard; APPENDIX A: MEMBRANE STRESSES IN A SPHERE DUE TO SOLAR OR DYNAMIC PRESSURE, Robert W. Fralich, July 1964

TN D-2358 AXIAL-LOAD FATIGUE PROPERTIES OF PH 15-7 Mo STAINLESS STEEL IN CONDITION TH 1050 AT AMBIENT TEMPERATURE AND 500° F, Walter Illg and Claude B. Castle, July 1964

TN D-2359 THE EFFECTS OF COMBINED PRIOR STRESS AND ATMOSPHERIC CORROSION ON THE FATIGUE LIFE OF ALUMINUM ALLOYS, Herbert A. Leybold, August 1964.

TN D-2372 AZIMUTHAL MAGNETIC FIELD OF A THICK, FINITE-LENGTH, HELICAL SOLENOID, Edmund E. Callaghan and James C. Stoll, July 1964

TN D-2397 RADIATIVE EQUILIBRIUM IN PLANETARY ATMOSPHERES. I. APPLICATION OF THE STRONG LINE ABSORPTION LAW TO THE ATMOSPHERE OF VENUS, Rudolf A. Hanel and Brank Bartko, August 1964

TN D-2398 AN EXPERIMENTAL AND ANALYTICAL VIBRATION STUDY OF A RING-STIFFENED CYLINDRICAL SHELL STRUCTURE WITH VARIOUS SUPPORT CONDITIONS, John L. Sewall, Robert R. Clary, and Sumner A. Leadbetter, August 1964

TN D-2410 ELECTROCHEMICAL OXIDATION OF TITANIUM DIBORIDE, Warren Philipp, August 1964

TN D-2430 LOW-COVERAGE HEAT OF ADSORPTION. I - ALKALI METAL ATOMS ON TUNGSTEN; ATOM-METAL INTERACTION THEORIES, Harold E. Neustadter and Keung P. Luke, August 1964

TN D-2431 LOW-COVERAGE HEAT OF ADSORPTION. II - ALKALI METAL ATOMS ON TUNGSTEN; LENNARD-JONES ATOM-ATOM INTERACTION THEORY, Harold E. Neustadter, Keung P. Luke, and Thomas Sheahan, August 1964

TN D-2434 STUDY OF CARBONATE IMPURITY IN SURFACE REGION OF SODIUM CHLORIDE CRYSTALS, Dumas A. Otterson and Myron O. Davies, August 1964

TN D-2439 EVALUATION OF AN ENERGY METHOD USING FINITE DIFFERENCES FOR DETERMINING THERMAL MIDPLANE STRESSES IN PLATES, Harry G. Schaeffer and Walter L. Heard, Jr., August 1964

TN D-2445 MICROMETEOROID SATELLITE (EXPLORER XVI) STAINLESS-STEEL PENETRATION RATE EXPERIMENT, Elmer H. Davison and Paul C. Winslow, Jr., August 1964

TN D-2456 BEHAVIOR OF A FLAT STRETCHED MEMBRANE WRINKLED BY THE ROTATION OF AN ATTACHED HUB, Martin M. Mikulas, Jr., September 1964

TN D-2459 SURFACE FAILURE OF TITANIUM CARBIDE CERMET AND SILICON CARBIDE BALLS IN ROLLING CONTACT AT TEMPERATURES TO 2000° F, Richard J. Parker, Salvatore J. Grisaffe, and Erwin V. Zaretsky, August 1964

TN D-2461 ANALYSIS OF BONDING MECHANISM BETWEEN PLASMA-SPRAYED TUNGSTEN AND A STAINLESS STEEL SUBSTRATE, William A. Spitzig and Salvatore J. Grisaffe, September 1964

TN D-2464 INVESTIGATION OF THERMAL SHOCK RESISTANCE OF ZIRCONIA WITH METAL ADDITIONS, Alan Arias, September 1964

TN D-2499 THE SUSCEPTIBILITY OF SIX STAINLESS STEELS TO STRESS CORROSION AT AMBIENT AND ELEVATED TEMPERATURES, David N. Braski, December 1964

TN D-2503 EFFECTS OF PURITY AND STRUCTURE ON RECRYSTALLIZATION, GRAIN GROWTH, DUCTILITY, TENSILE, AND CREEP PROPERTIES OF ARC-MELTED TUNGSTEN, William D. Klopp and Peter L. Raffo, November 1964

TN D-2523 MARKED INFLUENCE OF CRYSTAL STRUCTURE ON THE FRICTION AND WEAR CHARACTERISTICS OF COBALT AND COBALT-BASE ALLOYS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY. I - POLYCRYSTALLINE AND SINGLE CRYSTAL COBALT, Donald H. Buckley and Robert L. Johnson, December 1964

TN D-2524 MARKED INFLUENCE OF CRYSTAL STRUCTURE ON THE FRICTION AND WEAR CHARACTERISTICS OF COBALT AND COBALT BASE ALLOYS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY. II - COBALT ALLOYS, Donald H. Buckley and Robert L. Johnson, December 1964

TN D-2561 MECHANICAL PROPERTIES OF ARC-MELTED AND ELECTRON-BEAM-MELTED TUNGSTEN-BASE ALLOYS, Peter L. Raffo, William D. Klopp, and Walter R. Witzke, January 1965

TN D-2563 PROBLEMS OF FATIGUE OF METALS IN A VACUUM ENVIRONMENT, C. Michael Hudson, January 1965

TN D-2566 MECHANICAL RESONANCE DISPERSION AND STRESS-STRAIN BEHAVIOR OF SEVERAL IONIC SINGLE CRYSTALS, Edward R. Gotsky and Carl A. Stearns, January 1965

TN D-2599 FRACTURE TOUGHNESS TESTING, John E. Strawley and William F. Brown, Jr., January 1965

TN D-2607 STABILITY OF 4 TITANIUM-ALLOY AND 4 STAINLESS-STEEL SHEET MATERIALS AFTER EXPOSURES UP TO 22000 HOURS AT 550° F (561° K), George J. Heimer, February 1965

TN D-2613 RESIDUAL STRENGTH OF ALLOYS POTENTIALLY USEFUL IN SUPERSONIC AIR-CRAFT, I. E. Figge, February 1965

TN D-2629 FATIGUE UNDER RANDOM AND PROGRAMED LOADS, Eugene C. Maumann, February 1965

TN D-2638 MAGNETIC SUSCEPTIBILITIES OF COMPOSITIONS IN TANTALUM-TANTALUM CARBIDE SYSTEM, Gilbert J. Santoro, January 1965

TN D-2640 EFFECT OF COMPONENT DIFFERENTIAL HARDNESS ON ROLLING-CONTACT FATIGUE AND LOAD CAPACITY, Erwin V. Zaretsky, Richard J. Parker, and William J. Anderson, March 1965

TN D-2647 AN INVESTIGATION OF THE VANADIUM-GALLIUM SYSTEM BETWEEN 50 AND 100 ATOMIC PERCENT VANADIUM, John J. Fischer and Hubert B. Probst, February 1965

TN D-2649 GRAIN GROWTH IN DILUTE TUNGSTEN-BORON ALLOYS, Peter L. Raffo and Robert F. Hehemann, March 1965

Applicable NACA Technical Reports

TR 696 TENSILE ELASTIC PROPERTIES OF TYPICAL STAINLESS STEELS AND NON-FERROUS METALS AS AFFECTED BY PLASTIC DEFORMATION AND BY HEAT TREATMENT, D. J. McAdam, Jr., and R. W. Mebs, National Bureau of Standards, 1940

Interesting but dated information. The metals literature, particularly the A.S.M. Manual, is a source for updated information.

TR 697 INVESTIGATIONS ON THE INCOMPLETELY DEVELOPED PLANE DIAGONAL-TENSION FIELD, Paul Kuhn, 1940

This information is among the sources used by Kuhn to prepare his 1965 book for McGraw-Hill, Stresses in Aircraft and Shell Structures. See also TN 2661 and TN 2662 for more recent work by the same author.

TR 701 MECHANICAL PROPERTIES OF FLUSH-RIVETED JOINTS, W. C. Brueggeman and Frederick C. Roop, 1940

This report showed that countersunk rivets are stronger and have better aerodynamic qualities (smoother skin) than dimpled rivets. The reason for the superiority of the countersunk rivets was the fact that they fit the holes tighter and that dimpling causes local stresses in the skin.

TR 724 EFFECT OF AGING ON MECHANICAL PROPERTIES OF ALUMINUM-ALLOY RIVETS, Frederick C. Roop, 1941

Reprint of TN 804.

TR 733 CRITICAL COMPRESSIVE STRESS FOR FLAT RECTANGULAR PLATES SUPPORTED ALONG ALL EDGES AND ELASTICALLY RESTRAINED AGAINST ROTATION ALONG THE UNLOADED EDGES, Eugene E. Lundquist and Elbridge Z. Stowell, 1942

A chart is presented for the values of the coefficient in the formula for the critical compressive stress at which buckling may be expected to occur in flat rectangular plates supported along all edges and, in addition, elastically restrained against rotation along the unloaded edges. The mathematical derivations of the formulas required in the construction of the chart are given.

TR 734 CRITICAL COMPRESSIVE STRESS FOR OUTSTANDING FLANGES, Eugene E. Lundquist and Elbridge Z. Stowell, 1942

A chart is presented for the values of the coefficient in the formula for the critical compressive stress at which buckling may be expected to occur in outstanding flanges. These flanges are flat rectangular plates supported along the loaded edges, supported and elastically restrained along one unloaded edge, and free along the other unloaded edge. The mathematical derivations of the formulas required for the construction of the chart are given.

TR 735 RESTRAINT PROVIDED A FLAT RECTANGULAR PLATE BY A STURDY STIFFENER ALONG AN EDGE OF THE PLATE, Eugene E. Lundquist and Elbridge Z. Stowell, 1942

A sturdy stiffener is defined as a stiffener of such proportions that it does not suffer cross sectional distortion when moments are applied to some part of the cross section. When such a stiffener is attached to one edge of a plate, it will resist rotation of that edge of the plate by means of its torsional properties. A formula is given for the restraint coefficient provided the plate by such a stiffener. This coefficient is required for the calculation of the critical compressive stress of the plate.

TR 737 BENDING OF RECTANGULAR PLATES WITH LARGE DEFLECTIONS, Samuel Levy, 1942

Report presents the solution of von Karman's fundamental equations for the large deflections of a plate simply supported and under combined edge compression and lateral loading. A numerical solution is given for square and rectangular plates with width-span ratios of 3:1.

TR 739 SHEAR LAG IN BOX BEAMS. METHODS OF ANALYSIS AND EXPERIMENTAL INVESTIGATION, Paul Kuhn and Patrick T. Chiarito, 1942

This information in more current and complete form is included in Kuhn's book previously cited.

TR 740 SQUARE PLATE WITH CLAMPED EDGES UNDER NORMAL PRESSURE PRODUCING LARGE DEFLECTION, Samuel Levy, 1942

A theoretical analysis is given for the stress and deflections of a square plate with clamped edges under normal pressure producing large deflections. Values of the bending stress and membrane stress at the center of the plate and at the midpoint of the edge are given for center deflections up to 1.9 times the plate thickness. The shape of the deflected surface is given for low pressures and for the highest pressure considered. Convergence of the solution is considered and it is estimated that the possible error is less than 2 percent. The results are compared with the only previous approximate analysis known to the author and agree within 5%. They are also shown to compare favorably with the known exact solutions for the long rectangular plate and the circular plate.

TR 744 *NORMAL PRESSURE TESTS OF CIRCULAR PLATES WITH CLAMPED EDGES*, Albert E. McPherson, Walter Ramberg and Samuel Levy, 1942

Supersedes TN 848. See previously.

TR 748 NORMAL PRESSURE TESTS OF RECTANGULAR PLATES, Walter Ramberg, Albert E. McPherson and Samuel Levy, 1942

Supersedes TN 849. See previously.

TR 799 CHARTS FOR THE DETERMINATION OF WING TORSIONAL STIFFNESS REQUIRED FOR SPECIFIED ROLLING CHARACTERISTICS OR AILERON REVERSAL SPEED, Henry A. Pearson and William S. Aiken, Jr., 1944

"Charts . . ." and governing equations.

The charts apply to linearly tapered wings and elliptical wings of tubular shell construction having various aspect ratios with aileron span and location of ailerons as variables. In the derivations of the charts, induced lift effects have been taken into account and the form of the wing torsional stiffness curve has been assumed.

TR 809 PRINCIPLES OF MOMENT DISTRIBUTION APPLIED TO STABILITY OF STRUCTURES COMPOSED OF BARS OR PLATES, Eugene E. Lundquist, Elbridge Z. Stowell and Evan H. Schuette, 1945

The principles of the Cross method of moment distribution, which have previously been applied to the stability of structures composed of bars under axial load, are applied to the stability of structures composed of long plates under longitudinal load. A brief theoretical treatment of the subject, as applied to structures composed of either bars or plates, is included, together with an illustrative example for each of these two types of structure. The appendix presents the derivation of the formulas for the various stiffnesses and carry over factors used in solving problems in the stability of structures composed of long plates.

TR 827 CHARTS FOR THE MINIMUM-WEIGHT DESIGN OF 24S-T ALUMINUM-ALLOY FLAT *COMPRESSION PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS*, Evan H. Schuette, 1945

Design charts are developed for 24S-T aluminum flat compression panels with longitudinal Z-section stiffeners. "These charts make possible the design of the lightest panels of this type for a wide range of design requirements." Examples of the use of the charts are given and it is pointed out on the basis of these examples that, over a wide range of design conditions, that the maintenance of buckle free surfaces does not conflict with the achievement of high structural efficiency.

TR 828 BENDING AND SHEAR STRESSES DEVELOPED BY THE INSTANTANEOUS ARREST OF THE ROOT OF A MOVING CANTILEVER BEAM, Elbridge Z. Stowell, Edward B. Schwartz and John C. Houbolt, 1945

A theoretical and experimental investigation has been made of the behavior of a cantilever beam in transverse motion when its root is suddenly brought to rest. Equations are given for determining the stresses, the deflections and the accelerations that arise in the beam as a result of the impact. The theoretical equations, which have been confirmed experimentally, reveal that, at a given percentage of the distance from root to tip, the bending stress for a particular mode is independent of the length of the beam whereas the shear stresses vary inversely with the length.

TR 845 QUANTITATIVE TREATMENT OF THE CREEP OF METALS BY DISLOCATION AND RATE-PROCESS THEORIES, A. S. Nowick and E. S. Machlin, 1946

The need for heat resistant alloys for use in gas turbines has led to the fact that the creep rate is one of the more important factors in heat-resistance. This report gives an equation for the creep rate for steady-state conditions; the values obtained from the equation are in very good agreement with data for pure annealed metals. The equation suggests that one of the requirements for a heat resistant alloy is that its matrix be a metal that has a high modulus of rigidity and therefore a high modulus of elasticity.

$$u = \frac{2d_1 kT}{Lh} e^{-(VGx^2f^2 + P'T)/kT} \sinh[qVxf(\sigma - 2\tau_b)/kT]$$

u = tensile creep rate at steady-state conditions
d_1 = distance between atoms in slip direction
f = fraction whose value is about 1/2
G = modulus of rigidity at any temperature
h = Planck's constant
k = Boltzmann's constant
L = distance between imperfections in a single
P' = $-k \log_e p^5$
p = probability of occurrence of oscillation in crystallographic direction under consideration
q = stress-concentration factor
T = absolute temperature
V = volume associated with one atom
x = ratio of d_1 to d_2
σ = externally applied tensile stress
τ_b = back stress

TR 847 CRITICAL COMBINATIONS OF SHEAR AND TRANSVERSE STRESS FOR AN INFINITELY LONG FLAT PLATE WITH EDGES ELASTICALLY RESTRAINED AGAINST ROTATION, S. B. Batdorf and John C. Houbolt, 1946

For cases of combinations of shear and transverse stress where the shear is applied along the entire length the interaction formula of the type

$$R_1^p + R_2^q + R_3^r + \ldots = 1$$

must be replaced by:

$$k_s = \frac{1}{2f_1\theta}\left[\frac{b^2}{\lambda^2}(1+\theta^2)^2 f_1 + 2(1+3\theta^2)f_2 + \frac{\lambda^2}{b^2}f_3 + \frac{2\epsilon}{\pi^2}\frac{\lambda^2}{b^2}\right.$$

$$\left. - k_c\left(\frac{\lambda^2}{b^2}f_2 + \theta^2 f_1\right)\right]$$

f_1 $= \left(\frac{\pi^2}{120} + \frac{1}{8} + \frac{2}{\pi^2}\right)\epsilon^2 + \left(\frac{1}{2} - \frac{4}{\pi^2}\right)\epsilon + \frac{1}{2}$

f_2 $= (5/24 - 2/\pi^2)^2 + (1/2 - 4/\pi^2)\epsilon + 1/2$

f_3 $= (1/8 - 1/\pi^2)\epsilon^2 + (1/2 - 4/\pi^2)\epsilon + 1/2$

b = width of plate

k_c, k_s = critical compressive and shear-stress coefficients respectively

f_1, f_2, f_3 = functions of restraint coefficient given in report

ϵ = nondimensional coefficient of edge restraint, zero edge restraint is simply supported edges and infinite edge restraint is clamped edges

λ = parameter determining buckle form (half wave length of buckle)

θ = $\tan\phi$

ϕ = angle between buckle mode and y-axis

An infinitely long flat plate may be loaded with an appreciable fraction of its critical stress (from one-third to more than one-half, depending on the degree of restraint) in pure shear without causing any reduction in the transverse compressive stress necessary to produce buckling. It is expected that the feature of an appreciable fraction of the critical shear stress reducing the critical compressive stress very little for infinitely long plates will be closely approached in the case of long finite plates.

TR 848 THE LAGRANGIAN MULTIPLIER METHOD OF FINDING UPPER AND LOWER LIMITS TO CRITICAL STRESSES OF CLAMPED PLATES, Bernard Budiansky and Pai C. Hu, 1946

This report is a reprint of TN 1103.

TR 874 A SIMPLIFIED METHOD OF ELASTIC-STABILITY ANALYSIS FOR THIN CYLINDRICAL SHELLS, S. B. Batdorf, 1947

Similar information may be found in Kuhn's book.

TR 887 CRITICAL STRESS OF THIN-WALLED CYLINDERS IN AXIAL COMPRESSION, S. B. Batdorf, Murry Schildcrout and Manuel Stein, 1947

Empirical design curves are presented for the critical stress of thin walled cylinders loaded in axial compression. These curves are plotted in terms of the nondimensional parameters of small deflection theory and are compared with theoretical curves derived for the buckling of cylinders with simply supported and clamped edges. An emprical equation is given for the buckling of cylinders having a length radius ratio greater than 0.75.

The test data obtained from various sources follow the general trend of the theoretical curve for cylinders with clamped edges, agreeing closely with the theory in the case of short cylinders, but falling considerably below the theoretical results for long cylinders. The discrepancy in the case of long cylinders increases with increasing values of the ratio of radius to wall thickness.

TR 898 A UNIFIED THEORY OF PLASTIC BUCKLING OF COLUMNS AND PLATES, Elbridge Z. Stowell, 1948

For compression long columns which bend without twisting require the tangent modulus and long flanges that twist without bending require the secant modulus. For structures that twist and bend a combination of the tangent and secant modulus is required.

STRUCTURE	η
Long flange, one unloaded edge simply supported	$\frac{E_{sec}}{E}$
Long flange, one unloaded edge clamped	$\frac{E_{sec}}{E}\left(0.330 + 0.670 \sqrt{1/4 + 3/4 \frac{E_{tan}}{E_{sec}}}\right)$

Long plates, both unloaded edges simply supported	$\frac{E_{sec}}{E}\left(1/2 + 1/2\sqrt{1/4 + 3/4\frac{E_{tan}}{E_{sec}}}\right)$
Long plate, both unloaded edges clamped	$\frac{E_{sec}}{E}\left(0.352 + 0.648\sqrt{1/4 + 3/4\frac{E_{tan}}{E_{sec}}}\right)$
Short plate loaded as a column ($\ell/b = 1$)	$\frac{1}{4}\frac{E_{sec}}{E} + \frac{3}{4}\frac{E_{tan}}{E}$
Square plate loaded as a column ($\ell/b = 1$)	$0.114\frac{E_{sec}}{E} + 0.886\frac{E_{tan}}{E}$
Long column ($\ell/b = 1$)	$\frac{E_{tan}}{E}$

η is the number by which the critical stress computed for the elastic case must be multiplied to give the critical stress for the plastic case.

TR 899 A GENERAL SMALL-DEFLECTION THEORY FOR FLAT SANDWICH PLATES, Charles Libove and S. B. Batdorf, 1948

A reprinting essentially of TN 1526.

TR 914 EFFECT OF CENTRIFUGAL FORCE ON THE ELASTIC CURVE OF A VIBRATING CANTILEVER BEAM, Scott H. Simpkinson, Laurel J. Eaterton and Morton B. Millenson, 1948

Centrifugal force has no effect on high vibratory-stress positions. Therefore nonrotating vibration surveys of propeller blades are valuable in predicting high vibratory-stress locations under operating conditions.

TR 934 RECOMMENDATIONS FOR NUMERICAL SOLUTION OF REINFORCED-PANEL AND FUSELAGE-RING PROBLEMS, N. J. Hoff and Paul A. Libby, 1949

Reproduction of TN 1786. Nothing new in this report.

TR 946 PLASTIC BUCKLING OF A RECTANGULAR PLATE UNDER EDGE THRUSTS, G. H. Handelman and W. Prager, 1949

This report replaced TN 1530 and uses a "plastic flow" theory for a new plastic theory of a plate under compression. This report uses reduced stresses, that is the actual stress divided by Young's modulus.

For $\dot{W} \geqq 0$, where $\dot{W} = dw/dt$,

$$\dot{\epsilon}_x = \lambda\dot{\sigma}_x - (\nu + \frac{\lambda-1}{2})\ \dot{\sigma}_y \qquad \dot{\epsilon}_z = -(\nu + \frac{\lambda-1}{2})\ \dot{\sigma}_x - (\nu - \frac{\lambda-1}{4}\ \dot{\sigma}_y)$$

$$\dot{\epsilon}_y = -(\nu + \frac{\lambda-1}{2})\dot{\sigma}_x + \frac{\lambda+3}{4}\ \dot{\sigma}_y \qquad \dot{\gamma}_{xy} = 2(1 + \nu)\ \dot{\tau}_{xy}$$

For $\dot{W} \leqq 0$,

$$\dot{\epsilon}_x = \dot{\sigma}x - \nu\dot{\sigma}_y$$

$$\dot{\epsilon}_y = - \nu\dot{\sigma}_x + \dot{\sigma}_y$$

$$\dot{\epsilon}_z = - \nu\dot{\sigma}_x - \nu\dot{\sigma}_y$$

$$\dot{\gamma}_{xy} = 2(1 + \nu)\ \tau_{xy}$$

w = deflection
$\dot{\epsilon}$ = strain rate
$\dot{\sigma}$ = stress rate
ν = Poisson's ratio
τ = shear stress component
λ = ratio of Young's modulus to tangent modulus

TR 960 DETERMINATION OF PLATE COMPRESSIVE STRENGTHS AT ELEVATED TEMPERATURES, George J. Heimerl and William M. Roberts, 1950

Supersedes TN 1806. See previously.

TR 967 ELASTIC AND PLASTIC BUCKLING OF SIMPLY SUPPORTED SOLID-CORE SANDWICH PLATES IN COMPRESSION, Paul Seide and Elbridge Z. Stowell, 1950

Supersedes TN 1822. See previously.

TR 975 SMALL BENDING AND STRETCHING OF SANDWICH-TYPE SHELLS, Eric Reissner, 1950

More recent material on this subject may be found in NASA CR-396, March 1966.

TR 1001 FUNDAMENTAL EFFECTS OF AGING ON CREEP PROPERTIES OF SOLUTION-TREATED LOW-CARBON N-155 ALLOY, D. N. Frey, J. W. Freeman and A. E. White, 1950

Supersedes TN 1940. See previously.

TR 1005 ANALYTICAL DETERMINATION OF COUPLED BENDING-TORSION VIBRATIONS OF CANTILEVER BEAMS BY MEANS OF STATION FUNCTIONS, Alexander Mendelson and Selwyn Gendler, 1951

Supersedes TN 2185. See previously.

TR 1008 A SMALL-DEFLECTION THEORY FOR CURVED SANDWICH PLATES, Manuel Stein and J. Mayers, 1951

Supersedes TN 2017. See previously.

TR 1009 INVESTIGATION OF FRETTING BY MICROSCOPIC OBSERVATION, Douglas Godfrey, 1951

Supersedes TN 2039. See previously.

TR 1021 ANALYSIS OF PLANE-PLASTIC-STRESS PROBLEMS WITH AXIAL SYMMETRY IN STRAIN-HARDENING RANGE, M. H. Lee Wu, 1951

A simple method is developed for solving plane-plastic-stress problems with axial symmetry in the strain-hardening range which is based on the deformation theory of plasticity employing the finite-strain concept. The equations defining the problems are first reduced to two simultaneous nonlinear differential equations involving two dependent variables. By multiplying the load and dividing the radius by an arbitrary constant, it is possible to solve these problems without iteration for any value of the modified load. The constant is determined by the boundary condition.

CONCLUSIONS:

1. Inasmuch as the ratios of the principal stresses remain essentially constant during loading for the materials considered, the deformation theory is applicable to this group of problems.

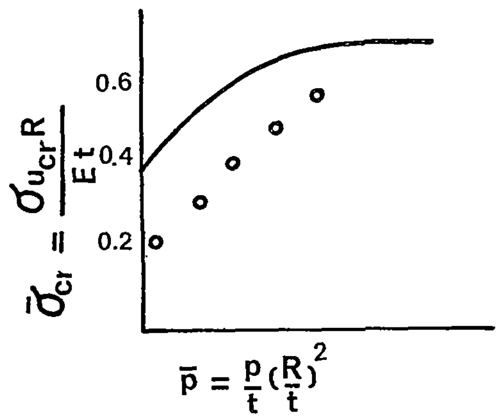
2. In plastic deformation, the distributions of the principal strains and of the octahedral shear strain are less uniform than in the elastic range, although the distributions of the principal stresses were more uniform. The stress-concentration factor around the hole is reduced with plastic deformation, but a high strain concentration factor occurs.

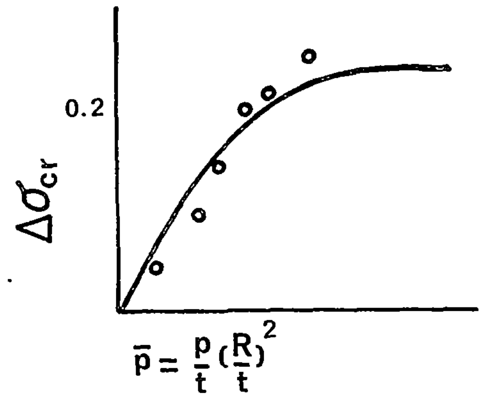
3. For the rotating disk and the infinite plate the deformation that can be sustained by the member before failure depends mainly on the maximum octahedral shear strain of the material.

4. The added load that the member could sustain between the onset of yielding and failure depended mainly on the octahedral shear stress-strain relations of the material.

TR 1027 BUCKLING OF THIN WALLED CYLINDER UNDER AXIAL COMPRESSION AND INTERNAL PRESSURE, Hsu Lo, H. Crate and E. B. Schwartz (supersedes TN 2021), 1951

Before this report an investigation of thin-walled cylinders under axial compression with internal pressure by Flugge had found that the internal pressure made little difference in the buckling load, since this was in contradiction to the results of a series of tests, the following investigation was made. A cylinder 15" in diameter made of 24S-T Al was axially loaded and tests were run to see if the buckling load varied with internal pressure. The internal pressure did vary the buckling load. A new theory using large deflections (Flugge used a small-deflection theory) was developed; while the theory and experimental data agreed as to trends, they do not coincide.





p = internal pressure
R = radius of the cylinder
t = wall thickness
E = Young's modulus
σu_{cr} = buckling stress

TR 1029 COMPRESSIVE STRENGTH OF FLANGES, Elbridge Z. Stowell, 1951

A theoretical analysis of the compressive strength of flanges, based on a deformation theory of plasticity combined with the theory of finite deflections for this structure, and comparison with experimental data lead to the following conclusions:

1. The maximum load for a flange under compression and hinged along one edge may be accurately computed from the dimensions of the flange and the compressive stress-strain curve for the material.

2. Maximum load occurs when, because of the onset of plasticity, the effective modulus has been reduced to such a low value that it is no longer possible for the average stress to increase with increasing strain. Failure is not a local phenomenon but is an integrated effect over the cross section of the flange.

3. For a wide variety of cruciform sections, the stress intensity (averaged over the thickness) along the hinge line at maximum load is a constant to about 1 percent. This value of stress intensity is very close to the yield stress for the material.

4. The fact that maximum loads may be computed in this case suggests that the deformation theory of plasticity is sufficiently accurate when the stress state changes from compression to combined compression and shear as is the case when the shear strains are less than about two-thirds of the compressive strains.

TR 1043 A NUMERICAL METHOD FOR THE STRESS ANALYSIS OF STIFFENED SHELL STRUCTURES UNDER NONUNIFORM TEMPERATURE DISTRIBUTIONS, Richard R. Heldenfels, 1951

A numerical method for the stress analysis of stiffened shell structures under non-uniform temperature distributions has been presented. The method is not applicable to the solution of all structural problems involving temperature effects because it requires extensive and tedious calculations and because the basic assumptions of bulkheads rigid in their own plane and constant shear stress in a given panel occasionally lead to unsatisfactory results. It is however, a powerful tool for the solution of many structural problems because:

1. It is a means for accurately determining all types of secondary stresses in complicated structures that cannot be satisfactorily analyzed by simplified methods.

2. It is sufficiently feasible to cope with a wide variety of structural problems involving nonuniform temperature distributions.

3. It involves only simple arithmetic that can be handled by automatic computing machinery.

TR 1072 INELASTIC COLUMN BEHAVIOR, John E. Duberg and Thomas W. Wilder, III, (supersedes TN 2267), 1952

The significant findings of a theoretical study of column behavior in the plastic stress range are presented. When the behavior of a straight column is regarded as the limiting behavior of an imperfect column as the initial imperfection (lack of straightness) approaches zero, the departure from the straight configuration occurs at the tangent-modulus load. Without such a concept of the behavior of a straight column, one is led to the unrealistic conclusion that lateral deflection of the column can begin at any load between the tangent-modulus value and the Euler load, based on the original elastic modulus.

The behavior of a column with vanishing initial lack of straightness at loads beyond the tangent-modulus load depends upon the stress-strain curve for the material. A family of curves showing load against lateral deflection is presented for idealized H-section columns of various lengths and of various materials that have a systematic variation of their stress-strain curves. These curves show that, for columns in which the material stress-strain curves depart gradually from the initial elastic slope as is characteristic of stainless steels, the maximum column loads may be significantly above the tangent-modulus load. If the departure from the elastic curve is more abrupt, such as for the high-strength aluminum or magnesium alloys, the maximum load is only slightly above the tangent-modulus load.

TR 1097 STRESSES IN A TWO-BAY NONCIRCULAR CYLINDER UNDER TRANSVERSE LOADS, George E. Griffith (supersedes TN 2512), 1952

A method, taking into account the effects of flexibility and based on a general eighth-order differential equation, is presented for finding the stresses in a two-bay, noncircular cylinder in the cross section of which can be composed of circular arcs. Numerical examples are given for two cases of ring flexibility for a cylinder of doubly symmetrical (essentially elliptic) cross section, subjected to concentrated radial, moment, and tangential loads. The results parallel those already obtained for shells with circular rings.

TR 1117 A STUDY OF ELASTIC AND PLASTIC STRESS CONCENTRATION FACTORS DUE TO NOTCHES AND FILLETS IN FLAT PLATES, H. F. Hardrath and L. Ohman, (supersedes TN 2566), 1953

The elastic stress concentration factors were found to be slightly higher than those calculated by Neuber's method and those obtained photoelastically by Frocht. The results showed further that the stress concentration factor decreases as strains at the discontinuity enter the plastic range.

A generalization of Stowell's relation for the plastic stress concentration factor at a circular hole in an infinite plate was applied to the specimen shapes tested and gave good agreement with test results.

TR 1129 TRANSVERSE VIBRATIONS OF HOLLOW THIN-WALLED CYLINDRICAL BEAMS, Bernard Budiansky and Edwin T. Kruszewski (supersedes TN 2682), 1953

The numerical calculations show that secondary effects have appreciable influence on the natural frequencies of rectangular box beams of uniform wall thickness. These results constitute an indication of the probable inadequacy of elementary beam theory for the vibration analysis of actual aircraft structures of the monocoque and semimonocoque type and emphasize the need for practical calculations procedures for such structures that would take into account transverse shear deformation, shear lag, and, when necessary, longitudinal inertia. The general solutions for cylinders of uniform thickness, as well as the results for rectangular box beams, should be useful in the assessment of the accuracy of any procedure of this kind that may be developed.

TR 1131 DEFLECTION AND STRESS ANALYSIS OF THIN SOLID WINGS OF ARBITRARY PLAN FORM WITH PARTICULAR REFERENCE TO DELTA WINGS, Manuel Stein, J. Edward Anderson and John M. Hedgepeth, (supersedes TN 2621), 1953

The structural analysis of arbitrary solid cantilever wings by small-deflection thin-plate theory is reduced to the solution of linear ordinary differential equations by the assumption that the chordwise deflections at any spanwise station may be expressed in the form of a power series in which the coefficients are functions of the spanwise coordinates. If the series is limited to the first two and three terms (that is, if linear and parabolic chordwise deflections, respectively, are assumed), the differential equations for the coefficients are solved exactly for uniformly loaded solid delta wings of constant thickness and of symmetrical double-wedge airfoil section with constant thickness ratio. For cases for which exact solutions to the differential equations cannot be obtained, a numerical procedure is derived. Experimental deflection and stress data for constant-thickness delta-plate specimens of 45° and 50° sweep are presented and are found to compare favorably with the present theory.

TR 1170 BEHAVIOR OF MATERIALS UNDER CONDITIONS OF THERMAL STRESS, S. S. Manson, (supersedes TN 2933), 1954

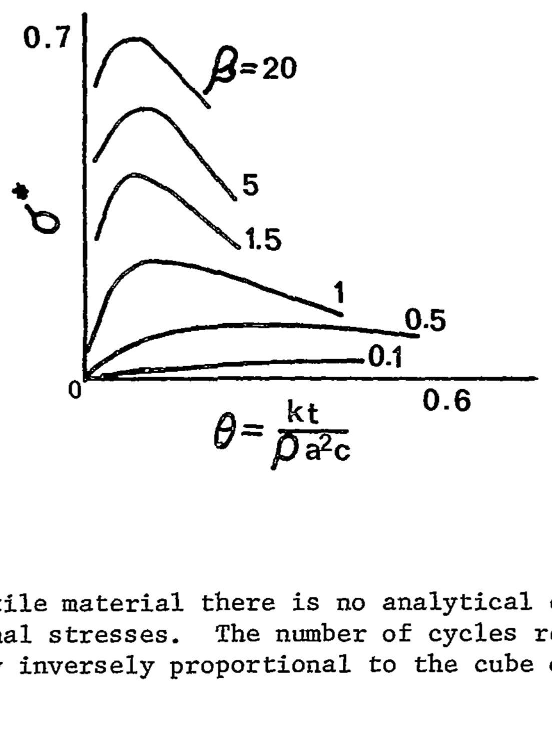
This report deals with thermal stresses in both brittle and ductile materials. Thermal stresses are so severe in brittle materials that they are called thermal shocks and it usually requires only one cycle for failure with brittle materials. The following two equations give the stresses caused by thermal loading.

$$\frac{1}{\sigma^*} = 1.5 + \frac{3.25}{\beta} \quad \text{for} \quad \beta < 5 \qquad \sigma^* = \sigma \frac{(1-\mu)}{E\alpha T_o}$$

$$\frac{1}{\sigma^*} = 1.0 + \frac{3.25}{\beta^{2/3}} \quad \text{for} \quad \beta \text{ from 5 to 20}$$

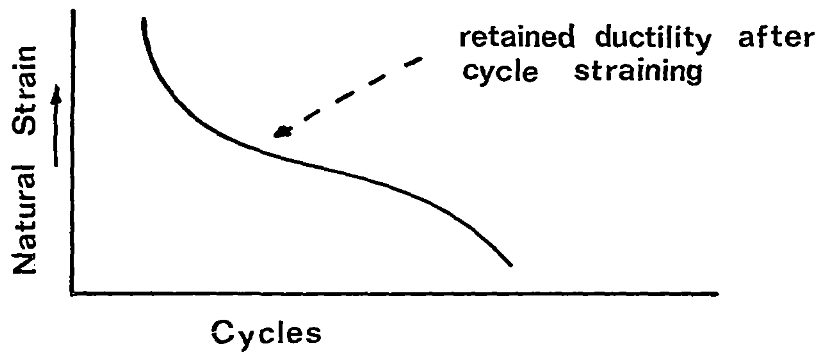
where:

β = ah/k
σ = actual stress
μ = Poisson's ratio
E = elastic modulus
α = coefficient of expansion
T_o = initial uniform temperature of above ambient temperature
h = heat-transfer coefficient
a = half thickness of plate
k = conductivity of the material
ρ = density of the material
c = specific heat



For a ductile material there is no analytical expression dealing with thermal stresses. The number of cycles required for failure is usually inversely proportional to the cube of the strain per cycle.

Stress concentration, large areas, corrosion, and tight constraints should be avoided where possible. Pre-stressing is helpful for both ductile and brittle materials. The materials should be stressed with attention to its operation. For example, if it is going to be operated in a tension condition then it should be pre-stressed by compressive forces. Combinations of ductile and brittle materials to achieve the most resistance to thermal stresses are called cermets and are an improvement. Care should be taken to test materials under operational conditions, since the index of merit for many materials varies with temperature.



TR 1181 STRUCTURAL RESPONSE TO DISCRETE AND CONTINUOUS GUSTS OF AN AIRPLANE HAVING WING-BENDING FLEXIBILITY AND A CORRELATION OF CALCULATED AND FLIGHT RESULTS, John C. Houbolt and Eldon E. Kordes, (supersedes TN 3006, 2763, 2897), 1954

An analysis is made of the structural response to gusts of an airplane having the degrees of freedom of vertical motion and wind bending flexibility and basic parameters are established. A convenient and accurate numerical solution of the response equations is developed for the case of discrete-gust encounter, an exact solution is made for the simpler case of continuous-sinusoidal-gust encounter, and the procedure is outlined for treating the more realistic condition of continuous random atmospheric turbulence, based on the methods of generalized harmonic analysis. Correlation studies between flight and calculated results are then given to evaluate the influence of wing bending flexibility on the structural response to gusts of two twin-engine transports and one four-engine bomber. It is shown that calculated results obtained by means of a discrete-gust approach reveal the general nature of the flexibility effects and lead to qualitative correlation with flight results. In contrast, calculations by means of the continuous-turbulence approach shows good quantitative correlation with flight results and indicate a much greater degree of resolution of the flexibility effects.

TR 1190 AXIAL-LOAD FATIGUE PROPERTIES OF 24S-T AND 75S-T ALUMINUM ALLOY AS DETERMINED IN SEVERAL LABORATORIES, H. J. Grover, W. S. Hyler, Paul Kuhn, Charles B. Landers and F. M. Howell, (supersedes TN 2928), 1954

The report presents axial load fatigue data on 24S-T and 75S-T aluminum alloy obtained at 4 labs. Tests at the Battelle Memorial Institute and at Langley were made on polished sheet specimens from the same lot of material. Tests at the National Bureau of Standards were made on unpolished specimens from different lots of sheet material. Tests at the Aluminum Research Labs. of the Alcoa were made on rod material.

For the 24S-T, agreement between results from all four labs is very good; the differences between polished and unpolished specimens, or between rod and sheets, are shown to be small.

For the 75S-T, similarly good agreement exists only if the comparison is confined to sheet material tested at medium stresses. If the comparison is extended to include sheet material tested at low stresses and rod material, discrepancies appear. At the present, it is difficult to say how much of the discrepancy should be attributed to variability of material and how much to unrecognized differences in test conditions.

TR 1195 FORMULAS FOR ELASTIC CONSTANTS OF PLATES WITH INTEGRAL WAFFLE-LIKE STIFFENING, Norris F. Dow, Charles Libove and Ralph E. Hubka, (supersedes RML 53L13a), 1954

Formulas are derived for the fifteen elastic constants associated with bending, stretching, twisting and shearing of plates with closely spaced integral ribbing in a variety of configurations and proportions. In the derivation the plates are considered as more uniform orthotropic plates. The constants, which include the effectiveness of the ribs for resisting deformations other than bending and stretching in their longitudinal directions are defined in terms of four coefficients, and theoretical and experimental methods for the evaluation of these coefficients are discussed. Four of the more important elastic constants are predicted by these formulas and are compared with tests results. Good correlation is obtained.

TR 1251 STRESS ANALYSIS OF CIRCULAR SEMIMONOCOQUE CYLINDERS WITH CUTOUTS, Harvey G. McComb, Jr., (supersedes TN 3199), 1955

A method is presented for the stress analysis of circular semi-monocoque cylinders with cutouts. It is more accurate in problems where the cutout is located far from external restraints. The loading may be any combination of torsion, bending, shear or axial load. Other loadings are permissible if the stress distribution in the cylinder without a cutout is known. The method of analysis is based on the superposition of certain perturbation stress distributions to give the effects of the cutout on the stress distribution which would exist in the cylinder without a cutout. The equations for the three necessary perturbation stress distributions are derived in this report, and tables of coefficients calculated from these equations are presented for a wide range of structural properties. Ring bending flexibility is taken into account in the tables. The tables refer to a structure having 36 stringers, but they can be used for cylinders having any number of stringers by redistribution of the actual stringer area into 36 fictitious stringers. Sample calculation utilizing the tables of coefficients are presented to illustrate the analytical procedure.

TR 1255 AN ANALYSIS OF THE STABILITY AND ULTIMATE COMPRESSIVE STRENGTH OF SHORT SHEET-STRINGER PANELS WITH SPECIAL REFERENCE TO THE INFLUENCE OF THE RIVETED CONNECTION BETWEEN SHEET AND STRINGER, Joseph W. Semonian and James P. Peterson, 1956

A method of strength analysis of short compression panels has been presented which relates the panel strength to the pitch, diameter, and location of the rivets used to assemble the panel. A large number of panels have been analyzed with this method. These panels covered a wide range of panel configurations. They had elements with aspect ratios which ranged from 20 to 50 and were assembled with rivets which had pitch diameter ratios from 3 to 15. Both 2024-ST and 7075-T6 aluminum alloy panels were considered. The following conclusions can be made from these studies:

1. Panel strength is highly influenced by variations in rivet pitch, diameter and location.

2. Favorable variations in the pitch, diameter, and location of rivets for a given panel results in increased panel strength until the riveting is adequate to force failure in the local mode; further variations in riveting will produce negligible increases in panel strength.

3. The minimum riveting specifications that will force the panel to fail in the local mode depend on the panel configuration and on the panel material.

TR 1267 PLASTIC DEFORMATION OF ALUMINUM SINGLE CRYSTALS AT ELEVATED TEMPERATURES, R. D. Johnson, A. P. Young and A. D. Schwope, (supersedes TN 3351), 1956

Constant-stress creep tests were run on aluminum crystals from 400 to 900° F, while constant-load creep tests were run up to

1100° F. X-ray techniques showed a definite polygonization of the crystalline lattice during creep. It was concluded that plastic deformation takes place predominantly by slip which is accompanied by the mechanisms of kinking and polygonization. Duplex slip has been observed within the band structure in specimens, but is more apparent in the lower purity specimens.

TR 1302 ON PANEL FLUTTER AND DIVERGENCE OF INFINITELY LONG UNSTIFFENED AND RING-STIFFENED THIN-WALLED CIRCULAR CYLINDERS, Robert W. Leonard and John M. Hedgepeth, 1957

A preliminary theoretical investigation of the panel flutter and divergence of infinitely long, unstiffened and ring stiffened thin walled circular cylinders is described, using Donnel's cylinder theory and linearized unsteady potential flow theory. A limited study of the resulting stability criteria has yielded the following information:

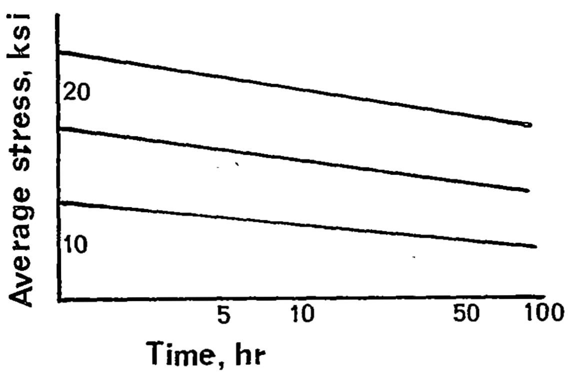
For unstiffened cylinders with vanishingly small structural damping the only possible instability at subsonic Mach numbers is static divergence. For Mach numbers greater than 1 plus the ratio of the speeds of sound in the fluids inside and outside the cylinder, no adjustment of the physical properties of the cylinder will render it stable. The presence of even the smallest amount of structural damping is found to be an important factor in analyses of infinitely long unstifeened cylinders.

TR 1308 INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP LIFETIME OF 2024-T3 ALUMINUM ALLOY PLATES AT ELEVATED TEMPERATURES, Eldon E. Mathauser and William D. Deveikis, (supersedes NACA TN 3552), 1957

This report investigates the effect of elevated temperatures on the strength of 2024-T3 Al. It was found that the following relation can be used for obtaining maximum plate strength for all materials at either room or elevated temperatures.

$$\bar{\sigma}_f = C \sqrt{E_s \sigma_{cy}} \ t/b$$

It was found that plates with width-thickness ratios of 20 will support equal tensile or compressive stress for an equal lifetime.



b = width
t = thickness
E_s = secant modulus
C = constant (for 2024-T3 = 1.6, depends on slope)
$\bar{\sigma}_f$ = average stress at maximum (failing) load
σ_{cy} = 0.2 percent offset compressive yield stress

TR 1316 TORSIONAL STIFFNESS OF THIN-WALLED SHELLS HAVING REINFORCING CORES AND RECTANGULAR, TRIANGULAR OR DIAMOND CROSS SECTION, Harvey G. McComb, (supersedes TN 3749), 1957

This report deals with the problem of torsion of composite bars, thin-walled shells with reinforcing cores. Because the thickness of the shell wall is small compared with the overall dimensions of the cross section, the stress in the wall can be assumed to be uniformly distributed over the thickness. This stress is equal to the normal derivative and is given by:

$$\tau_{wall} = \frac{\partial \phi_1}{\partial \nu} = - \frac{\phi_1}{t} \Big|_{C_2}$$

This leads to: $\phi_1 \Big|_{C_1} = 0$

and $$\frac{\partial \phi_2}{\partial \nu} \Big|_{C_2} = - \frac{G_2 \phi_1}{G_1 t} \Big|_{C_2} = - \frac{G_2}{G_1} \frac{\phi_2}{t} \Big|_{C_2}$$

If the middle, outer and inner boundaries of the thin shell, then finding a function ϕ satisfying the equation

$$\nabla^2 \phi = - 2 G_2 \theta$$

in R and the equation

$$\partial\phi/\partial\nu \,\Big|_C = - (G_2/G_1)(\phi/t) \,\Big|_C$$

along C is the next part of the problem.

For a composite bar of rectangular cross-section the torsional stiffness can be expressed as:

$$\frac{M}{\theta} = G_1 J_1 = G_2 J_2$$

where:

$$J_1 = 4ct_o^2\ tK\Lambda$$

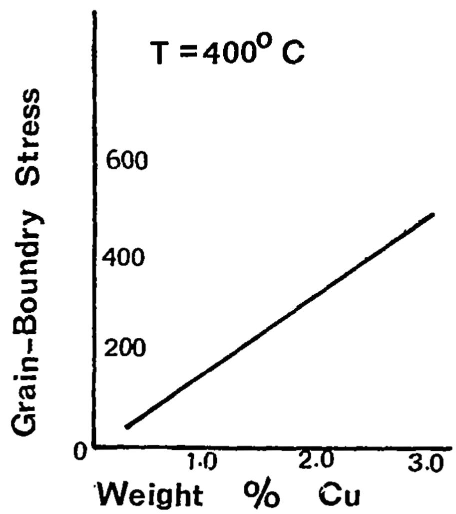
$$J_2 = 2ct_o^3\ \Lambda$$

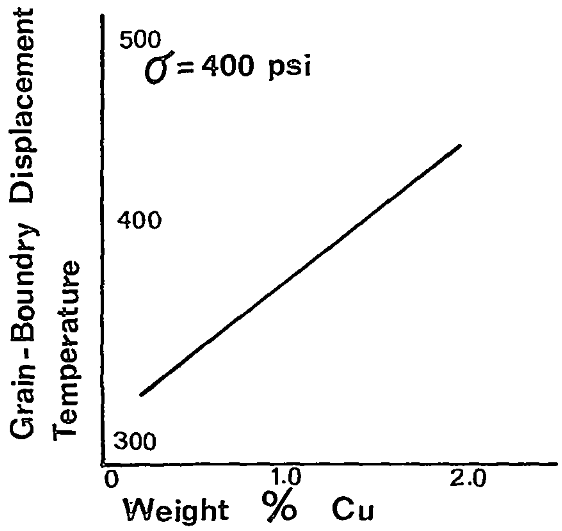
and where

$$\Lambda = \sum_{n=o}^{\infty} \left[\frac{\sin^2\lambda_n b}{\lambda_n^3 b^3(\lambda_n b + \sin\lambda_n b\cos\lambda_n b)}\right] \left[1 - \frac{b}{a}\ \frac{K\sinh\lambda_n a}{\lambda_n b(\lambda_n b\sinh\lambda_n a + K\cosh\lambda_n a)}\right]$$

TR 1331 INFLUENCE OF ALLOYING UPON GRAIN-BOUNDARY CREEP, F. N. Rhines, W. E. Bond and M. A. Kissel, (supersedes TN 3678), 1957

It was found that the grain-boundary displacement is a function of the percent copper (in Cu alloys) and the minimums in stress and temperature, below which grain-boundary motion does not occur, increases regularly with the copper content.





TR 1341 INFLUENCE OF HOT-WORKING CONDITIONS ON HIGH-TEMPERATURE PROPERTIES OF A HEAT-RESISTANT ALLOY, John F. Ewing and J. W. Freeman, 1957

Alloy of 20% chromium, 20% nickel, 20% cobolt, 3% molybdenum, 2% tungsten and 1% columbium.

Extensive precipitation reaction at 1600° to 2000° F. This material was hot-worked and solution treated at 2200° F. This temperature is the operating temperature for some alloys at this date. For this reason, this report is considered to be superseded by a more current alloy.

TR 1342 A VARIATIONAL THEOREM FOR CREEP WITH APPLICATIONS TO PLATES AND COLUMNS, J. Lyell Sanders, Jr., Harvey G. McComb, Jr., and Floyd R. Schlechte, 1958

A variation theorem for creep has been formulated which is an extension of a variational theorem developed by Reissner. Various systems of equations leading to approximate solutions to problems of the creep behavior of plates, columns, beams and shells may be obtained by using direct methods of the calculus of variations in conjunction with the stated theorem. The application of the theorem is illustrated for plated and columns by the solution of two sample problems.

REFERENCES:

Reissner, Eric: On a Variational Theorem in Elasticity. Jour. Math. and Phys., Vol. XXIX, No. 2, July 1950, pp. 90-95.

Reissner, Eric: On a Variational Theorem for Finite Elastic Deformations. Jour. Math. and Phys., Vol. XXXII, Nos. 2-3, July-Oct. 1953, pp. 129-135.

Reissner, Eric: On Bending of Elastic Plates. Quarterly Appl. Math., Vol. V, No. 1, April 1947, pp. 55-58.

TR 1343 A PHENOMENOLOGICAL RELATION BETWEEN STRESS, STRAIN RATE AND TEMPERATURE FOR METALS AT ELEVATED TEMPERATURES, Elbridge Z. Stowell, (supersedes TN 4000), 1958

The following equation is given in this report to relate stress, strain rate, creep rate, creep rupture, heating times and temperature.

$$\dot{\epsilon} = \frac{d}{dt}\left(\frac{\sigma}{E}\right) + \alpha \frac{dT}{dt} + 2s\,Te^{-\frac{\Delta H}{RT}} \sinh \frac{\sigma}{\sigma_o}$$

t	=	time in hours
$\dot{\epsilon}$	=	strain rate per hour
σ	=	stress, ksi
σ_o	=	constant, ksi
E	=	Young's modulus
α	=	linear expansion coefficient, per ^oK
T	=	temperature, ^oK
ΔH	=	activation energy, cal per mole
R	=	gas constant, taken as 2 cal per mole per ^oK
s	=	constant, per hr per ^oK

In a comparison of experimental data and data obtained using the above equation 7075-T6 aluminum was used. The data for creep rate, time for creep rupture, and for rapid-heating agreed very well, while the stress-strain relations showed agreement between data obtained from the equation and experiment for 400^o and 600^o F temperatures but did not show agreement at 200^o F. Although the author thinks that even better correlation would be possible with more pure metal, care should be used in the use of this equation.

Not Applicable NACA Technical Reports

TR	707	THE ADDITIONAL-MASS EFFECT OF PLATES AS DETERMINED BY EXPERIMENTS, William Gracey, 1940
TR	864	EFFECTS OF TEMPERATURE DISTRIBUTION AND ELASTIC PROPERTIES OF MATERIALS ON GAS-TURBINE-DISK STRESSES, Arthur G. Holms and Richard D. Faldetta, 1947
TR	906	DETERMINATION OF STRESSES IN GAS-TURBINE DISKS SUBJECTED TO PLASTIC FLOW AND CREEP, M. B. Millenson and S. S. Manson, 1948
TR	929	DISLOCATION THEORY OF THE FATIGUE OF METALS, E. S. Machlin, 1949
TR	952	DIRECT METHOD OF DESIGN AND STRESS ANALYSIS OF ROTATING DISKS WITH TEMPERATURE GRADIENT, S. S. Manson, 1949
TR	972	THE EFFECT OF TORSIONAL FLEXIBILITY ON THE ROLLING CHARACTERISTICS AT SUPERSONIC SPEEDS OF TAPERED UNSWEPT WINGS, Warren A. Tucker and Robert L. Nelson, 1950
TR	989	CRITICAL STRESS OF RING-STIFFENED CYLINDERS IN TORSION, Manuel Stein, J. Lyell Sanders, Jr., and Harold Crate, 1950
TR	1003	CORRELATION OF PHYSICAL PROPERTIES WITH MOLECULAR STRUCTURE FOR SOME DICYCLIC HYDROCARBONS HAVING HIGH THERMAL-ENERGY RELEASE PER UNIT VOLUME, P. H. Wise, K. T. Serijan, and I. A. Goodman, 1950
TR	1013	EFFECTS OF WING FLEXIBILITY AND VARIABLE AIR LIFT WING BENDING MOMENTS DURING LANDING IMPACTS OF A SMALL SEAPLANE, Kenneth F. Merten and Edgar B. Beck, 1951
TR	1023	DIFFUSION OF CHROMIUM IN ALPHA COBALT-CHROMIUM SOLID SOLUTIONS, John W. Weeton, 1951
TR	1058	INFLUENCE OF CHEMICAL COMPOSITION ON RUPTURE PROPERTIES AT 1200° F OF FORGED CHROMIUM-COBALT-NICKEL-IRON BASE ALLOYS IN SOLUTION-TREATED AND AGED CONDITION, E. E. Reynolds, J. W. Freeman, and A. E. White, 1951
TR	1059	A BIHARMONIC RELAXATION METHOD FOR CALCULATING THERMAL STRESS IN COOLED IRREGULAR CYLINDERS, Arthur G. Holms, 1951
TR	1074	HYDRODYNAMIC IMPACT OF A SYSTEM WITH A SINGLE ELASTIC MODE. I - THEORY AND GENERALIZED SOLUTION WITH AN APPLICATION TO AN ELASTIC AIRFRAME, Wilbur L. Mayo, 1952
TR	1075	HYDRODYNAMIC IMPACT OF A SYSTEM WITH A SINGLE ELASTIC MODE. II - COMPARISON OF EXPERIMENTAL FORCE AND RESPONSE WITH THEORY, Robert W. Miller and Kenneth F. Merten, 1952

TR 1122 SURVEY OF PORTIONS OF THE CHROMIUM-COBALT-NICKEL-MOLYBDENUM QUATERNARY SYSTEM AT 1,200° C, Sheldon Paul Rideout and Paul A. Beck, 1953

TR 1148 A SPECIAL INVESTIGATION TO DEVELOP A GENERAL METHOD FOR THREE-DIMENSIONAL PHOTOELASTIC STRESS ANALYSIS, M. M. Frocht and R. Guernsey, Jr., 1953

TR 1166 RELATION BETWEEN ROUGHNESS OF INTERFACE AND ADHERENCE OF PORCELAIN ENAMEL TO STEEL, J. C. Richmond, D. G. Moore, H. B. Kirkpatrick, and W. N. Harrison, 1954

TR 1173 ON TRAVELING WAVES IN BEAMS, Robert W. Leonard and Bernard Budiansky, 1954

TR 1177 COMPARISON OF PERFORMANCE OF EXPERIMENTAL AND CONVENTIONAL CAGE DESIGNS AND MATERIALS FOR 75-MILLIMETER-BORE CYLINDRICAL ROLLER BEARINGS AT HIGH SPEEDS, William J. Anderson, E. Fred Macks, and Zolton N. Nemeth, 1954

TR 1178 CALIBRATION OF STRAIN-GAGE INSTALLATIONS IN AIRCRAFT STRUCTURES FOR THE MEASUREMENT OF FLIGHT LOADS, T. H. Skopinski, William S. Aiken, Jr., and Wilber B. Huston, 1954

TR 1254 FRICTION, WEAR, AND SURFACE DAMAGE OF METALS AS AFFECTED BY SOLID SURFACE FILMS, Edmond E. Bisson, Robert L. Johnson, Max A. Swikert and Douglas Godfrey, 1956

TR 1288 COOPERATIVE INVESTIGATION OF RELATIONSHIP BETWEEN STATIC AND FATIGUE PROPERTIES OF WROUGHT N-155 ALLOY AT ELEVATED TEMPERATURES, 1956

TR 1290 DEVELOPMENT OF CRAZE AND IMPACT RESISTANCE IN GLAZING PLASTICS BY MULTIAXIAL STRETCHING, G. M. Kline, I. Wolock, B. M. Axilrod, M. A. Sherman, D. A. George, and V. Cohen, 1957

TR 1367 CALCULATED AND MEASURED STRESSES IN SIMPLE PANELS SUBJECT TO INTENSE RANDOM ACOUSTIC LOADING INCLUDING THE NEAR NOISE FIELD OF A TURBOJET ENGINE, Leslie W. Lassiter and Robert W. Hess, 1958

TR 1392 BORON AND ZIRCONIUM FROM CRUCIBLE REFRACTORIES IN A COMPLEX HEAT-RESISTANT ALLOY, R. F. Decker, John P. Rowe, and J. W. Freeman, 1958

Applicable NASA Technical Reports

TR R-13 EFFECT OF A STRINGER ON THE STRESS CONCENTRATION DUE TO A CRACK IN A THIN SHEET, J. Lyell Sanders, Jr., 1959

It is necessary to be able to determine the static strength of cracked parts. It has been found that a stress concentration factor obtained from elasticity theory will give the strength of the cracked part. A formula for calculating the stress concentration factor is given in NACA TN 3816 by McEvily, Illg, and Hardrath.

The purpose of NASA TR R-13 is to deal with the effect of a stringer on the concentration factor of a cracked sheet. The stringer extends equally on both sides of the crack and is perpendicular to the crack. The case of the broken stringer is also considered. The ratio, C, between stress concentration factors for a cracked sheet with and without stringers is presented in tables and graphically.

TR R-24 AN IMPROVED FIRST-APPROXIMATION THEORY FOR THIN SHELLS, J. Lyell Sanders, Jr., 1959

An improvement over Love's first approximation theory has been derived. All strains vanish for small rigid-body motions of the shell in the improved version. In both versions transverse and normal shear are neglected. The principal of virtual work was used to develop the derivations. The theory has been developed for two-dimensional cases.

Three strain compatibility equations are given which lead to expressions for the stress resultants and couples in terms of a set of stress functions. The expressions for the stress resultants and couples satisfy the equations of equilibrium identically.

TR R-30 LOCAL INSTABILITY OF THE ELEMENTS OF A TRUSS-CORE SANDWICH PLATE, Melvin S. Anderson, 1959

Double and single truss-core sandwich plates were analyzed to obtain the compressive buckling coefficient for local instability. Such configurations are desirable from a weight to strength basis.

The truss were idealized so that the core consisted of straignt-line elements. It was also assumed that buckling occurred with rotation of the joints but with no deflection of the joints. Angles between different elements at a joint are maintained during buckling. End effects are also neglected. The buckling coefficient was calculated and is presented in six pages of graphs at the end of the report.

TR R-39 THE PHENOMENON OF CHANGE IN BUCKLE PATTERN IN ELASTIC STRUCTURES, Manuel Stein, 1959

It has been observed that the buckling pattern of stiffened and unstiffened plates and shells changes when the buckle mode becomes unstable. The change occurs as the structure seeks a stable configuration.

The model chosen to use in analyzing the change consists of three rigid rods restrained by nonlinear springs which introduce the cubic nonlinear characteristics of plates. For initially perfect specimens, intersections between curves for the various equilibrium configurations lead to changes in the buckle pattern. These curves are presented and a discussion of how the present results may be applied to plates and other elastic structures is given.

TR R-40 LOADS AND DEFORMATIONS OF BUCKLED RECTANGULAR PLATES, Manuel Stein, 1959

Rectangular plates which are supported on all edges may carry considerable load beyond their buckling load. Von Karman's nonlinear large-deflection equations for plates are converted into a set of linear partial differential equations by expanding the displacements into a power series in terms of an arbitrary parameter. These linear equations give some solutions for the postbuckling behavior of plates in the elastic range.

Some solutions for plates with simply supported edges are presented, and these solutions are said to provide a conservative estimate of the postbuckling behavior of a rectangular plate of thin-wall construction supported by relatively stiff supporting elements. Comparison between results obtained by the linear equations will not solve the postbuckling problems of plates with initial eccentricities. Temperature was also considered in using the linear equations.

TR R-103 THEORETICAL ELASTIC STRESS STRESS DISTRIBUTIONS ARISING FROM DISCONTINUITIES AND EDGE LOADS IN SEVERAL SHELL-TYPE STRUCTURES, Robert H. Johns and Thomas W. Orange, 1961

It was necessary to find a better way to calculate the stress distributions for several different types of shells since there was no method at the time that could be used by the average engineer.

The method of analysis dealt primarily with regions where discontinuity forces were located. Where more than one discontinuity was present, it was assumed that they had no effect of the discontinuity shear and moment of the other. All shells were considered to rotate symmetrically and to be loaded by internal pressure. Stresses due to weight were not considered. The shell was imagined to be physically separated at the discontinuity. A discontinuity shear and moment must be present to preserve continuity of rotation and deflection.

The summary of solutions includes:

- Discontinuity Shear Forces and Bending Moments
  - At an axial change of thickness in a circular cylinder
  - At an axial change of thickness of a cone
  - At a change in thickness of a portion of a sphere
  - At the junction of a cylinder and a portion of a sphere
  - At the junction of a cylinder and a flat head
  - At the junction of a cone and a portion of a sphere
- Determination of Stresses and Deformations in Edge-Loaded Shells
  - Right circular cylinders
  - Frustum of a cone
  - Portion of a sphere
  - Simply supported flat plate

Not Applicable NASA Technical Reports

TR R- 5 APPLICATION OF MORSE POTENTIAL FUNCTION TO CUBIC METALS, Louis A. Girifalco and Victor G. Weizer, 1959

TR R- 12 EFFECT OF THE PROXIMITY OF THE WING FIRST-BENDING FREQUENCY AND THE SHORT-PERIOD FREQUENCY ON THE AIRPLANE DYNAMIC-RESPONSE FACTOR, Carl R. Huss and James J. Donegan, 1959

TR R- 21 ON SOLUTIONS FOR THE TRANSIENT RESPONSE OF BEAMS, Robert W. Leonard, 1959

TR R- 28 PRACTICAL SOLUTION OF PLASTIC DEFORMATION PROBLEMS IN ELASTIC-PLASTIC RANGE, A. Mendelson and S. S. Manson, 1959

TR R- 44 A PHENOMENOLOGICAL THEORY FOR THE TRANSIENT CREEP OF METALS AT ELEVATED TEMPERATURES, Elbridge Z. Stowell, 1959

TR R- 59 PREDICTED BEHAVIOR OF RAPIDLY HEATED METALS IN COMPRESSION, Elbridge Z. Stowell and George J. Heimerl, 1960

TR R- 60 A STUDY OF SOME FACTORS AFFECTING ROLLING-CONTACT FATIGUE LIFE, Thomas L. Carter, 1960

TR R- 70 AN EVALUATION OF EFFECTS OF FLEXIBILITY ON WING STRAINS IN ROUGH AIR FOR A LARGE SWEPT-WING AIRPLANE BY MEANS OF EXPERIMENTALLY DETERMINED FREQUENCY-RESPONSE FUNCTIONS WITH AN ASSESSMENT OF RANDOM-PROCESS TECHNIQUES EMPLOYED, Thomas L. Coleman, Harry Press, and May T. Meadows, 1960

TR R- 91 THE EFFECT OF REPEATED STRESSING ON THE BEHAVIOR OF LITHIUM FLUORIDE CRYSTALS, Arthur J. McEvily, Jr., and E. S. Machlin, 1961

TR R-105 SPUTTERING OF METALS BY MASS-ANALYZED N_2+ AND N+, Michel Bader, Fred C. Witteborn, and Thomas W. Snouse, 1961

TR R-112 A METHOD FOR THE CALCULATION OF LATTICE ENERGIES OF COMPLEX CRYSTALS WITH APPLICATION TO THE OXIDES OF MOLYBDENUM, William S. Chaney, 1961

Applicable Wartime Reports

WR L 2 STRESSES NEAR THE JUNCTURE OF A CLOSED AND AN OPEN TORSION BOX AS INFLUENCED BY BULKHEAD FLEXIBILITY, Paul Kuhn and Harold G. Brilmyer, August 1945

This material, while interesting, is covered in later publications. See particularly the book by Paul Kuhn, Stresses in Aircraft and Shell Structures, McGraw-Hill, 1956.

WR L 10 AN ANALYSIS OF THE FATIGUE LIFE OF AN AIRPLANE WING STRUCTURE UNDER OVERLOAD CONDITIONS, Abbott A. Putnam and Thomas D. Reisert, February 1946

Results of an analysis to determine the effect of overload operations on wing fatigue life are presented. The investigation was confined to one transport type airplane, which was assumed to operate at cruising power and with overload up to 50% of design gross weight.

Overload weight concentrated in the fuselage was found to adversely affect the fatigue life, but overload weight distributed proportionally to the design gross weight had negligible effect on the fatigue life. The fatigue life, furthermore, was adversely affected by overload to a smaller degree than the single gust life. As in the case of single gust life, the wing weight ratio was a main factor in determining the relative reduction of fatigue life by overload.

WR L 11 APPLICATION OF A NUMERICAL PROCEDURE TO STRESS ANALYSIS OF STRINGER REINFORCED PANELS, Joseph Kempner, March 1945

A numerical procedure, as well as the underlying theory and assumptions, is presented for the calculations of the stringer stresses and shear stresses in reinforced panels. The method may be applied to all panel problems in which the loads may be considered acting in the plane of the sheet.

The numerical procedure parallels that of Southwell's relaxation method and Cross's moment-distribution method but is given in the report so that the reader need have no previous knowledge of these techniques.

WR L 14 SECONDARY STRESSES IN OPEN BOX BEAMS SUBJECTED TO TORSION, Paul Kuhn, S. B. Batdorf, and Harold G. Brilmyer, November 1944

Kuhn's book, previously cited, is a more up-to-date treatment of this material.

WR L 20 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS 17S-T ALUMINUM ALLOY SHEET, George J. Heimerl and J. Albert Roy, June 1945

These tests are part of an extensive research investigation to provide data on the structural strengths of various aircraft materials. Results are presented in the form of curves and charts that may be used in the design and analysis of aircraft structures.

WR L 27 BENDING AND SHEAR STRESSES DEVELOPED BY THE INSTANTANEOUS ARREST OF THE ROOT OF A CANTILEVER BEAM ROTATING WITH CONSTANT ANGULAR VELOCITY ABOUT A TRANSVERSE AXIS THROUGH THE ROOT, Elbridge Z. Stowell, Edward B. Schwartz and John C. Houbolt, June 1945

Such stresses occur in the structure of an airplane as a result of the shocks experienced in landing. Equations are given for determining the stresses, the deflection, and the accelerations that occur in the beam as a result of the arrest of motion.

The equations for bending and shear stress reveal that, at a given percentage of the distance from the root to tip and at a given tip velocity, the bending stresses for a particular mode are independent of the length of the beam and the shear stresses vary inversely with the length. When examined with respect to a given angular velocity instead of a given tip velocity, the equations reveal that the bending stress is proportional to the length of the beam; whereas the shear stress is independent of the length.

Sufficient experimental verification of the theory has previously been given in connection with another problem of the same type.

WR L 32 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS EXTRUDED 24S-T ALUMINUM ALLOY, George J. Heimerl and J. Albert Roy, July 1945

Column and plate compressive strengths of extruded 24S-T aluminum alloy were determined both within and beyond the elastic range from tests of thin-strip columns and local instability tests of H-, A, and channel section columns. These tests are part of an extensive research investigation to provide data on the structural strength of various aircraft materials. The results are presented in the form of curves and charts that are suitable for use in the design and analysis of aircraft structures.

WR L 33 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS EXTRUDED R303-T ALUMINUM ALLOY, George J. Heimerl and Douglas P. Fay, October 1945

Strengths determined both within and beyond the elastic range from tests of thin-strip columns and local-instability tests of H-, Z-, and channel-section columns. These tests are part of an extensive research investigation to provide data on the structural strength of various aircraft materials. The results are presented in the form of curves and charts that are suitable for use in the design and analysis of aircraft structures.

WR L 34 COMPARISON OF STRUCTURAL EFFICIENCIES OF DIAGONAL TENSION WEBS AND TRUSS WEBS OF 24S-T ALUMINUM ALLOY, David W. Ochiltree, July 1945

A comparison was made of the structural efficiencies of 24S-T aluminum-alloy Pratt and Warren truss webs and diagonal-tension webs designed on the basis of identical allowable stresses. It was concluded that the diagonal-tension web is more efficient than a truss web except for a small range in which a Warren truss web is more efficient. For complete beams (webs and flanges), however, the diagonal-tension beam probably always will be more efficient than the Warren truss beam because of the low efficiency of the flanges in the Warren truss beam.

WR L 35 AN ANALYSIS OF LIFE EXPECTANCY OF AIRPLANE WINGS IN NORMAL CRUISING FLIGHT, Abbott A. Putnam, July 1945

In order to provide a basis for judging the relative importance of wing failure by fatigue and by single intense gusts, an analysis of wing life for normal cruising flight was made based on data on the frequency of atmospheric gusts. The independent variables considered in the analysis included stress-concentration factor, stress-load relation, wing loading, design and cruising speeds, design gust velocity, and airplane size. The results indicated that:

1. The fatigue life and single-gust life appear to be of about equal importance; the actual life involving either fatigue or direct failure due to overload depends on the influence of the operating conditions and the detail design and construction.

2. Occasional failures of the overload type and fatigue failures with moderate values of stress-concentration factor may be expected within the operating life of some existing airplanes.

3. The trends in design toward higher wing loading, reduced load factor, larger size, and increased speed appear to have a secondary effect on both the fatigue life and the single-gust life.

4. The design allowable stresses used for a given material have an important effect on the fatigue life of a structure, and the trend to increased design allowable stresses and more effective utilization of a material will lead to reduced fatigue life.

5. Fatigue life is determined primarily by detail design and construction and is affected only to a secondary degree by normal changes in operating speed and by moderate changes in design gust velocity.

6. Single-gust life is not appreciably affected by the detail design but is markedly affected by operating speed and by changes in design gust velocity.

WR L 37 TESTS AND APPROXIMATE ANALYSIS OF BENDING STRESSES DUE TO TORSION IN A D-SECTION BOX, John E. Duberg and Harold G. Brilmyer, May 1944

An approximation to the maximum bending stresses due to torsion that occurs near the flange of a D-section box may be obtained by computing the stresses in an equivalent rectangular box that circumscribes the D-section box. The approximation may not be conservative for the stresses near the leading edge of the D-section box, but these stresses will usually not be critical for design purposes.

WR L 44 EFFECT OF VARIATION IN DIAMETER AND PITCH OF RIVETS ON COMPRESSIVE STRENGTH OF PANELS WITH Z-SECTION STIFFENERS. I - PANELS WITH CLOSE STIFFENER SPACING THAT FAIL BY LOCAL BUCKLING, Norris F. Dow and William A. Hickman, August 1945

Experimental investigation to determine the effect of varying the rivet diameter and pitch on the compressive strength of 24S-T aluminum alloy panels with longitudinal Z-stiffeners. Panels selected on the basis of available design charts and the panel proportions were limited to the region of these charts in which the panels have the closest stiffener spacings and the smallest values of width-to-thickness ratio for the webs of the stiffeners and have such length that failure is by local buckling. The results showed that for these panels the compressive strengths increased appreciably with either an increase in the diameter of the rivets or a decrease in the pitch of the rivets. Data are also presented from which the rivet diameter and pitch required to develop a given stress in the panels may be determined.

WR L 49 CRITICAL COMBINATIONS OF LONGITUDINAL AND TRANSVERSE DIRECT STRESS FOR AN INFINITELY LONG FLAT PLATE WITH EDGES ELASTICALLY RESTRAINED AGAINST ROTATION, S. B. Batdorf, Manuel Stein, and Charles Libove, March 1946

Interaction curves are presented that give the critical combinations of stress for several different degrees of elastic edge restraint, including simple support and complete fixity. It was found that an appreciable fraction of the critical longitudinal stress may be applied to the plate without any reduction in the transverse compressive stress required for buckling.

WR L 57 EFFECT OF NORMAL PRESSURE ON THE CRITICAL COMPRESSIVE AND SHEAR STRESS OF CURVED SHEET, Norman Rafel and Charles W. Sandlin, Jr., March 1945

Results of tests of 40 specimens to determine the effect of normal pressure on the critical compressive and shear stress of curved sheet indicated the following conclusions:

1. Normal pressure appreciably raised the critical compressive stress for curved sheet when inward snap diaphragm buckling occurred.

2. Normal pressure lowered the critical compressive stress for curved sheet when outward bulging occurred.

3. Normal pressure raised the critical shear stress for curved and flat sheet regardless of whether buckles formed slowly or with a snap.

4. The greater the ratio of radius of curvature to thickness of the sheet, the greater the percentage increase in critical compressive and shear stress with increasing normal pressure.

WR L 58 AN EMPIRICAL FORMULA FOR THE CRITICAL SHEAR STRESS OF CURVED SHEETS, Paul Kuhn and L. Ross Levin, January 1945

This material is also treated by Kuhn's book. It is cited here only for reference.

WR L 59 STRAIN MEASUREMENTS AND STRENGTH TESTS ON THE TENSION SIDE OF A BOX BEAM WITH FLAT COVER, Patrick T. Chiarito and Simon H. Diskin, February 1945

In the tests of the flat stiffened tension cover of an open box beam, the stresses measured at high loads were within 10 percent of the calculated stresses for all stations except the root, at which the average measured value was about 17% lower than the value calculated by the approximate shear-lag theory and 12% lower than the value obtained by an adaptation of the exact method. When the normal stress in the flange reached the yield stress for the material and after the cover sheet in the luter panels had buckled, a spanwise readjustment of flange stress took place. The shear stresses in the cover sheet were calculated to within 10% of the measure values.

The extrapolated ultimate strain in the corner-flange angle at the root of the beam was approximately 0.012, whereas 0.015 was obtained for a double-angle tension specimen of the same cross section. These values were only about 10% of the maximum strains that were measured in gage lengths of 2 inches on standard tensile specimens of solid truss sections. These values provide an index of the maximum elongation of the corner flange of the box beam in comparison with the values of the standard tensile specimens.

The variations in strains measured at different locations on the beam and the double-angle specimen emphasized the fact that doubt still accompanies the interpretation of strains measured in riveted structures. In order to interpret more exactly the strains measured up to failure, it is necessary to obtain additional information about the influences of rivet holes.

WR L 61 PRELIMINARY INVESTIGATION OF THE RELATION OF THE COMPRESSIVE STRENGTH OF SHEET STIFFENER PANELS TO THE DIAMETER OF RIVET USED FOR ATTACHING STIFFENERS TO SHEET, Norris F. Dow and William A. Hickman, November 1944

This experiment was run to find the effect of rivet diameter on the compression strength of stiffened panels. It was found that for equal rivet spacing the compressive strength increased as the ratio of rivet diameter to overall thickness (sheet plus stiffener) increased to 1.25. These experiments were run for five different ratios of stiffener thickness to skin thickness and for different rivet spacings.

WR L 62 COMPRESSIVE STRENGTH OF FLAT PANELS WITH Z- AND HAT-SECTION STIFFENERS, Joseph N. Kotanchik, R. W. Weinberger, G. W. Zender, and J. Neff, Jr., June 1944

Has already been covered by TN 2792.

WR L 63 BENDING AND SHEAR STRESSES DEVELOPED BY THE INSTANTANEOUS ARREST OF THE ROOT OF A MOVING CANTILEVER BEAM, E. Z. Stowell, E. B. Schwartz, and J. C. Houbolt, November 1944

A theoretical and experimental investigation has been made of the behavior of a cantilever beam in transverse motion when its root is suddenly brought to rest. Equations are given for determining the stresses, the deflections, and the accelerations that arise in the beam as a result of the impact. The theoretical equations, which have been confirmed experimentally, reveal that, at a given percentage of the distance from root to tip, the bending stresses for a particular mode are independent of the length of the beam whereas the shear stresses vary inversely with the length.

This was republished as NACA Technical Report 828.

WR L 64 A METHOD FOR ESTIMATION OF MAXIMUM STRESSES AROUND A SMALL RECTANGULAR CUTOUT IN A SHEET STRINGER PANEL IN SHEAR, E. M. Moggio and H. G. Brilmyer, April 1944

Available in Chapter 8 of Kuhn's Stresses in Aircraft and Shell Structures, McGraw-Hill, 1956.

WR L 66 THE EFFECT OF CONCENTRATED LOADS ON FLEXIBLE RINGS IN CIRCULAR SHELLS, Paul Kuhn, John E. Duberg, and George E. Griffith, December 1945

Kuhn collected the more significant features of this and other of his studies in his book.

WR L 67 THE EFFECT OF INTERNAL PRESSURE ON THE BUCKLING STRESS OF THIN-WALLED CIRCULAR CYLINDERS UNDER TORSION, H. Crate, S. B. Batdorf, and G. W. Baab, May 1944

The critical stress of a cylinder in torsion increases as the internal pressure increases. The following interaction formula was found to represent approximately the buckling of a cylinder of moderate length under the combined effects of torsion and internal pressure:

$$R_s^2 + R_p = 1$$

where R_s is the ratio of critical shear stress with internal pressure to critical shear stress without internal pressure and R_p is the ratio of internal pressure to the critical pressure in the absence of torsion.

WR L 104 STRAIN MEASUREMENTS AND STRENGTH TESTS OF 25-INCH DIAGONAL-TENSION BEAMS WITH SINGLE UPRIGHTS, James P. Peterson, November 1945

For the tests onnine beams described herein, the stresses in the uprights throughout the load range were predicted with fair accuracy unless the stresses exceeded the elastic limit of the material used in the uprights. The loads at which the uprights failed were predicted with a maximum error of 10%.

The theoretical stress concentration in the webs caused by the flexibility of the flanges was too high for the beams with a 20 inch upright spacing and the strength predictions for these beams were therefore up to 32% conservative. The strength of the webs of beams with a 10 inch upright spacing were predicted with a maximum error of 6%.

WR L 106 SHEAR LAG TESTS OF A BOX BEAM WITH A HIGHLY CAMBERED COVER IN TENSION, James P. Peterson, July 1945

1. The average stringer stresses near the root were in fair agreement with the stresses calculated by the shear-lag theory, although individual stress values showed appreciable scatter.

2. The ultimate tensile stress developed by the beam was only slightly higher than the tensile yield stress of the material.

WR L 121 FREQUENCY OF OCCURRENCE OF ATMOSPHERIC GUSTS AND OF RELATED LOADS ON AIRPLANE STRUCTURES, Richard V. Rhode and Philip Donely, November 1944

Data from V-G records totaling 9,000,000 miles of operation are related. Similar data of German origin are also included for comparison.

It was concluded that the distribution of gusts within turbulent regions of the earth's atmosphere follows a substantially fixed pattern regardless of the source of the turbulence. The total frequencies are therefore governed by the total length of the flight path in rough air, and operating conditions determine the total frequencies only by affecting the ratio of the length of flight path in rough air to total length of the path. Gust load frequencies were found to be inversely proportional to airplane size.

It was further concluded that the gust frequencies can be applied with small error to the estimation of stress frequencies in the primary structures of airplanes. The results of the analysis are applicable to the fatigue testing of the primary structure of the airframe and to the estimation of the probability of encountering gusts of excessive intensity within any stated period of operation.

WR L 173 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS EXTRUDED 75S-T ALUMINUM ALLOY, George J. Heimerl and J. Albert Roy, July 1945

The results, which are presented in the form of curves and charts that are suitable for use in the design and analysis of aircraft structures, supersede preliminary results published previously.

These tests are part of an extensive research program to provide data on the structural strength of various aircraft materials.

WR L 176 TENSILE TESTS OF NACA AND CONVENTIONAL MACHINE COUNTERSUNK FLUSH RIVETS, Merven W. Mandel and Leonard M. Bartone, October 1944

For the same rivet-head angle and for a given value of c/d, ratio of countersunk depth to rivet diameter, the NACA rivets developed a higher tensile strength than the conventional rivets.

Results are in chart and graph form.

WR L 180 DETERMINATION OF DESIRABLE LENGTHS OF Z AND CHANNEL SECTION COLUMNS FOR LOCAL INSTABILITY TESTS, George J. Heimerl and J. Albert Roy, October 1944

For local instability tests of Z and channel section columns, the specimens should be just long enough to avoid the increased strength associated with short lengths but of such length that a buckling pattern convenient for test purposes occurs. A buckling pattern of three half-waves meets these requirements; the proper length for this condition may be obtained from a curve based on tests. When the strength for local instability is very high, a reduction in this length may be necessary to prevent column failure. In order to avoid the increased strength associated with short lengths, a ratio of length to web width above 3.5 should be used.

WR L 183 CRITICAL COMBINATIONS OF SHEAR AND TRANSVERSE DIRECT STRESS FOR AN INFINITELY LONG FLAT PLATE WITH EDGES ELASTICALLY RESTRAINED AGAINST ROTATION, S. B. Batdorf and John C. Houbolt, January 1945 (Reissued as TR 847)

This report found that an infinitely long flat plate may be loaded with an appreciable fraction of its critical stress in pure shear without the transverse compressive stress necessary to produce buckling being reduced. Interaction formulas of the type

$$R_1^p + R_2^q + R_3^r + \dots = 1$$

are decidedly conservative when used for finding the results of shear and transverse compression when applied to an infinitely long plate.

$$K_s^2 =$$

$$K_c^2\left[\left(\epsilon\pi\sqrt{K_c}+2\pi\sqrt{K_c}+\frac{2\epsilon}{\pi\sqrt{K_c}}\right)\sin\pi\sqrt{K_c}+\left(\frac{\pi^2}{2}-2\epsilon-\frac{\epsilon^2}{2}\right)\cos\pi\sqrt{K_c}-\frac{\epsilon^2}{\pi^2K_c}\left(\cos\pi\sqrt{K_c}-1\right)\right]$$

$$\Big/\left[\left(-\frac{\pi^3}{12}K_c\sqrt{K_c}-6\pi\sqrt{K_c}-2\pi\epsilon\sqrt{K_c}+\frac{\epsilon^2}{12}\pi\sqrt{K_c}+\frac{3\epsilon^2}{2\pi}\sqrt{K_c}\right)\sin\pi\sqrt{K_c}+\left(-\frac{3\pi^2}{4}K_c\right.\right.$$

$$\left.+\frac{\epsilon\pi^2K_c}{6}-\frac{3}{4}\epsilon^2\right)\cos\pi\sqrt{K_c}$$

$$\left.+\left(4+8\epsilon+2\epsilon^2+\frac{3\epsilon^2}{2\pi^2K_c}\right)\left(\cos\pi\sqrt{K_c}-1\right)\right]$$

$$\epsilon = \frac{-\pi\sqrt{K_c}}{\tan\frac{\pi\sqrt{K_c}}{2}}$$

The above equations give the relation between the critical compressive and the critical shear-stress coefficients K_c and K_s respectively.

$$\sigma_y = \frac{K_c \pi^2 D}{b^2 t}$$

$$\tau = \frac{K_s \pi^2 D}{b^2 t}$$

σ_y = transverse direct shear
τ = shear stress
D = $Et^3/12(1 - \mu^2)$
t = thickness of plate
b = width of plate
E = Young's modulus
μ = Poisson's ratio

WR L 187 CHARTS FOR THE DETERMINATION OF WING TORSIONAL STIFFNESS REQUIRED FOR SPECIFIED ROLLING CHARACTERISTICS OR AILERON REVERSAL SPEED, Henry A. Pearson and William S. Aiken, Jr., December 1944 (Reissued as TR 799)

This report gives a series of charts which give the required wing torsional stiffness required to meet a given standard of rolling effectiveness, the aileron span and location are variables, induced lift effects have been included, and the charts can be used for both linearly tapered and elliptical wings of tubular construction. Wing aspect ratios run from 5 to 16.

WR L 189 INVESTIGATION OF METHODS OF SUPPORTING SINGLE THICKNESS SPECIMENS IN A FIXTURE FOR DETERMINATION OF COMPRESSIVE STRESS-STRAIN CURVES, Joseph N. Kotanchik, Walter Woods and Robert A. Weinbergen, May 1945

TN 819 is a reissue of this report.

WR L 190 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS 24S-T ALUMINUM ALLOY SHEET, Eugene E. Lundquist, Evan H. Schuette, George J. Heimerl, and J. Albert Roy, June 1945

The report contains the test data from a series of experiments made on 24S-T sheet. This data may be used in the design and analysis of aircraft structure. It is available as curves and listed in charts. This data should only be used where the structure uses 24S-T sheet having similar compressive properties.

WR L 192 ON THE SHEAR STRENGTH OF SKIN STIFFENED PANELS WITH INSPECTION CUT OUTS, Paul Kuhn and Simon H. Diskin, March 1945

Information available in Kuhn's Stresses in Aircraft and Shell Structures.

WR L 197 CHARTS FOR THE MINIMUM WEIGHT DESIGN OF 24S-T ALUMINUM ALLOY FLAT COMPRESSION PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS, Evan H. Schuette, August 1945 (Reissued as TR 827)

This report presents charts for designing flat compressive panels with z-section stiffeners of 24S-T aluminum of the lighest possible kind. It was found that for many uses this lightest possible panel maintained a buckle-free surface. However, the report points out that this maximum possible efficient structure uses closer stiffeners than those in use at the time of this report.

WR L 198 THE DETERMINATION OF EFFECTIVE COLUMN LENGTH FROM STRAIN MEASUREMENTS, Evan H. Schuette and J. Albert Roy, June 1944

A method was needed for experimental determining the effective length of a column. It was found that by mounting strain gages along the sides of the column the curvature could be measured.

$$1/r = \frac{\epsilon_1 - \epsilon_2}{d}$$

$1/r$ = curvature
ϵ = strain at point in cross section
d = distance between points in cross section for the strains ϵ_1 and ϵ_2 are taken measured perpendicular to the neutral axis

The points of zero curvature are the points of inflection. This method should not be used when there is buckling since this adversely affects the strain measurements.

WR L 204 CHARTS FOR CALCULATION OF THE CRITICAL COMPRESSIVE STRESS FOR LOCAL INSTABILITY OF IDEALIZED WEB- AND T-STIFFENED PANELS, Rolla B. Boughan and George W. Baab, August 1944

Working charts are presented for use in calculating the critical compressive stress of stiffened panels, and examples are included to demonstrate their use.

WR L 224 CHARTS FOR CRITICAL COMBINATIONS OF LONGITUDINAL AND TRANSVERSE DIRECT STRESS FOR FLAT RECTANGULAR PLATES, Charles Libove and Manuel Stein, March 1946

This report presents charts for the critical combinations of longitudinal and transverse direct stress of isotropic flat rectangular plates with all edges simply supported, long edges simply supported and short edges clamped, long edges clamped and short edges simply supported, and all edges clamped. The charts are based on energy equations. In the charts k_x is plotted against β and then k_x is plotted versus k_y.

The following equations give the critical longitudinal and transverse stresses.

$$\sigma_y = k_y \frac{\pi^2 D}{b^2 t} \qquad \sigma_x = k_x \frac{\pi^2 D}{b^2 t}$$

a = length of plate
b = width of plate
β = length-width ratio (a/b)
t = thickness of plate
E = elastic modulus
μ = Poisson's ratio
D = $Et^3/12(1 - \mu^2)$
σ_x = longitudinal direct stress, positive for compression
σ_y = transverse direct stress
k_x, k_y = dimensionless stress coefficients

WR L 225 MATERIAL PROPERTIES OF TWO TYPES OF PLASTIC-BONDED GLASS CLOTH, Norman Rafel and Evan H. Schuette, December 1944

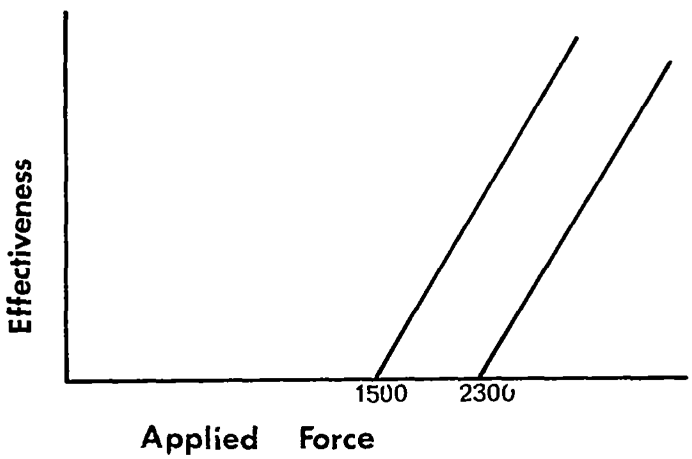
Outdated. Concerned with fiberglas to determine its value in aircraft use. Fiberglas is in common use today as a permanent cover for fabric aircraft.

WR L 252 COMPARISON OF TIGHTNESS OF 78° MACHINE-COUNTERSUNK RIVETS DRIVEN IN HOLES PREPARED WITH 78° AND 82° COUNTERSINKING TOOLS, Robert Gottlieb and Merven W. Mandel, September 1942

There is not enough difference in the strength when 78° countersinking tools are used instead of 82° countersinking tools to be of practical use. It was found that if the rivet projects above the skin before being driven then a tight rivet is obtained.

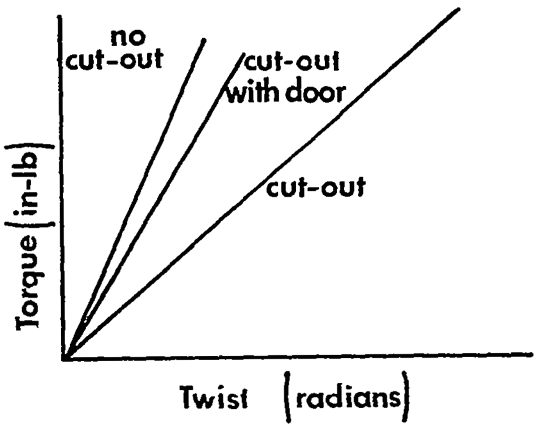
WR L 253 TESTS OF STRESS CARRYING DOOR IN COMPRESSION, Robert Gottlieb, September 1942

Tests were made of a monocoque box in compression to determine the effectiveness of a door placed in the cutout on the compression side of the cylinder. The effectivensss is defined as either the ratio of the stress around the cutout before the door to the stress around the cutout after the door is in place, or the ratio of the load carrying capacity that was lost to the load carrying capacity that was regained when the door was inserted. The door becomes effective in load carrying at 1500 lbs. and in stress reducing at 2300 lbs. The door is not effective at low loads because a certain amount of load is necessary to close the gap between the door and the cutout.



WR L 254 TESTS OF A STRESS-CARRYING DOOR IN SHEAR, Robert Gottlieb, August 1942

A monocoque box with a stress carrying door placed in a cutout was tested in torsion. It was found that much of the torsional stiffness lost when the cutout was made was regained by the door, in fact if the door and its frame are made sufficiently heavy then the torsional stiffness can be greater with the door than before the cutout.



WR L 255 EXTENDED TABLES OF STIFFNESS AND CARRY-OVER FACTOR FOR STRUCTURAL MEMBERS UNDER AXIAL LOAD, Eugene E. Lundquist and W. D. Kroll, February 1944

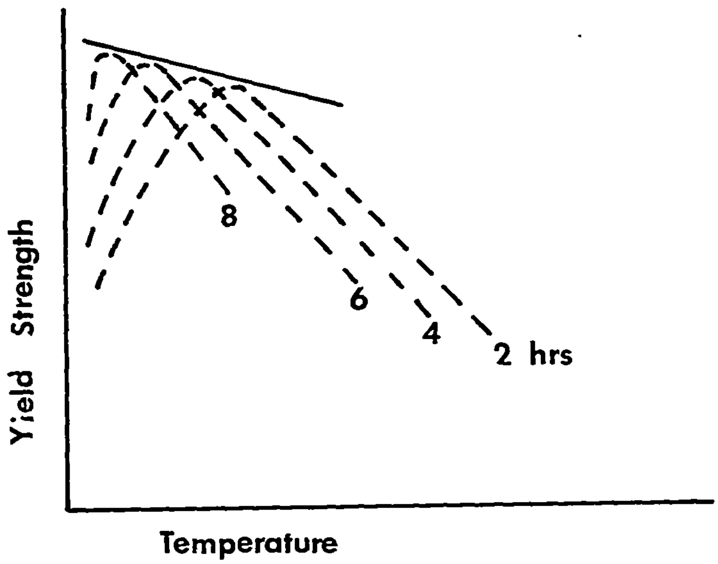
Concerns member under axial load with equal end moments; the solution to this problem is available in Bruhn's handbook.

WR L 256 THE EFFECT OF INITIAL DISPLACEMENT OF THE CENTER SUPPORT ON THE BUCKLING OF A COLUMN CONTINUOUS OVER THREE SUPPORTS, Eugene E. Lundquist and Joseph N. Kotanchik, November 1940

Tests were run to determine the effect on the critical load of the two spans of a column supported by three supports when the center support is allowed an initial displacement. The critical load for the two spans are both reduced by the initial displacement, but this displacement is so small that the effect of curvature due to bending on the critical load for the compression flange material of a box beam is probably small and can be neglected in engineeringdesign. The center support was allowed to deflect by being hinged so as to be free to move parallel to the column during buckling.

WR L 257 THE EFFECT OF ARTIFICIAL AGING ON THE TENSILE PROPERTIES OF ALCLAD 24S-T AND 24S-T ALUMINUM ALLOY, Joseph N. Kotanchik, Walter Woods, and George W. Zender, August 1943

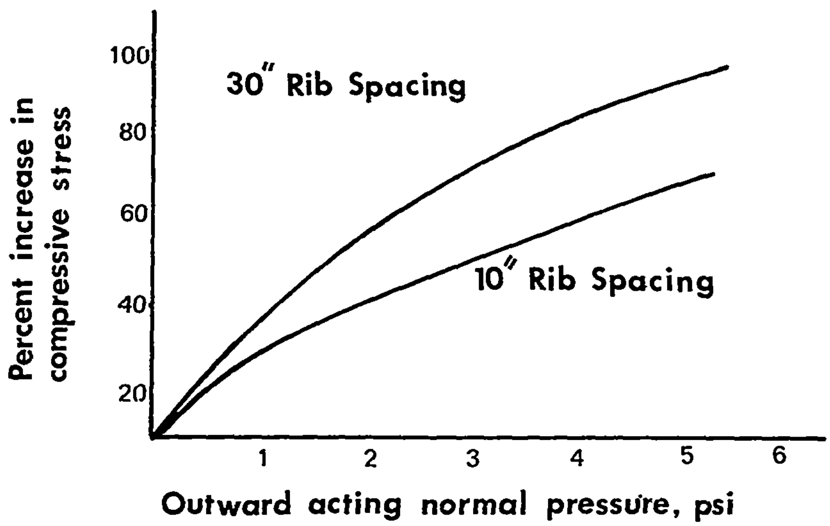
The effect of aging on 24S-T Alclad and sheet is nearly the same. For every temperature there is a length of time that gives a maximum value of strength. While aging caused a slight increase in ultimate yield strength in cause of large decrease in elongation.



WR L 258 EFFECT OF NORMAL PRESSURE ON THE CRITICAL COMPRESSIVE STRESS OF CURVED SHEET, Norman Rafel, November 1942

Tests were made to determine experimentally the effect of normal pressure on the critical compressive stress of a curved sheet. A shell was formed by fastening two curves sheets together at the edges and applying an air load to their inner surfaces.

Loading the sheets by applying the air load increases the critical compressive stress. The increase in compressive load, percentage-wise, is greater for unstiffened or lightly stiffened sheets.



WR L 259 SOME STRENGTH TESTS OF STIFFENED CURVED SHEETS LOADED IN SHEAR, Patrick T. Chiarito, April 1944

First part of a series of tests to be run to find the effect of shear on curved sheets. Tests were made of curved web beams and cylindrical shells of 24S-T aluminum alloy. No conclusions were made but the data from the first series of tests was listed. There was a wide scattering of the data.

WR L 268 THE EFFECT OF ANGLE OF BEND BETWEEN PLATE ELEMENTS ON THE LOCAL INSTABILITY OF FORMED Z-SECTIONS, J. Albert Roy and Evan H. Schuette, September 1944

39 Z-sections formed from 24S-T alloy sheet with the angle of bend between the flanges and the web varying from 5° to 120° were tested as columns. Angles of bend from 30° to 120° had little or no effect on the critical stress or on the average stress at maximum load for local instability of the columns. The lengths of the columns were such that at angles of bend below 30° they failed by Euler buckling.

WR L 280 COMPARISON TESTS OF SIX CURVED PAPER-BASE PLASTIC PANELS WITH OUTWARD-ACTING NORMAL PRESSURE, Evan H. Schuette, Norman Rafel, and Charles V. Dobrowski, September 1944

Outdated material.

WR L 284 COLUMN AND PLATE COMPRESSIVE STRENGTHS OF AIRCRAFT STRUCTURAL MATERIALS EXTRUDED 14S-T ALUMINUM ALLOY, George J. Heimerl and Donald E. Niles, May 1946

Column and plate compressive strengths of extruded 14S-T aluminum alloy were determined both within and beyond the elastic range from tests of flat-end H-section columns and from local-instability tests of H-, Z- and channel-section columns. These tests are part of an extensive research investigation to provide data on the structural strength of various aircraft materials. The results are presented in the form of curves and charts that are suitable for use in the design and analysis of aircraft structures.

WR L 293 TESTS OF HYDRAULICALLY EXPANDED RIVETS, Merven W. Mandel, Harold Crate, and Evan H. Schuette, March 1944

An investigation was made to determine the tightness, shear strength, tensile strength and life under pulsating loads of hollow, hydraulically expanded rivets. Two types of 17S-T aluminum alloy rivets of 1/8 inch diameter - countersunk-head rivets with a 24S-T aluminum-alloy insert in the hollow shank and modified-roundhead rivets with no insert - were investigated. The tests results indicate that the countersunk-head rivets, with inserts, had an average maximum load in shear more than 150% greater than the average maximum load for the modified-roundhead rivets, which had no insert. The average yield load for the countersunk-head rivets, however, was only slightly more than that for the modified-roundhead rivets. For modified-roundhead rivets having bores of 0.085 inch or of 0.100 inch diameter, there was no appreciable difference due to bore diameter in either the yield load or the maximum load in shear, or in the maximum tensile load. In tension tests, both types of rivet tended to fail by pulling the shank end of the rivet through the sheet, if the hollow length of the rivet protruded 0.116 inch or less beyond the sheets. In the pulsating-load tests, the looseness of the rivets apparently induced relatively severe loading conditions. As a result, the life of the joints was very short, 70 cycles or less.

WR L 294 A STUDY OF THE TIGHTNESS AND FLUSHNESS OF MACHINE-COUNTERSUNK RIVETS FOR AIRCRAFT, Eugene E. Lundquist and Robert Gottlieb, June 1942

Methods investigated:

1. The manufactured head of the countersunk rivet is buckled on a flat plate while the shank end is driven by hand with a hammer.

2. The manufactured head of the countersunk rivet is buckled on a flat plate while the shank end is driven with a vibrating gun.

3. The manufactured head of the countersunk rivet is driven with a vibrating gun while the shank end is buckled with a bar.

4. The countersunk rivet is driven with a pneumatic squeeze.

5. The manufactured roundhead of the rivet is driven with a vibrating gun while the shank end is buckled with a bar. After the rivet is driven, the portion of the formed head that protrudes above the skin surface is milled off and finished smooth with the sheet.

CONCLUSIONS:

A comparison of the quality of machine-countersunk riveted joints on the basis of maximum load alone is not justified. For the rivets on the exterior surfaces of aircraft, it appears that flushness and yield load as a measure of tightness should be the criterior or quality.

The fact that higher yield loads were obtained by riveting methods 1, 2, 3 and 4 when h_b was positive than when h_b was negative indicated that the driving of the rivet material into the hole to fill it is the most important factor in obtaining tight rivets.

Because riveting method 5 gave higher yield loads than methods 1, 2, 3 and 4, it is probable that, of the riveting methods investigated, this method of riveting fills the hole most completely. In the process of driving the rivets of method 5, the shank swells along its entire length, filling the countersunk-rivet hole progressively from bottom to top.

In addition to producing right rivets, any method of riveting that completely fills the machine countersunk holes and removes the protruding portions of the rivet heads after driving also provides a method of obtaining a uniform surface finish that is particularly useful where extreme smoothness is required. Use of either of the milling tools to remove the protruding portions of the rivet heads will give a surface sufficiently smooth that, when the surface is painted and rubbed down, the rivets cannot be detected. If paint is not applied, a final rubbing down or finishing operation on the metal surface is required to accomplish the same results. Rivets installed by method 5 could not be detected by inspection of the unpainted surface when the final finish was made.

It appears that separate operations are necessary in the procedure of riveting if the joints are to be of high quality with respect to both tightness of the joint and flushness of the rivet.

h_b = height of the rivet head above or below the skin surface before driving

WR L 297 COMPARATIVE TESTS OF THE STRENGTH AND TIGHTNESS OF COMMERCIAL FLUSH RIVETS OF ONE TYPE AND NACA FLUSH RIVETS IN MACHINE COUNTERSUNK AND COUNTERPUNCHED JOINTS, Merven W. Mandel

An investigation was conducted to compare the strength and tightness of machine-countersunk flush-riveted joints assembled with NACA flush rivets and one type of commercial flush rivet and also to compare the strength and tightness of counterpunched flush-riveted joints assembled with the same types of rivet. The results of the investigation are presented in the form of load-displacement curves, which indicate that the NACA flush-riveted joints tended to be somewhat stronger and tighter than the corresponding commercial flush-riveted joints. The test results also show that both the commercial and NACA counterpunched flush-rivet specimens had considerably greater strength than the machine-countersunk specimens of corresponding sheet thickness.

WR L 307 SHEAR-LAG TESTS OF TWO BOX BEAMS WITH FLAT COVERS LOADED TO DESTRUCTION, Patrick T. Chiarito, October 1942

Strain-gage tests were made on two box beams loaded to destruction in an attempt to verify the shear-lag theory at stresses beyond the yield point. The tests results indicated that the corner-flange stresses can be predicted with a fair degree of accuracy. Collapse of both beams was precipitated by failure of the corner angles at stresses close to the column yield stress of the material.

Theory tested: NACA Rep. 739, 1942, Kuhn, Paul, and Chiarito, Patrick T.

WR L 310 COMPARISON OF AN APPROXIMATE AND AN EXACT METHOD OF SHEAR-LAG ANALYSIS, John E. Duberg, January 1944

In beams of practical proportions the approximate theory of the substitute single stringer will predict a conservative value for the maximum corner-flange stress which, on the basis of the exact solutions, will be in error by less than 10%. Comparisons with experimental results indicate that the difference between the substitute single-stringer solution for the maximum corner flange and observed values is, in general, less than the value of 10% indicated by the exact method.

Adequate values for design stress for stringers and sheets of axially loaded panels can be obtained by the substitute single-stringer method, while the exact method greatly exaggerates the maximum shear stress.

WR L 315 EFFECT OF COUNTERSUNK DEPTH ON THE TIGHTNESS OF TWO TYPES OF MACHINE-COUNTERSUNK RIVET, Robert Gottlieb, October 1942

Method 3 - The manufactured head of the countersunk rivet is driven with a vibrating gun while the shank end is bucked with a bar. The commercial rivet head is turned down in a lathe in order to control, for the different countersunk depths, the height h_b of the rivet head above or below the skin surface before driving. This height is designated as positive when the rivet head is above the sink surface and negative when the rivet head is below the skin surface. In this investigation, h_b was made approximately 0.005, 0.000 or -0.005 inch.

Method 5 - The manufactured roundhead of the rivet is driven with a vibrating gun while the shank end is bucked with a bar. After the rivet is driven, the portion of the formed head that protrudes above the skin surface is milled off with a flush-rivet milling tool.

CONCLUSIONS:

1. Riveting method 5 produces flush rivets of consistently higher strength quality than method 3 for all depths of countersink investigated.

2. For a given sheet thickness, the yield load for riveting method 5 is almost independent of the depth of countersink; whereas, for riveting method 3, the yield load is appreciably lowered by an increase in the depth of countersink.

3. For a given sheet thickness and depth of countersink, riveting method 3 develops better strength qualities when h_b is positive than when h_b is negative.

WR L 323 THE STRENGTH AND STIFFNESS OF SHEAR WEBS WITH ROUND LIGHTENING HOLES HAVING 45° FLANGES, Paul Kuhn, December 1942

WR L 324 AN APPROXIMATE METHOD OF SHEAR-LAG ANALYSIS FOR BEAMS LOADED AT RIGHT ANGLES TO THE PLANE OF SYMMETRY OF THE CROSS SECTION, Paul Kuhn and Harold G. Brilmyer, September 1943

These two reports were reviewed by Kuhn for his book. The essential features and subsequent developments are reported therein. The reports are cited here only to indicate their applicability to the present project.

WR L 326 PRINCIPLES OF MOMENT DISTRIBUTION APPLIED TO STABILITY OF STRUCTURES COMPOSED OF BARS OR PLATES, Eugene E. Lundquist, Elbridge Z. Stowell, and Evan H. Schuette, November 1943

The principles of the Cross method of moment distribution, which have previously been applied to the stability of structures composed of bars under axial load, are applied to the stability of structures composed of long plates under longitudinal load. A brief theoretical treatment of the subject, as applied to structures composed of either bars or plates, is included, together with an illustrative example for each of these two types of structure. An appendix presents the derivation of the formulas for the various stiffnesses and carry-over factors used in solving problems in the stability of structures composed of long plates.

References: Cross, Hardy, Analysis of Continuous Frames by Distributing Fixed-End Moments. Trans. Am. Soc. Civil Eng., vol. 96, 1932, pp. 1-10.

WR L 340 CRITICAL STRESS FOR AN INFINITELY LONG FLAT PLATE WITH ELASTICALLY RESTRAINED EDGES UNDER COMBINED SHEAR AND DIRECT STRESS, Elbridge Z. Stowell and Edward B. Schwartz, November 1943

It is concluded that the values of combined shear and direct stress at which an infinitely long, flat plate supported along the edges with equal elastic restraints against rotation may be determined for practical engineering purposes by the equation

$$R_c + R_s^2 = 1$$

where:

R_c = ratio of direct stress when buckling occurs in combined shear and direct stress to compressive stress when buckling occurs in pure compression; tension is regarded as negative compression

R_s = ratio of shear stress when buckling occurs in combined shear and direct stress to shear stress when buckling occurs in pure shear

WR L 352 A METHOD OF CALCULATING BENDING STRESSES DUE TO TORSION, Paul Kuhn, December 1942

WR L 367 THE STRENGTH OF PLANE WEB SYSTEMS IN INCOMPLETE DIAGONAL TENSION, Paul Kuhn and Patrict T. Chiarito

WR L 368 STRESSES AROUND RECTANGULAR CUTOUTS IN SKIN-STRINGER PANELS UNDER AXIAL LOADS - II, Paul Kuhn, John E. Duberg, and Simon H. Diskin, October 1943

Comments on these three reports are the same as those for WR L 324.

WR L 393 SHEAR TESTS ON DUPONT EXPLOSIVE RIVETS WITH THE COUNTERSUNK HEAD MILLED FLUSH AFTER EXPANSION, Robert Gottlieb and Leonard M. Bartone, May 1943

In previous reports it has been found desirable to allow the head of a machine-countersunk rivet to protrude a definite amount above the skin surface before driving and then to remove the protruding portion after driving. In this way, tight and smooth rivets were obtained even though large tolerances in countersunk depth were permitted.

This paper is a similar investigation in which the heads of DuPont explosive countersunk rivets were allowed to protrude varying amounts above the skin surface before expansion and the protruding portions were removed after expansion.

On the basis of these few tests, it would appear desirable to investigate the possibility of filling the entire shank with an explosive charge in order to permit greater tolerances in the diameter of the drilled hole and still produce consistently tight rivets. This advantage might outweigh the disadvantage of the reduced maximum load that would result from the decrease in cross-sectional area of the rivet shank.

WR L 398 TABLES OF STIFFNESS AND CARRY-OVER FACTOR FOR FLAT RECTANGULAR PLATES UNDER COMPRESSION, W. D. Kroll, November 1943

38 pages of tables are presented of stiffness and carry-over factor for infinitely long flat plates subjected to a uniformly distributed longitudinal compressive load. The tables are intended for use in solving problems in the stability of structures composed of plates under compression.

WR L 399 STRESSES AROUND RECTANGULAR CUTOUTS IN SKIN-STRINGER PANELS UNDER AXIAL LOADS, Paul Kuhn and Edwin M. Moggio, June 1942

WR L 401 A PROCEDURE FOR THE SHEAR-LAG ANALYSIS OF BOX BEAMS, Paul Kuhn, January 1943

WR L 402 THE STRENGTH AND STIFFNESS OF SHEAR WEBS WITH AND WITHOUT LIGHTENING HOLES; Paul Kuhn, June 1942

The material in these three reports has been adequately summarized in Kuhn's book.

WR L 416 EFFECT OF NORMAL PRESSURE ON THE CRITICAL SHEAR STRESS OF CURVED SHEET, Norman Rafel, January 1943

1. Loading of the specimen until buckling occurred at normal pressure as high as 6 psi did not appreciably injure the specimen for additional tests at different pressures. The presence of permanent buckles, however, did lower the critical shear stress for the specimen.

2. An outward-acting normal pressure appreciably raises the critical shear stress for unstiffened curved sheet.

3. The absolute increase in critical shear stress caused by normal pressure was slightly greater for a 30-inch rib spacing than for a 10-inch spacing. On the basis of percentage, however, the increase in critical shear stress caused by normal pressure is considerably greater for the 30-inch rib spacing than for the 10-inch spacing.

4. The curve of shear stress against normal pressure at which buckles disappeared was always below the curve of shear stress against normal pressure at which the buckled appeared.

5. The relationship between shear stress and normal pressure at which buckles disappeared is independent of whether the buckles were made to disappear by increase of normal pressure or by decrease of shear stress.

6. The torsional stiffness of the specimens before buckling was not affected significantly by an outward-acting normal pressure.

WR L 429 CHARTS FOR CALCULATION OF THE CRITICAL STRESS FOR LOCAL INSTABILITY OF COLUMNS WITH I-, Z-, CHANNEL AND RECTANGULAR-TUBE SECTION, W. D. Kroll, Gordon P. Fisher, and George J. Heimerl, November 1943

These charts are intended to replace the less complete charts published in NACA TN 743.

An experimental curve is included for use in taking into account the effect of stresses above the elastic range on the modulus of elasticity of 24S-T aluminum alloy.

WR L 442 STRENGTH TESTS OF THIN-WALL TRUNCATED CONES OF CIRCULAR SECTION, Eugene E. Lundquist and Evan H. Schuette, December 1942

Since monocoque fuselages usually have some taper, tests were made to determine the strength of thin-wall truncated cones of circular section in torsion, compression, and combine transverse shear and bending. It was found that the strength of the cone could be computed by the formulas for thin-walled cylinders as long as the angle between the sides of the cone and the axis is taken into account.

T = applied torque at failure
r = radius at a particular section
t = thickness
f_s = shear stress at failure
f_c = compressive stress at failure
P = applied compressive load
α = angle between axis of the cone and the longitudinal elements of the surface
f_b = maximum bending stress at failure
M = applied moment at failure
I = moment of inertia of the cross section
f_v = maximum shear stress at failure for combination loading
V' = effective shear at failure $(V - V_b)$
V = applied transverse shear
V_b = shear resisted by bending stresses $(M \tan \alpha)/r$

$$f_s = \frac{T}{2\pi r^2 t} \qquad f_c = \frac{P}{2\pi r t} \sec \alpha \qquad f_c = f_{c_1} \frac{r_1}{r}$$

$$f_b = \frac{Mr}{I} \sec \alpha = \frac{M}{\pi r^2 t} \sec \alpha$$

$$f_v = \frac{V' r^2}{I} = \frac{V'}{\pi r t}$$

Subscript 1 denotes cone base.

WR L 466 CRITICAL STRESSES FOR PLATES, Eugene E. Lundquist and Evan H. Schuette, October 1943

This is a review of part of the work done by NACA on the subject of the critical stresses for plates in compression and in shear, as well as in combined direct stress and shear. Although some theoretical methods are presented, the main emphasis is on the practical significance and use of the results of both theoretical studies and laboratory tests concerned with the buckling of plates.

WR L 472 THE LONGITUDINAL SHEAR STRENGTH REQUIRED IN DOUBLE-ANGLE COLUMNS OF 24S-T ALUMINUM ALLOY, Paul Kuhn and Edwin M. Moggio, May 1943

Tests were made of riveted double-angle columns to determine the total rivet strength that is required to make these built-up columns develop the strength predicted by the standard column formulas. Results of the tests led to the conclusion that the required rivet strength may be calculated by the beam method of design where:

$$R_R = 100 \frac{Q}{b} \sqrt{c}$$

with:

R_R = required rivet strength, ksi
Q = static moment of cross-section of one angle about neutral axis of column, $in.^3$
b = width of outstanding lag, inches
c = fixity coefficient

The minimum pitch, of course, must be chosen to prevent buckling of the individual angles between rivets.

WR L 476 CRITICAL SHEAR STRESS OF AN INFINITELY LONG FLAT PLATE WITH EQUAL ELASTIC RESTRAINTS AGAINST ROTATION ALONG THE PARALLEL EDGES, Elbridge Z. Stowell, November 1943

A chart for the values of the coefficient in the formula for the critical shear stress at which buckling may be expected to occur in an infinitely long flat plate with parallel edges is presented.

The plate is assumed to have supported edges with equal elastic restraints against rotation along their length. The mathematical derivations of the formulas required for the construction of the chart are given in two appendices.

WR L 482 SHEAR-LAG TESTS OF TWO BOX BEAMS WITH CORRUGATED COVERS LOADED TO FAILURE, Patrick T. Chiarito, January 1944

Strain measurements were made on the compressive side of the box beams with corrugated aluminum sides loaded to failure. The corner flanges were formed from sheet for box 1 where the angle was extruded for box 2. The shear lag theory gave values within 10% for beam 1 and 5% for beam 2. Failure in the beams occurred at the corner angles at a stress that was higher than the compressive yield stress of the material. Both the formed and extruded angles were thicker than the cover (side) sheet.

WR L 495 A PRELIMINARY STUDY OF MACHINE-COUNTERSUNK FLUSH RIVETS SUBJECTED TO A COMBINED STATIC AND ALTERNATING SHEAR LOAD, Harold Crate, December 1943

Tests were made to determine the effect of the length of the head of the rivet protruding on the number of cycles to failure of a machine-countersunk flush-riveted joint under a combined static and alternating shear load.

When the head of the rivet protruded before the rivet was driven the number of cycles to failure varied from 500,000 to 1,000,000; when the head was below the level of the skin the number of cycles varied from 50 to 100. If h_b, height of the rivet head above the sheet before being driven, was zero or positive the failure was in the sheet, but if h_b was negative the failure was by shear of the rivet.

WR L 499 COMPRESSIVE STRENGTH OF FLAT PANELS WITH Z-SECTION STIFFENERS, Carl A. Rossman, Leonard M. Bartone, and Charles V. Dobrowski, February 1944

This was a study to determine the effect of varying ratios of different dimensions.

b_A = width of attachment flange
b_F = width of outstanding flange
b_S = spacing of stiffeners
b_W = width of web
t_W = thickness of web
t_S = thickness of sheet
L = length

The specimens with $b_F/b_W = .2$ had less compressive stress at maximum load than those specimens with b_F/b_W's of .3, .4 or .5. Little change takes place in the average stress when b_F/b_W is above .3. The average stress at maximum load and the buckling stress decrease with increasing b_S/t_S. The average stress at maximum load increases with increasing t_w/t_s, but there appears to be no trend with buckling stress for changes in t_w/t_s. Changes in b_w/t_w appear to have little effect on either the buckling load or the stress at maximum load.

WR L 500 TESTS OF 10-INCH 24S-T ALUMINUM-ALLOY SHEAR PANELS WITH 1-1/2 INCH HOLES, Paul Kuhn and L. Ross Levin, June 1943

Tests were made on stress panels to determine the effect on the strength of 1-1/2 inch holes. This is the size hole that is used for conduits, tubing and control cables. The average factor of stress was about 1.1 times the stress without the hole. In thin specimens with holes, permanent set began at the buckling stress. The panels were of 24S-T aluminum and reinforcing the holes did not increase the ultimate strength.

WR L 501 THE INFLUENCE OF BULKHEAD SPACING ON BENDING STRESSES DUE TO TORSION, Paul Kuhn, May 1942

If a rectangular torsion box with bulkheads spaced at finite distances has a built-in root section, the normal stresses and the shear stresses caused by the constraint at the root can be calculated by Ebner's formulas with an accuracy sufficient for most practical purposes.

The theory tends to be slightly on the unconservative side, particularly in the immediate vicinity of the root. Part of the discrepancy can be traced to a nonlinear distribution of the bending stresses; this factor may require attention when the cover consists of stiffeners and thin skin.

Special allowances must be made on the shear stresses at stations where concentrated torques are introduced, because it will not be possible in many cases to predict very closely the efficiency of the bulkhead in distributing the load around the periphery of the box.

WR L 512 TESTS OF 10-INCH 24S-T ALUMINUM-ALLOY SHEAR PANELS WITH 1-1/2 INCH HOLES - II - PANELS HAVING HOLES WITH NOTCHED EDGES, Paul Kuhn and L. Ross Levin, April 1944

"Previous tests had shown that the yielding of 24S-T aluminum alloy is sufficient to reduce the stress-concentration factor for small holes to values only slightly greater than unity and that reinforcing rings consequently affect no significant improvement in the static strength developed by shear panels with small holes. It appears impossible, therefore, to base design criterions of the strength and stiffness of reinforcing rings on static strength. The present tests established the fact that the stress concentration around such holes is very materially increased by the presence of a notch and that this stress concentration caused by notches can be reduced effectively by reinforcing rings. Notches or cracks would not exist in actual structure, however, except as the result of accidental damage or vibration. It appears, therefore, that design criterions for reinforcing rings will need to be based on service experience."

WR L 519 TEST DATA ON THE SHEAR STRENGTH OF JOINTS ASSEMBLED WITH ROUND-HEAD AND BRAZIER-HEAD RIVETS, Merven W. Mandel and Evan H. Schuette, June 1943

This report makes a comparison between round-head rivets (AN 430) and brazier-head rivets (AN 455). For 1/8 inch rivets brazier-head rivets are tighter for thicknesses of skin between 0.064 and 0.081; round-head rivets are tighter for skin thicknesses of 0.025; for skin thicknesses of 0.032 to 0.040 inches there was no difference in the fit. The tighter fit enables the rivet to carry a larger load.

WR L 523 TEST DATA ON THE SHEAR STRENGTH OF MACHINE-COUNTERSUNK RIVETED JOINTS ASSEMBLED BY AN NACA FLUSH-RIVETING PROCEDURE, Robert Gottlieb

When the manufactured round head of the rivet is driven with a vibrating gun while the shank end is bucked into the countersunk hole with a bar and the portion of the formed head that protrudes above the skin surface after the rivet is driven is removed with a flush-rivet milling tool, it is concluded that:

1. The variations of rivet-head angle investigated (45° to 82°) had no consistent effect on the yield and maximum shear loads.

2. The yield load is almost independent of countersunk depth.

Interchanging the vibrating gun and the bucking bar in the foregoing method of driving does not change the yield and maximum shear loads for the rivets.

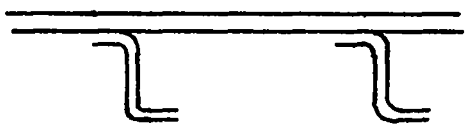
When the hole is countersunk at both ends, a headless rivet inserted, and countersunk heads formed at both ends of the rivet, there is no change in the yield and maximum shear loads from the values obtained by the preceding methods of driving.

WR L 524 TESTS OF BEAMS HAVING WEBS WITH LARGE CIRCULAR LIGHTENING HOLES, L. Ross Levin

Tests were made on two beams to determine the effect of large lightening holes in the web on the strength. It was found that beams cannot be designed without corrections for the holes, however, there was not enough data to establish a method for making the corrections.

WR L 527 A PRELIMINARY STUDY OF THE EFFECT OF COMPRESSIVE LOAD ON THE FAIRNESS OF A LOW-DRAG WING SPECIMEN WITH Z-SECTION STIFFENERS, Eastman N. Jacobs, Eugene E. Lundquist, Milton Davison, and John C. Houbolt

The fairness of a wing is measured by rolling a straight edge over the surface to see if there are any flat or buckled areas. For the type of structure shown below there was no damaging effect for compressive loading up to 65% of the ultimate stress.



The loading produces some flat areas at all loads; the deflection caused by the loading is:

$$\delta_f = \frac{1}{1 - \frac{f}{f_{cr}}} \delta_o$$

f = load

f_{cr} = critical load

δ_f = deflection at load f

δ_o = deflection at zero load

WR L 536 THE ANALYSIS OF STRAINS INDICATED BY MULTIPLE-STRAND RESISTANCE-TYPE WIRE STRAIN GAGES USED AS ROSETTES, Norris F. Dow

This material now is of historical interest only.

WR L 557 DATA ON BUCKLING STRENGTH OF CURVED SHEET IN COMPRESSION, Harold Crate and L. Ross Levin, October 1943

It was found that the critical compressive load for a curved sheet between stiffeners is either the critical compressive stress for an unstiffened circular cylinder of the same radius-thickness ratio or the critical compressive stress for the same sheet when flat whichever gives the larger value of critical compression. The critical compressive stress may be lower for the second and subsequent loadings by the deformation when the sheet buckles under the first load.

WR L 586 BENDING AND SHEAR STRESSES DEVELOPED BY THE INSTANTANEOUS ARREST OF THE ROOT OF A CANTILEVER BEAM WITH A MASS AT ITS TIP, Elbridge Z. Stowell, Edward B. Schwartz, John C. Houbolt, and Albert K. Schmieder

When a plane lands the vertical component of velocity is sudd‹·ly reduced to zero, the shock of the sudden change in motion gives rise to vibratory stresses in the airplane. The theoretical equations which were confirmed by experiment are:

$$\omega_n = \rho c \frac{\theta_\eta^2}{L^2}$$

where θ_η is the nth root of the equation

$$1 + \cos\theta \cosh\theta + r\theta \; (\sinh\theta \cos\theta - \cosh\theta \;\; \sin\theta \;) = 0$$

$$\sigma_n = A_n \frac{v}{c} \frac{y}{\rho} E_e - \frac{\lambda w_n^2}{2E} t \sin w_n t$$

$$\bar{\tau}_n(x,t) = B_n \frac{v}{c} \frac{\rho}{L} E_e - \frac{\lambda w_n^2}{2E} t \sin w_n t$$

$$w_n(x,t) = C_n \frac{v}{c} \frac{L^2}{\rho} e - \frac{\lambda w_n^2}{2E} \; t \sin w_n t$$

ω_n	=	the angular frequency
E	=	modulus of elasticity
c	=	velocity of sound in a material
	=	radius of gyration of cross section of beam
L	=	length of beam
x	=	coordinate along beam measure from root
y	=	distance from neutral axis of beam to any fiber
t	=	time, zero at impact
n	=	integers designating a particular mode of vibration
r	=	ratio of tip mass to beam mass
v	=	velocity of beam prior to impact
$w_n(x,t)$	=	deflection of beam at station x and t for the nth mode
$a(x,t)$	=	acceleration
$\sigma_n(x,y,t)$	=	bending stress in beam at station x, y at time t for the nth mode of vibration
$\bar{\tau}_n(x,t)$	=	average stress (shear) over cross section of beam at station x and t for the nth mode of vibration
A_n, B_n, C_n	=	coefficient for the nth mode of vibration

The higher modes are quickly damped and therefore the lower modes are the only ones of practical interest.

WR L 587 COMPARISON OF THE COMPRESSIVE STRENGTH OF PANELS WITH ALCLAD 24S-T81 SHEET OR WITH ALCLAD 24S-T86 SHEET RIVETED TO ALCLAD 24S-T84 HAT-STIFFENERS, Robert A. Weinberger, Carl A. Rossman, and Gordon P. Fisher

An investigation was made to determine whether sheets of Alclad 24S-T86 were stronger than sheets of Alclad 24S-T81 when both are reinforced by 24S-T84 stiffeners. There was no increase in strength with the stiffeners 9- and 12-inches apart. So much buckling occurred that the effective sheet area was less than 20% of the total panel. For stiffener spacing of 6 inches the 24S-T86 had the higher compressive strength by several percent and the effective area was more than 20% of the entire panel area.

WR L 588 COMPRESSIVE STRENGTH OF CORRUGATED-SHEET-STIFFENED PANELS FOR CONSOLIDATED XB-36 AIRPLANE, Robert A. Weinberger, William C. Sperry, and Charles V. Dobrowski

The report gives an equation for finding the average stress at maximum load for a sheet stiffened by a corrugated sheet.

$$\sigma = \frac{P - 2a(t_s\sigma_s + t_c\sigma_c)}{A - 2a(t_s + t_c)}$$

t_c = thickness of corrugated sheet
t_s = thickness of flat sheet
A = cross-sectional area of specimen
P = maximum load on panel
σ_s = stress in flat sheet at maximum load
σ_c = stress in corrugated sheet at maximum load
a = distance from outer row rivets to edge of sheet

The strain in the flat sheet and the strain in the corrugated sheet are assumed to be the same and from the stress-strain relations it is possible to find the stress for both the corrugated and the flat sheets. The strain in the sheet was found by measuring the amount of shortening per inch of corrugated specimen length and the strain at maximum load was found by extrapolation.

WR L 604 TENSILE AND COMPRESSIVE STRESS-STRAIN CURVES AND FLAT-END COLUMN STRENGTH FOR EXTRUDED MAGNESIUM ALLOY J-1, Carl A. Rossman, April 1942

The most apparent conclusions regarding the properties of extruded magnesium J-1, as drawn from the table and 4 graphs, are:

1. It has a very low proportional limit in relation to the yield and ultimate strengths.

2. It has a very low yield point for compression as compared with tension.

The dimensions of the column specimens, which were selected on the basis of a much higher yield point, do not cover a sufficient range of slenderness ratio to establish the column curve near the Euler range.

WR L 690 PRELIMINARY DATA ON BUCKLING STRENGTH OF CURVED SHEET PANELS IN COMPRESSION, Eugene E. Lundquist, November 1941

Results presented in compression tests of 8 stiffened panels. Radius-thickness ratio of skin between stiffeners varied from 400 to infinity.

From these few tests, it is concluded that the critical compressive stress for a curved sheet between stiffeners is equal to the larger of:

1. The critical compressive stress for an unstiffened circular cylinder of the same radius-thickness of ratio.

2. The critical compressive stress for the same sheet when flat.

WR L 691 CRITICAL COMPRESSIVE STRESS FOR CURVED SHEET SUPPORTED ALONG ALL EDGES AND ELASTICALLY RESTRAINED AGAINST ROTATION ALONG THE UNLOADED EDGES, Elbridge Z. Stowell, September 1943

A formula is given for the critical compressive stress for slightly curved sheet with equal elastic restraints against rotation along the unloaded edges. The theory of small deflections is used and the formula reduces to that given by Timoshenko for the case of simply-supported edges.

Reference: Timoshenko, S.: Theory of Elastic Stability. McGraw-Hill Book Co., Inc., 1936.

WR W 31 ALUMINUM-ZINC-MAGNESIUM-COPPER CASTING ALLOYS, L. W. Eastwood and L. W. Kempf, July 1941

The tensile properties and hardness of aluminum-zinc-magnesium-copper alloys containing approximately 0.25% chromium and 0.15% titanium have been investigated over a range of 0 to 1.75% copper, 3 to 13% zinc, and 0 to 1.0% magnesium. The chromium and titanium were added for their specific effects on resistance to corrosion and grain refinement, respectively. Aluminum ingot which contained approximately 0.15% iron, 0.08% silicon, and 99.75 + percent aluminum was used as a base. In sand castings, approximately 0.4% copper, 6.6% zinc, 0.33% magnesium, 0.25% chromium and 0.15% titanium appears to give a good combination of strength and ductility together with satisfactory resistance to corrosion. Such an alloy ages at room temperature without any previous heat treatment and attains high tensile properties, endurance limit, resistance to failure by impact, and good resistance to corrosion in the accelerated tests utilized in this investigation. Castings of this type of alloy, however, have the disadvantage of being somewhat "hot short". Its tensile properties at elevated temperatures are relatively low, and it overages with the consequent loss of tensile strength and hardness when exposed for a few months at temperature as low as 212° F. At 300° F, this over-aging effect is rapid with consequent marked deterioration of the tensile properties and hardness.

WR W 33 A METHOD OF SHEAR-LAG ANALYSIS OF BOX BEAMS FOR AXIAL STRESSES, SHEAR STRESSES, AND SHEAR CENTER, Oscar Erlandsen, Jr., and Lawrence M. Mead, Jr., April 1942

A practical and relatively rapid method of compensating for shear lag in box-beam analysis, with accuracy sufficient for design purposes, is presented. Effectiveness curves for box-beam elements are derived for an ideal, symmetrical structure. Application of the ideal curves to practical structures is described in detail.

Tabular computation forms for rapid, accurate calculation of axial stresses, shear center, and shear stresses for a beam with shear lag are included. Results of analysis are compared with test stress distributions. Analytical methods of checking the shear lag curves by the use of the principle of consistent deformations are illustrated as a further indication of their reliability.

WR W 34 PROCEDURE USED AT ALUMINUM RESEARCH LABORATORIES FOR DETERMINING TYPE OF ATTACK IN SOME ALUMINUM ALLOYS, C. J. Walton and F. Keller, August 1942

Methods are described for determining the type of corrosion attack in duralumin-type alloys. They will indicate only a rough measure of the resistance of the material to corrosion. This procedure is not intended to supplant the accelerated alternate-immersion test and the standard salt-spray test. A reliable evaluation of the resistance of duralumin-type alloys to corrosion requires the mechanical testing of corroded samples and the determination of changes in mechanical properties in comparison with uncorroded samples of the same material.

The methods developed are to obtain an approximate idea of the resistance to corrosion of different samples without resorting to mechanical testing of corroded samples.

For design purposes, the exact reactions must be known. Therefore, this approximate method is of no interest for design.

WR W 35 THE EFFECT OF VARIOUS SURFACE CONDITIONS ON PRESS FITS OF STEEL BUSHINGS AND 17S-T ALUMINUM-ALLOY FITTINGS, E. C. Hartmann and J. F. Reedy, December 1942

Specimens of 17S-T aluminum alloy fittings with pressed-in steel bushings were tested for various surface conditions. The maximum load required to insert the bushing into the fitting was measured when both surfaces were bare, when the 17S-T was anodically coated and the steel cadmium plated, and when either surface was treated and the other was bare, both without lubrication and with Gredag No. 83 as a lubricant. Coefficients of friction for the various press fits were determined from these loads and from the calculated pressures on the specimens. Use of anodic coating on the aluminum alloy fitting reduced the load required for a press fit to less than one-half and use of cadmium plating on the steel bushing to less than one-third the load required when both surfaces were bare. The use of the lubricant was very beneficial when both surfaces were bare but had little effect for the other surface conditions.

WR W 36 THE PROBLEM OF THERMAL-EXPANSION STRESSES IN REINFORCED PLASTICS, P. S. Turner, June 1942

Somewhat unrelated.

Failure of adhesive bonds is attributed to boundary stress concentrations. An analysis of the causes of internal stress concentrations in rigid adhesive layers leads to the conclusion that stress concentrations can be eliminated in many cases by matching the coefficients of thermal expansion of the component parts. A stress equilibrium formula for calculating the thermal expansion coefficients of mixtures involves the density, modulus of elasticity, coefficient of thermal expansion, and proportion by weight of the ingredients. Illustrations of the application of the formula derived are included. The thermal expansion coefficients of a number of pure and reinforced plastics are reported. Bonds

Obtained when the thermal coefficients are matched are stable over a wide temperature range.

WR W 38 PROGRESS REPORT ON FATIGUE OF SPOT-WELDED ALUMINUM, H. W. Russel and L. R. Jackson, February 1943

This report contains a detailed account of approximately half of the work planned on Contract NAW 1659.

Fatigue tests on three simple basic types of spot welded test pieces from 24S-T:

1. Sheet lap joint loaded in repeated tension.

2. Stiffened panel to be loaded in repeated compression.

3. A nonstresses attachment joint; sheet loaded in repeated tension but no load on the attachment.

For lap joints:

1. Three typical types of failure:

   a. On all static tension tests and on some high-load fatigue tests, failure was by shear through the spots.
   b. On some high-load fatigue tests, spots failed by pulling buttons.
   c. On low-load fatigue tests, failure was by cracks in the sheet.

2. On static tension tests, the load-bearing ability was the same for spot spacing of 3/4 as for 1-1/4 inches; however, on fatigue tests, the 3/4 spacing was weaker in pounds per spot.

3. Tests run at different ratios of minimum to maximum stress indicated that the stress range allowable for a given life falls off as the mean stress is increased.

Results of tests on stiffened panels can be summarized as follows:

1. The stiffened panels consisted of hat-shaped stiffeners spot-welded to sheets and were so designed that failure was by buckling of the sheet rather than by Euler column failure of the structure as a whole. The buckling produced tension type failures in the spots.

2. Two thicknesses of stiffened sheet were investigated and two spot spacings. All tests so far were run at a ratio of Min to Max load of 0.25. Except at high loads, where the life was less than 100,000 cycles, the thick sheet withstood higher loads than the thin sheet and in all cases, the test pieces with 3/4 inch

spot spacing were stronger than those with 1-1/4 inch spot spacing.

3. At a life of 2×10^6 cycles, the 0.051 sheet withstood loads of about 62% of its static strength, and the 0.032 inch sheet withstood loads of 41% of its static strength. At a life of 100,000 cycles, the 0.032 panels had a strength of over 70% of the static strength while the 0.051 sheet withstood 68% of its static strength; thus, for relatively high loads, the thinner panels were as effective as the thicker ones.

WR W 46 EFFECT OF pH ON STRENGTH OF RESIN BONDS, R. C. Rinker, F. W. Reinhart, and G. M. Kline, October 1943

The increased use of resin-bonded plywood for structural parts has made it necessary to determine the effect of various chemical properties of the resins on the strength properties of the resin bonds. This report deals with the effect of the pH factor of the catalysts that are used with class R and M (room temperature and room temperature plus to 160° F cure) on the strength of the bond.

It was found that for birch plywood panels the pH ranged from 1.7 to 8.4, for urea-formaldehyde from 1.9 to 5.7, and 1.7 to 8.4 for the phenolic materials. The pH values of 3.7 to 4.0 were obtained for Lamic. Urea-formaldehyde, phenolic and Lamic are the resins used to bond the birch plywood.

The pH values of the birch panels are not markedly affected by moderate baking or by exposure to cycles of heat and fog. The pH factor for urea-formaldehyde resins for optimum flexural and impact strength was above 3.8. For phenolic resin for optimum strengths the critical pH value is between 3.1 and 3.6. The delamination of birch plywoods made with urea-formaldehyde is affected by the pH while the plywoods made with phenolic resins are not affected by the pH, however, when the pH is below 3.1 for the phenolic the materials are not as flexible as those with pH values above 3.6. For urea-formaldehyde the lower the pH the fewer cycles required for delamination to occur.

WR W 48 PROGRESS REPORT ON STRENGTH AND CREEP OF SPECIAL CERAMIC BODIES IN TENSION AT ELEVATED TEMPERATURES, R. F. Geller and M. D. Burdick, June 1946

In this report six ceramic bodies were tested to determine their tensile strength at high temperature for possible use in gas turbines.

BODY	TENSILE STRENGTH (psi)
Body 151, density 3.8	13,000 at 1500°F
Body 163, density 4.4	15,000 at 1700°F
Body 353, density 4.4	11,000 at 1800°F
Body 358, density 4.9	13,000 at 1700°F
Body 4811, density 3.0	4,000 at 2050°F
Body 16021, density 3.0	12,000 at 1700°F

WR W 51 EFFECT OF DEVELOPED WIDTH ON STRENGTH OF AXIALLY LOADED CURVED SHEET STRINGER PANELS, Albert E. McPherson, Kenneth L. Fienup, and George Zibritosky, November 1944

Compression tests were made on six 24S-T aluminum alloy curved sheet stringer panels 12 inches in length and 24 inches in width, reinforced by six Z stringers spaced 4 inches between centers. The panels had two radii of curvature, 76.5 inches and 25.5 inches, and three sheet thicknesses, 0.025, 0.100, and 0.189 inch. The panels were of the same design as six of the panels in TN 944.

The increase in developed width had no significant effect on the strain for buckling of sheet between stringers, the strain for buckling of sheet between rivets, the load carried per sheet bay, or the stress at failure; however, it did reduce the critical strain for buckling of the panel as a whole between edge guides.

WR W 53 IMPACT PROPERTIES AT DIFFERENT TEMPERATURES OF FLUSH-RIVETED JOINTS FOR AIRCRAFT MANUFACTURED BY VARIOUS RIVETING METHODS, G. A. Maney and L. T. Wyly, September 1945

The results of the tests showed the joints to be stronger under impact loads at temperatures varying from -50° to -70° F than at 70° F. No appreciable difference was found in the impact strength from -55° to -70° F. Torsion impact tests on commercially obtained specimens of aluminum 17S-T showed about 10% increase in shear strength at temp of -70° F as compared with that obtained at 70° F. Commercial countersunk rivets with the head .003 inch below the surface before driving produced the strongest joints under impact. Reverse-driven rivets produced the weakest joints for impact loads.

WR W 55 FATIGUE TESTS OF RIVETED JOINTS PROGRESS REPORT OF TESTS OF 17S-T AND 53S-T JOINTS, E. C. Hartmann, J. O. Lyst, and H. J. Andrews, September 1944

Part of a detailed study begun in 1935 on riveted joints of aluminum. There are in this report, 6 pages of results related to the "old" series aluminums.

WR W 56 FATIGUE STRENGTH AND RELATED CHARACTERISTICS OF AIRCRAFT JOINTS I - COMPARISON OF SPOT-WELD AND RIVET PATTERNS IN 24S-T ALCLAD SHEET - COMPARISON OF 24S-T ALCLAD AND 75S-T ALCLAD, H. W. Russell, L. R. Jackson, H. J. Grover, W. W. Beaver, December 1944

The report contains detailed results of the following tests:

1. Fatigue tests on spot welded lap joints in sheets of unequal thickness of Alclad 24S-T. These tests indicate that the fatigue strength of a spot welded joint in sheets of two different gages is slightly higher than that of a similar joint in two sheets of the thinner gate but definitely lower than that of a similar joint in two sheets of the thicker.

2. Fatigue tests on spot welded Alclad 75S-T. Spot welded lap joint specimens of Alclad 75S-T were not any stronger in fatigue than similar specimens of Alclad 24S-T.

3. Fatigue tests on lap joint specimens spot welded after various surface preparations. These included AC welding wire brushed surfaces, DC welding wire brushed surfaces, and DC welding chemically cleaned surfaces. While the AC welds were strongest statically, the DC welds on wire brushed surfaces were strongest in fatigue. Specimens prepared in this way were very nearly as strong as the best riveted specimens tested for comparison.

4. Fatigue tests on specimens spot welded with varying voltage so as to include a wide range of static spot weld strengths. The fatigue strengths were in the same order as the static strengths but showed less range.

5. Fatigue tests on lap joint specimens with several patterns of spot welds. In general these patterns which gave highest static strengths gave also highest fatigue strengths.

6. Fatigue tests on lap joint specimens with various rivet patterns. Again fatigue strengths were in the same order as static strengths. These riveted joints were generally stronger in fatigue than corresponding spot welded joints.

WR W 61 FATIGUE STRENGTH AND RELATED CHARACTERISTICS OF SPOT-WELDED JOINTS IN 24S-T ALCLAD SHEET, H. W. Russell, December 1943

The conclusions of this report are:

For maximum ultimate strength the spot welds should be 3/4 of an inch apart, the load sustained for a given lifetime increases as the distance between welds increases from 1-1/4 to 3/8. The fatigue strengths of stiffened panels tested in compression shows a decrease of as much as 50% for an increase in spot-weld spacing from 3/4 to 2 inches. Transverse cracks from overheating the welds did not incept fatigue failure.

WR W 63 FATIGUE STRENGTH AND RELATED CHARACTERISTICS OF JOINTS IN 24S-T ALCLAD SHEET, H. W. Russell, L. R. Jackson, H. J. Grover, and W. W. Beaver, May 1944

Tests showed that two sheets joined by a single row of transverse spot welds has about 84% of the static ultimate strength of the sheet. Samples post-aged after welding showed 90% of the strength of the sheet. The fatigue strength of the welds was about 80% of the fatigue strength of the sheet. Aging either before or after spot-welding had little effect on the fatigue or static shear strength of the spot welded lap-joint samples. Roll-welded joints were weaker than spot-welded joints by 0 to 18%.

WR W 64 FATIGUE CHARACTERISTICS OF SPOT-WELDED 24S-T ALUMINUM ALLOY, H. W. Russell, L. R. Jackson, H. J. Grover, and W. W. Beaver, June 1943

In this report on spot welds it was found that the static shear strength raises with the thickness of the material and that the quality of the weld is not as important in low stress (long life) cases as in high stress situations. For static strength-to-weight ratios the highest value is obtained with thin sheets, while for long life (low stress) the highest value of strength-to-weight is obtained with thick sheets. The most critical area of the weld was found to be the sharp re-entrant angle formed by the two sheets at the weld button.

WR W 74 A METALLURGICAL INVESTIGATION OF A LARGE FORGED DISC OF 19-DL ALLOY, J. W. Freeman, E. E. Reynolds, and A. E. White, March 1945

Investigation of effects of fabrication of large discs on the properties of the alloy. The alloy tested was 19-DL.

	(lb/sq in.)
0.02% offset yield strength at room temperature	39,275
0.2% offset yield strength at room temperature	54,700
At 900°F	38,000
1200°F	37,900
1350°F	31,000

Rupture strength at:	(10 hrs)	(100 hrs)	(1000 hrs)
1200°F	46,000	40,000	34,000
1350°F	28,000	23,000	15,500

The fabrication of this disc was by hot-work; cold work disc would have superior rupture strength at 1200°F and would give better values of strength at short-time, however by 1000 hrs the strength of hot and cold worked disc would be nearly the same.

WR W 75 THE RUPTURE TEST CHARACTERISTICS OF SIX PRECISION-CAST AND THREE WROUGHT ALLOYS AT 1700° AND 1800° F, J. W. Freeman, E. E. Reynolds, and A. E. White, November 1945

6059, Vitallium, 61, S-40, and X-50 were precision castings: S590, S816, and Low-carbon N-155 were in the wrought form. X-40 had the best rupture strength of the precision castings (and the best strength of all the alloys) and S590 had the best rupture strength of the wrought bar stock (S816 had the same strength as S590 at 1700° F, but S590 was better at 1800° F). All alloys showed a decrease in elongation and a reduction in area with increase in time for rupture except N-155 and 6059 at both temperatures and X-40 at 1700° F. For time longer than 10 hours the better precision casting showed higher rupture strength than the wrought stock. Solution treatment at high temperature promotes high rupture strength. The chemical compositions represented by X-40, X-50, 422-19, and cast S816 are probably inherently stronger than the other alloys.

WR W 76 COMPARATIVE FATIGUE TESTS OF RIVETED JOINTS OF ALCLAD 24S-T ALCLAD 24S-T81, ALCLAD 24S-RT, ALCLAD 24S-T86 AND ALCLAD 75S-T SHEET, R. L. Moore and H. N. Hill, August 1945

Comprehensive series of tests to determine the fatigue strength of various types of riveted and spot welded joints in the aluminum alloys of current interest in aircraft design. This progress report presents the results obtained to date on the riveted joints of this series.

The results are presented in charts.

WR W 78 EARLY DETECTION OF CRACKS RESULTING FROM FATIGUE STRESSING, John A. Bennett, September 1944

An apparatus has been developed for detecting the small changes in the deflection of a specimen in a rotating-beam fatigue machine and measuring them. This change in deflection has been found to be a function of the size of the fatigue crack in the specimen. The correlation between deflection and crack size has been investigated. The apparatus may be used for indicating the formation of fatigue cracks or for following the progress of cracks as they propagate through the specimen.

WR W 79 PROGRESS SUMMARY NO. I MECHANICAL PROPERTIES OF FLUSH-RIVETED JOINTS SUBMITTED BY FIVE AIRPLANE MANUFACTURERS, William Charles Brueggeman, February 1942

From tests on a series of standardized specimens obtained from a number of airplane manufacturers, the strength, occurrence of defects, and effect of the angle of the rivet head have been determined. The specimens represented combinations of structural members frequently joined by flush rivets and were designed to afford a comparison between the different types of rivet and riveting process.

Such information is believed to be available from manufacturers today.

Information in this report is in chart form.

WR W 80 PHYSICAL DATA ON CERTAIN ALLOYS FOR HIGH TEMPERATURE APPLICATIONS, A. E. White, J. W. Freeman, and F. B. Rote, April 1943

Data constitutes a summary of properties of 120 samples of alloys, representing 86 compositions which have been investigated for their suitability as turbosupercharger wheels materials.

Extensive data (250 pages) gives chemical composition, fabrication procedure, tensile test and hardness values at room temperature, and tensile and rupture test characteristics at 1200° F.

WR W 82 FATIGUE STRENGTH OF FLUSH-RIVETED JOINTS FOR AIRCRAFT MANUFACTURED BY VARIOUS RIVETING METHODS, G. A. Maney and L. T. Wyly, December 1945

The results of the tests showed that the fatigue strength of the joints was directly affected by the method of riveting used. The endurance limit of the rivets in completely reversed shear was greatest for commercial countersunk rivets with the head 0.010 inch above the plate surface before driving, while the endurance limit was lowest for commercial countersunk rivets with the head 0.003 inch below the surface before driving. The endurance limit for reverse-driven rivets was intermediate between the extremes. In several cases considerable variation in behavior under the same fatigue loads was found in specimens of the same series. The lowest endurance limit found in this investigation was about 9400 psi while the maximum found was about 15,000 psi. Static tests on the reverse driven rivets showed an ultimate strength of about 38,000 psi, this being the highest strength developed by any of the joints.

WR W 83 THE FATIGUE STRENGTHS OF SOME WROUGHT ALUMINUM ALLOYS, G. W. Stickley, June 1942

This information is in the Structures Aluminum Handbook.

It was derived to help complete it.

WR W 89 TORSION TESTS OF STIFFENED CIRCULAR CYLINDERS, R. L. Moore and C. Wescoat, May 1944

The torsion tests of stiffened circular cylinders described in this report are the first of a series to be completed in an experimental investigation of the shear buckling resistance and strength of stiffened curved sheet. Although a number of observations of interest have been made regarding the behavior of this particular group of 0.020 inch thick 24S-T cylinders, additional tests are in progress which should be considered before an attempt is made to formulate general conclusions.

WR W 91 THE APPLICATION OF DATA ON STRENGTH UNDER REPEATED STRESSES TO THE DESIGN OF AIRCRAFT, L. R. Jackson and H. J. Grover, October 1945

The examples in this report were confined to affect resulting from gust loading. They apply only to wing structures. Nevertheless, whenever the repeated load history of any part is known, it should be possibly to apply the same method of analysis used here.

In providing the link between load history and fatigue data, the most important factor is the assumption used for estimating damage from repeated loads. The one used in this report was proposed by Miner. This assumption is open to criticism, and it is possible to demonstrate that, under certain specific loading cycles, it is not correct. The sequence of loading cycles, under which Miner's proposal does not hold for steels at least, is one in which all high loads are separated from all low loads. Since in service loading the loads are mixed, it seems possible that his proposal will hold much more closely for service loading than for idealized load sequences.

Miner's proposal has already received some experimental verification for mixed loadings; however, in view of the importance of this assumption, it should receive further experimental study.

WR W 99 MECHANICAL TESTS OF MACERATED PHENOLIC MOLDING MATERIAL, William N. Finley, June 1943

These materials have been replaced by more modern materials in aircraft use today.

WR W 102 A METHOD FOR WELDING SHEET ALUMINUM TO SAE 4140 STEEL, W. F. Hess and E. F. Nippes, Jr., January 1944

CONCLUSIONS:

1. Silver is the most satisfactory metal for electroplating steel cylinder barrels to permit the bonding of aluminum fins. The optimum plating thickness is 0.25 mil.

2. Careful attention to the silver-plating technique must be given since the strength and permanence of the bond depends to

a large extent upon the perfection of the bond secured during the plating operation.

3. The bonding of aluminum to SAE 4144 steel may be accomplished below the critical temperature for this steel. Thus, objectionable rehardening during welding is avoided. An 0.011 inch stainless steel strip between the electrode and the aluminum provides a proper heat balance.

4. A seam-welding machine can be used for automatically bonding a flanged continuous aluminum strip to a silver-plated steel cylinder barrel during the winding of this strip in the form of a close spiral over the surface of the cylinder.

Not Applicable NACA Wartime Reports

WR W- 70 GENERAL RESISTANCE TESTS ON FLYING-BOAT HULL MODELS, F. W. S. Locke, Jr., February 1944

WR W- 73 A METALLURGICAL INVESTIGATION OF A LARGE FORGED DISC OF CSA (234-A-5) ALLOY, F. J. Freeman, E. E. Reynolds, and A. E. White, October 1945

WR W- 93 HIGH TEMPERATURE CHARACTERISTICS OF 17 ALLOYS AT 1200° AND 1350° F, J. W. Freeman, F. B. Rote, and A. E. White, March 1944

WR W-103 A METALLURGICAL INVESTIGATION OF A LARGE FORGED DISC OF LOW-CARBON N-155 ALLOY, J. W. Freeman and H. C. Cross, December 1945

Applicable NACA Research Memorandum

RM L 8I30b COMPRESSIVE BUCKLING OF FLAT RECTANGULAR PLATES SUPPORTED BY RIGID POSTS, Bernard Budiansky, November 1948

Results of a theoretical investigation of the compressive buckling of flat, rectangular, simply supported plates supported in the interior by equally spaced rows of rigid posts are presented. It is found that the plates buckle as if simply supported along all of the transverse lines or else all of the longitudinal lines passing through the rigid posts, the occurrence of the one buckling mode or the other depending on the number and spacing of the posts.

Not Applicable Research Memoranda

RM A51L17a THE EFFECT OF VARIOUS MISSILE CHARACTERISTICS ON AIRFRAME FREQUENCY RESPONSE, Howard F. Matthews and Walter E. McNeill, 1952

RM A53L21 INVESTIGATION OF A MISSILE AIRFRAME WITH CONTROL SURFACES CONSISTING OF PROJECTING QUADRANTS OF THE NOSE CONE, Frank A. Lazzeroni, 1954

RM A57K21 ANALOG STUDY OF INFLUENCE OF INTERNAL MODIFICATIONS TO WING LEADING EDGE ON ITS TRANSIENT TEMPERATURE RISE DURING HIGH-SPEED FLIGHT, Carr B. Neel, 1958

RM A58B26 A PRELIMINARY INVESTIGATION OF HIGH-SPEED IMPACT: THE PENETRATION OF SMALL SPHERES INTO THICK COPPER TARGETS, A. C. Charters and G. S. Locke, Jr., 1958

RM E7G18a DETERMINATION OF STRESS-RUPTURE PARAMETERS FOR FOUR HEAT-RESISTING ALLOYS, William G. Lidman, 1947

RM E53D06 INVESTIGATION OF EFFECTS OF GRAIN SIZE UPON ENGINE LIFE OF CAST AMS 5385 GAS TURBINE BLADE, C. A. Hoffman and C. A. Gyorgak, 1953

RM E53G03 EFFECTIVE THERMAL CONDUCTIVITIES OF MAGNESIUM OXIDE, STAINLESS STEEL, AND URANIUM OXIDE POWDERS IN VARIOUS GASES, C. S. Eian and R. G. Deissler, 1953

RM E53K24 KINETIC STUDY OF MASS TRANSFER BY SODIUM HYDROXIDE IN NICKEL UNDER FREE-CONVECTION CONDITIONS, Don R. Mosher and Robert A. Lad, 1954

RM E53L03 DYNAMIC CORROSION OF NICKEL AT 1500° F BY SODIUM HYDROXIDE WITH VARIOUS ADDITIVES IN A TOROID CIRCULATING APPARATUS, Leland G. Desmon and Don R. Mosher, 1954

RM E53L21 PRELIMINARY INVESTIGATION OF FREEZE-CASTING METHOD FOR FORMING REFRACTORY POWDERS, W. A. Maxwell, R. S. Gurnick, and A. C. Francisco, 1954

RM E54B08 APPLICATION OF PULSE TECHNIQUES TO STRAIN GAGES, Newell D. Sanders and George H. Brodie, 1954

RM E54B15 EFFECTS OF SOME METAL ADDITION ON PROPERTIES OF MOLYBDENUM DISILICIDE, H. A. DeVincentis and W. E. Russell, 1954

RM E54G22a RECOVERY CORRECTIONS FOR BUTT-WELDED, STRAIGHT-WIRE THERMOCOUPLES IN HIGH-VELOCITY, HIGH-TEMPERATURE GAS STREAMS, Frederick S. Simmons, 1954

RM E54H04 SLOWING-DOWN DISTRIBUTION TO INDIUM RESONANCE OF NEUTRONS FROM RA-A-BE SOURCE IN WATER-IRON MIXTURES [WITH LIST OF REFERENCES], Daniel Fieno, 1954

RM E54L10 MEASURED EFFECTIVE THERMAL CONDUCTIVITY OF URANIUM OXIDE POWDER IN VARIOUS GASES AND GAS MIXTURES [WITH LIST OF REFERENCES], J. S. Boegli and R. G. Deissler, 1955

RM E54L13 THE USE OF METALLIC INHIBITORS FOR ELIMINATING MASS TRANSFER AND CORROSION IN NICKEL AND NICKEL ALLOYS BY MOLTEN SODIUM HYDROXIDE, Americo F. Forestieri and Robert A. Lad, 1955

RM E55I27a AVERAGE BOND ENERGIES BETWEEN BORON AND ELEMENTS OF 4TH, 5TH, 6TH AND 7TH GROUPS OF PERIODIC TABLE [WITH LIST OF REFERENCES], Aubrey P. Altshuller, 1955

RM E56L10 PERMEABILITY VARIATION OF A TAPER-ROLLED WIRE CLOTH, Anthony J. Diaguila and Curt H. Liebert, 1957

RM E56L18 THERMAL DECOMPOSITION OF SOME GROUP I, II, AND III METAL ALKYLS, Louis Rosenblum, 1957

RM E57B14 REVIEW OF PHYSICAL AND THERMODYNAMIC PROPERTIES OF BORIC OXIDE [WITH LIST OF REFERENCES], Paul C. Setze, 1957

RM E57K22a ELEVATED-TEMPERATURE COMBINED STRESS-RUPTURE PLUS FATIGUE STRENGTH OF WASPALOY HAVING DIFFERENT AGING TREATMENTS AND/OR MOLYBDENUM CONTENTS [WITH LIST OF REFERENCES], C. A. Hoffman and M. B. Hornak, 1958

RM L7H28 DETERMINATION OF COUPLED MODES AND FREQUENCIES OF SWEPT WINGS BY USE OF POWER SERIES, Roger A. Anderson, 1947

RM L8I30b COMPRESSIVE BUCKLING OF FLAT RECTANGULAR PLATES SUPPORTED BY RIGID POSTS, Bernard Budiansky, 1948

RM L55E1b PRELIMINARY INVESTIGATION OF COMPRESSIVE STRENGTH AND CREEP LIFETIME OF 2024-T3 (FORMERLY 24S-T3) ALUMINUM-ALLOY PLATES AT ELEVATED TEMPERATURES [WITH LIST OF REFERENCES], Eldon E. Mathauser and William D. Deveikis, 1955

RM L55E09a SUMMARY OF RECENT THEORETICAL AND EXPERIMENTAL WORK ON BOX-BEAM VIBRATIONS [WITH LIST OF REFERENCES], John M. Hedgepeth, 1955

RM L55E12b TENSILE PROPERTIES OF SOME SHEET MATERIALS UNDER RAPID-HEATING CONDITIONS [WITH LIST OF REFERENCES], George J. Heimerl and John E. Inge, 1955

RM L55I30 EXPERIMENTAL STUDIES OF FLUTTER OF BUCKLED RECTANGULAR PANELS AT MACH NUMBERS FROM 1.2 TO 3.0 INCLUDING EFFECTS OF PRESSURE DIFFERENTIAL AND OF PANEL WIDTH-LENGTH RATIO, Maurice A. Sylvester, 1955

RM L55L23b HIGH-TEMPERATURE OXIDATION AND IGNITION OF METALS, Paul R. Hill, David Adamson, Douglas H. Foland, and Walter E. Bressette, 1956

RM L57D23a SOME EXPERIMENTS WITH INSULATED STRUCTURES, Richard Rosecrans, Aldie E. Johnson, Jr., and William M. Bland, Jr., 1957

RM L57E24 EXPLORATORY TESTS OF BEHAVIOR OF SEVERAL MATERIALS IN SUPERSONIC AIR JET AT 4,000° F, Russell N. Hopko and Otto F. Trout, Jr., 1957

RM L57G31 THE BEHAVIOR OF BERYLLIUM AND BERYLLIUM COPPER IN A 4,000° F SUPERSONIC AIR JET AT A MACH NUMBER OF 2, William H. Kinard, 1957

RM L57H01 TESTS OF AERODYNAMICALLY HEATED MULTI-WEB WING STRUCTURES IN A FREE JET AT MACH NUMBER 2. THREE ALUMINUM-ALLOY MODELS AND ONE STEEL MODEL OF 20-INCH CHORD AND SPAN WITH VARIOUS INTERNAL STRUCTURES AND SKIN THICKNESSES, Richard Rosecrans, Louis F. Vosteen, and William J. Batdorf, Jr., 1957

RM L57J07a INVESTIGATION OF TANTALUM IN A 3,800° F SUPERSONIC AIRSTREAM, Otto F. Trout, Jr., and Jerry L. Modisette, 1958

RM L57J17 EFFECTIVENESS OF VARIOUS PROTECTIVE COVERINGS ON MAGNESIUM FINS AT MACH NUMBER 2.0 AND STAGNATION TEMPERATURES UP TO 3,600° R [WITH LIST OF REFERENCES], William M. Bland, Jr., 1958

RM L57K15 PRELIMINARY INVESTIGATION OF GRAPHITE, SILICON CARBIDE, AND SEVERAL POLYMER-GLASS-CLOTH LAMINATES IN A MACH NUMBER 2 AIR JET AT STAGNATION TEMPERATURES OF 3,000° AND 4,000° F, Francis W. Casey, Jr., and Russell N. Hopko, 1958

RM L57K26 BEHAVIOR OF SOME MATERIALS AND SHAPES IN SUPERSONIC FREE JETS AT STAGNATION TEMPERATURES UP TO 4,210° F, AND DESCRIPTIONS OF THE JETS, E. M. Fields, Russell N. Hopko, Robert L. Swain, and Otto F. Trout, Jr., 1958

RM L57L13 TESTS OF AERODYNAMICALLY HEATED MULTI-WEB WING STRUCTURES IN A FREE JET AT MACH NUMBER 2. FOUR ALUMINUM-ALLOY MODELS OF 20-INCH CHORD AND SPAN WITH 0.064-INCH-THICK SKIN, 0.025-INCH-THICK RIBS AND WEBS, AND ZERO, ONE, TWO, OR THREE CHORDWISE RIBS, John R. Davidson, Richard Rosecrans, and Louis F. Vosteen, 1958

Applicable NACA Technical Memoranda

TM 933 THE STRENGTH OF SHELL AND TUBULAR SPAR WINGS, H. Ebner, February 1940

Similar information in Kuhn's Theory of Aircraft and Shell Structure.

TM 937 STRESSES IN SINGLE-SPAR WING CONSTRUCTIONS WITH INCOMPLETELY BUILT-UP RIBS, F. Reinitzhuber, March 1940

It is shown that the force distribution resulting from incomplete ribs in single spar wing structures may be determined with the aid of the shear field method by a statically indeterminant computation.

TM 939 THE TORSION OF BOX BEAMS WITH ONE SIDE LACKING, E. Cambilargiu, April 1940

The total normal stresses (positive if in tension) in the upper and lower edges of one vertical wall are:

$$\sigma_{\substack{\text{upper}\\\text{lower}}} = \frac{Eh}{2}\left(\frac{2E\,Jo}{2EJ_o + E\Omega b^2} \pm 1\right) y_1''$$

$$Y_1'' = \frac{PX}{EJ_v + \cfrac{h^2}{2\left(\cfrac{2}{E\Omega} + \cfrac{b^2}{EJo}\right)}}$$

where:

J_v = moment of inertia of one vertical wall
Jo = moment of inertia of horizontal wall
Ω = cross-sectional area of a vertical wall
h = height of a vertical wall
b = height of a horizontal wall
X = axial displacement
P = the force that together with an equal but opposite force produces the torque

The stress on the two vertical walls is equal but opposite. The horizontal wall is not strained as a whole, that is, its center line retains its original length.

TM 947 NEW EQUIPMENT FOR TESTING THE FATIGUE STRENGTH OF RIVETED AND WELDED JOINTS, W. Muller, July 1940

Special reprint of Schweizer Archiv No. 10, 1937. More recent work has been done on the subject.

TM 950 BUCKLING TESTS WITH A SPAR-RIB GRILL, Josef Weinhold, September 1940

Superseded by Kuhn's Stresses in Aircraft and Shell Structures.

TM 955 THE CAUSE OF WELDING CRACKS IN AIRCRAFT STEELS, J. Muller, October 1940

The various causes ascribed to welding crack tendency in the literature are considered and the result arrived at is: that causes arising from welding technique are not responsible, nor the type of construction, and that the fundamental causes of weld crack development lies in the composition of the material.

Weld hardness has no connection with the tendency to weld crack development. Si, Cr, Mo or V content has no appreciable effect, while increased manganese content tends to reduce the crack susceptibility.

"All experience with aircraft construction, as also all investigations of the last eight years, has given the one essential result, namely, that the tendency to develop weld cracks with unalloyed as well as with chrome-molybdenum and chrome vanadium alloyed aircraft structural steels is caused principally by too high sulphur content in the steel, which content with increasing carbon content must be correspondingly held within lower limits. High phosphorus content tends toward the same harmful effect. Non-uniform distribution of these components and crystal separation due to the accumulation of sulphur at the grain boundaries, can have an unfavorable effect. As high degree of purity and homogeneity of the steel as possible should therefore be aimed at. With the uniformity attained in present day aircraft structural parts, the average analysis of the C, P, S and Mn content gives a good criterion for the welding behavior of a steel."

TM 960 CREEP STRENGTH OF STABILIZED WROUGHT-ALUMINUM ALLOYS, W. Muller, November 1940

This information is more current in the ASM manual.

TM 985 TABLES FOR COMPUTING VARIOUS CASES OF BEAM COLUMNS, J. Cassens, August 1941

Similar to Table A10.1 in Bruhn but the report is much more complete. Mechanics of Deformable Solids by

Shames, has a similar table. The information is not new, just tabulated.

TM 987 FACTORS INFLUENCING THE FATIGUE STRENGTH OF MATERIALS, F. Bollenrath, September 1941

The stresses occurring under actual operating conditions are compared with those corresponding to the conventional test procedure. A distinction is to be made between structural parts which are subject to stresses lying between not widely varying limits or limit groups with a very large number of load cycles and structural parts for which the fluctuation of the stresses occur between irregularly varying limits with widely varying but restricted frequency corresponding to a prescribed length of life. For the former case the fatigue strength is to be investigated for the stresses arising within the multistage limits and the effect of any succession of limit groups of various frequency. The other case is to be considered statistically and the safe stress investigated for a given frequency. In discussing these problems consideration is given to the effect of intermittent breaks in operation on the Wohler strength and the methods whereby the test procedure can be made to approach the stresses under operating conditions. With the aid of a few examples from airplane construction, it is shown how the material can be tested in a statistical sense. With a strength investigation carried out from the point of view described a wider basis may be expected for the proper design of structural parts under actual stresses with a reliable safety estimate and better utilization of the material obtained. Finally some results are given of a few investigations on fatigue strength in mountings and the effect of surface pressures on the limited time and fatigue strengths.

TM 989 BUCKLING TESTS ON ECCENTRICALLY LOADED BEAM COLUMNS, J. Cassens, October 1941

Test results are presented on three sets of curves. Two of these, at least for the elastic range, are independent of the material tested. The third set, which is independent of the material, possesses greater clearness and is therefore used for comparing the test results with the theoretical.

The theory matches the tests.

TM 992 STATISTICAL ANALYSIS OF THE TIME AND FATIGUE STRENGTH OF AIRCRAFT WING STRUCTURES, Hans W. Kaul, October 1941

The results from stress measurements in flight operation afford data for analyzing the frequency of appearance of certain parts of the static breaking strength during a specified number of operation hours. Appropriate frequency evaluations furnish data for the prediction of the required strength under repeated stress in the wing structures of aircraft of the different stress catagories for the specified number of operating hours demanded during the life of a component. Measures adopted depend on the magnitude and frequency of the loads during the life of the aircraft and vary with the type of aircraft, purpose of use, and atmospheric conditions (gusts).

TM 994 EFFECT OF THREADED AND SERRATED HOLES ON THE LIMITED TIME AND FATIGUE STRENGTH OF FLAT LIGHT-ALLOY STRIPS, H. Burnheim, November 1941

It was found that the notch effect of the serrated holes in both metals is greater than that of the threaded holes and that, in turn, is greater than that of the cylindrical holes for both the unloaded holes and the pin-loaded holes. On the loaded holes the notch effect for all three forms assumes much greater values than on the unloaded ones; hence the limited time and fatigue strength of the tension lugs is considerably lower. While the fatigue strength ratio of plain and drilled specimens increases very little on the unloaded holes, it rises considerably with the number of cycles on the loaded ones.

TM 997 DETERMINATION OF THE BANDING AND BUCKLING EFFECT IN THE STRESS ANALYSIS OF SHELL STRUCTURES ACCESSIBLE FROM ONE SIDE ONLY, A. Dose, December 1941

The report describes a device for ascertaining the bending and buckling effect in stress measurements on shell structures accessible from one side only. The respective errors of the test method for great or variable skin curvature within the test range are analyzed and illustrated by specimen example.

TM 999 STRESS ANALYSIS OF CIRCULAR FRAMES, H. Fahlbusch and W. Wegner, December 1941

This material is covered adequately in Kuhn's book and more recent TN's.

TM 1004 STATICS OF CIRCULAR-RING STIFFENERS FOR MONOCOQUE FUSELAGES, W. Stieda, February 1942

Much work was done in the TN's later on this subject.

TM 1005 THE STRESSES IN STIFFENER OPENINGS, K. Marguerre, February 1942

Several TN's on this subject.

TM 1015 STATISTICAL ANALYSIS OF SERVICE STRESSES IN AIRCRAFT WINGS, Hans W. Kaul, June 1942

Tests were made for six different German aircraft to determine the service life of the wings using the component of the acceleration at the center of gravity in the direction of flight.

TM 1074 THE FRICTIONAL FORCE WITH RESPECT TO THE ACTUAL CONTACT SURFACE, Ragnar Holm, August 1944

Hardy's statement that the frictional force is largely adhesion, and to a lesser extent, deformation energy is proved by a simple experiment.

The actual contact surface of slicing contacts and hence the friction per unit of contact surface was determined in several cases. It was found for contacts in normal atmosphere to be about one-third to one-half as high as the microscopic tearing strength of the softest contact link. While contacts annealed in vacuum and then tested, disclosed frictional forces which are greater than the microscopic strength.

TM 1077 CALCULATIONS OF CENTRALLY LOADED THIN-WALLED COLUMNS ABOVE THE BUCKLING LIMIT, F. Reinitzhuber, April 1945

This subject has been covered by a TN and is also available in several handbooks.

TM 1086 DISTRIBUTION OF STRUCTURAL WEIGHT OF WING ALONG THE SPAN, V. V. Savelyev, August 1946

In the report that follows the true weight distribution law of the wing structure along the span is investigated. It is shown that the triangular distribution and that based on the proportionality to the chords do not correspond to the actual weight distribution. On the basis of extensive data on wings of the CAHI type airplane formulas are obtained from which it is possible to determine the true diagram of the structural weight distribution along the span from a knowledge of only the geometrical dimensions of the wing. At the end of the report are presented data that show how the structural weight is distributed between the straight center portion and the tapered portion as a function of their areas.

TM 1087 STRENGTH INVESTIGATIONS IN AIRCRAFT CONSTRUCTION UNDER REPEATED APPLICATION OF THE LOAD, E. Gassner, August 1946

This has been covered adequately by subsequent TN's.

TM 1094 INVESTIGATION OF THE BEHAVIOR OF THIN-WALLED PANELS WITH CUTOUTS, A. A. Podorozhny, September 1946

This material is applicable but represents nothing not covered in TN's of the era or later.

TM 1116 STABILITY OF PLATES AND SHELLS BEYOND THE PROPORTIONAL LIMIT, A. A. Ilyushin, October 1947

This material is treated by later TN's. For later Russian work see NASA TTF-341.

TM 1134 THE DISTRIBUTION OF LOADS ON RIVETS CONNECTING A PLATE TO A BEAM UNDER TRANSVERSE LOADS, F. Vogt, April 1947

For rivets under transverse loads with differences in pitch, cross-sectional area, and stiffness, the following equations give the loads and the slip.

The slip is: $\delta_i = C_i P_i \delta_o \qquad \delta_o = \ell_o/EA$

The moment is: $M_i = [P_i - P_{i+1} + N_i \ell_i (1/A_1 + 1/A_2)/E]$

The load is:

$$P_{i+1} = (C_i/C_{i+1}) P_i + (\ell_i A_o / \ell_o C_{i+1})[N_i\{1/A_1 + 1/A_2 + a^2/(I_1 + I_2)\} - aM_1/(I_1 + I_2)]$$

where ℓ_o and A_o are the rivet pitch and cross-sectional area at some standard section; C_i is the rivet stiffness; N_i is the total tensile load in the plate and is equal to the total compressive load in the beam; I_1 is the moment of inertia of the beam about an axis through the center of mass; I_2 is the moment of inertia of the plate about an axis through its center of mass; A_1 area of beam; A_2 area of plate and a is the distance between the center of mass of the plast and the center of mass of the beam.

TM 1135 THE LOAD DISTRIBUTION IN BOLTED OR RIVETED JOINTS IN LIGHT-ALLOY STRUCTURES, F. Vogt, April 1947

Current practice, represented by E. F. Bruhn's Analysis and Design of Flight Vehicle Structures, Tri State Offset Co., 1965, supersedes this treatment.

TM 1138 ON THE APPLICATION OF THE ENERGY METHOD TO STABILITY PROBLEMS, Karl Marguerre, October 1947

Energy methods have now been in use for some time and their application has been expanded and their exposition tightened. This material is thus primarily of historical interest.

TM 1182 THE PROBLEM OF TORSION IN PRISMATIC MEMBERS OF CIRCULAR SEGMENTAL CROSS SECTION, A. Weigand

This report solves the following equations for f(y,z) the stress function of the torsion problem. In the resentation the solution is in polar coo-dinates (r,ϕ)

$$\frac{\partial^2 f}{\partial r^2} + \frac{1}{r}\frac{\partial f}{\partial r} + \frac{1}{r^2}\frac{\partial^2 f}{\partial \phi^2} = -1 \tag{1}$$

$$f = 0 \tag{2}$$

the torsion constant is:

$$J_d = 4 \iint f(r,\phi) r \, dr \, d\phi \tag{3}$$

the shearing stress components:

$$T_r = \frac{2M_d}{J_d} \frac{1}{r} \frac{\partial f}{\partial \phi}$$

$$T_\phi = - \frac{2M_d}{J_d} \frac{\partial f}{\partial r}$$

The general solution of the differential equation (1) is:

$$f = -\frac{r^2}{4} + \sum_{o}^{n} [a_k f_k + b_k g_k] \ .$$

The easiest way to determine the coefficients a_k and b_k is by the method of least squares, since:

$$\oint f^2 \, ds = \text{Min.} \quad ds = \text{Boundary element}$$

The report uses the method in solving, the torsion problem for a semicircle. The analytical and experimental results are very close together.

TM 1188 THE ELASTO-PLASTIC STABILITY OF PLATES, A. A. Ilyashin, December 1947

TM 1204 SOME NEW PROBLEMS ON SHELLS AND THIN STRUCTURES, V. S. Vlasov, March 1949

TM 1207 THE THEORY OF PLASTICITY IN THE CASE OF SIMPLE LOADING ACCOMPANIED BY STRAIN-HARDENING, A. A. Ilyushin, February 1949

TM 1234 COMPUTATION OF THIN-WALLED PRISMATIC SHELLS, V. Z. Vlasov, June 1949

TM 1241 BASIC DIFFERENTIAL EQUATIONS IN GENERAL THEORY OF ELASTIC SHELLS, V. S. Vlasov, February 1951

The information presented in these 5 TM's is expanded and updated in NASA TTF-99. See also NASA TTF-341.

TM 1249 SUSCEPTIBILITY TO WELDING CRACKING, WELDING SENSITIVITY, SUSCEPTIBILITY TO WELDING SEAM CRACKING, AND TEST METHODS FOR THESE FAILURES, K. L. Zeyen, June 1949

Susceptibility to welding cracking is the cracking of the welded material during gas welding. The main cause of the cracking is the base material. Those steels most likely to crack are thin, high-strength, unalloyed steels. Steels containing silicon and magnesium are much less likely to fail even if they are high-strength than high-strength carbon steels. Steels, even high-strength unalloyed, are less likely to crack if they are manufactured in electric furnaces.

Welding sensitivity is the cracking of the base material during the welding of medium to thick steels using arc welding. The main cause of the cracking is the base material. However, in this case the material cracks because it hardens during the welding process. In arc welding thin materials, a minimum of heat should be used to reduce hardening, while for thick materials the heat supply should be large to avoid cracks due to weld embrittlement.

The third kind of cracking is susceptibility to welding seam cracking. In this case the cracks appear in the seam. This kind of cracking occurs most often for arc welding of high-strength steels using thickly coated electrodes. The condition occurs almost entirely in fillet seams, the most critical area of the seam is that part that cools last. Sulphur and phosphorous in the welding material increase the chance of seam cracking. Small thickness of the first layer and high amperages should be avoided in fillet seams.

TM 1266 PRELIMINARY RESULTS FROM FATIGUE TESTS WITH REFERENCE TO OPERATIONAL STATISTICS, E. Gassner, May 1950

"Since the initial statistics themselves as well as their prevailing interpretation and application to the practical test may be regarded as unconditionally lying on the safe side, it may be stated that no immediate cause for apprehension exists."

TM 1297 STATE AND DEVELOPMENT OF FLUTTER CALCULATION, A. Teichmann, March 1951

At the time of this report the only way to do accurate investigations of the flutter characteristics of airplanes was to make calculations for each individual model.

Not Applicable NACA Technical Memoranda

TM	964	MATERIALS FOR SLACK DIAPHRAGMS, Traute Puschmann, December 1940
TM	965	RECTANGULAR SHELL PLATING UNDER UNIFORMLY DISTRIBUTED HYDROSTATIC PRESSURE, M. Neubert and A. Sommer, December 1940
TM	984	THE MECHANICAL PROPERTIES OF WOOD OF DIFFERENT MOISTURE CONTENT WITHIN-200° TO 200° C TEMPERATURE RANGE, F. Kollman, September 1941
TM	995	THE CREEP OF LAMINATED SYNTHETIC RESIN PLASTICS, H. Per Kuhn, November 1941
TM	1019	STRENGTH TESTS ON HULLS AND FLOATS, K. Mattheas, June 1942
TM	1020	THEORY OF HEAT TRANSFER AND HYDRAULIC RESISTANCE OF OIL RADIATORS, N. B. Mariamov, June 1942
TM	1031	CONTRIBUTION TO THE DESIGN OF PLYWOOD SHELLS, S. Blumrich, October 1942
TM	1035	CONTROL OF TORSIONAL VIBRATIONS BY PENDULUM MASSES, A. Stieglitz, November 1942
TM	1055	DETERMINATION OF THE STRESSES PRODUCED BY THE LANDING IMPACT IN THE BULKHEADS OF A SEAPLANE BOTTOM, V. M. Darevsky, January 1944
TM	1064	METHODS OF STRESS CALCULATION IN ROTATING DISKS, S. Tumarkin, September 1944
TM	1072	THE SURFACE STRUCTURE OF GROUND METAL CRYSTALS, W. Boas and E. Schmid, August 1944
TM	1080	A NEW APPARATUS FOR MEASURING THE TEMPERATURE AT MACHINE PARTS ROTATING AT HIGH SPEEDS, E. Gnam, April 1945
RM	1083	MICROMECHANICAL STUDY OF METALS, P. A. Velikov, N. P. Stchapov, and W. F. Lorenz, July 1945
TM	1088	A PHOTOGRAPHIC PROFILE RECORDER FOR AIRSCREWS AND WINGS MODELS, R. Kuhl and K. Raab, June 1946
TM	1090	ON THE PROBLEM OF STRESS CORROSION, L. Graf, July 1946
TM	1093	THE FURTHER DEVELOPMENT OF HEAT-RESISTANT MATERIALS FOR AIRCRAFT ENGINES, F. Bollenrath, September 1946

TM 1097 SCALE EFFECT AND OPTIMUM RELATIONS FOR SEA SURFACE PLANING, L. Sedov, February 1947

TM 1165 COEFFICIENT OF FRICTION, OIL FLOW AND HEAT BALANCE OF A FULL-JOURNAL BEARING, P. I. Orloff, October 1947

TM 1179 DETERMINATION OF THE STRESS CONCENTRATION FACTOR OF A STEPPED SHAFT IN TORSION BY MEANS OF PRECISION STRAIN GAUGES, A. Weigand, September 1947

TM 1183 TEMPERATURES AND STRESSES ON HOLLOW BLADES FOR GAS TURBINES, E. Pollmann, September 1947

TM 1192 ROTATING DISKS IN THE REGION OF PERMANENT DEFORMATION, F. Laszlo, August 1948

TM 1235 INVESTIGATION OF CONDITIONS OF TITANIUM CARBONIZATION - IV, G. A. Meerson and Y. M. Lipkes, July 1949

TM 1263 CONTRIBUTION TO THE PROBLEM OF BUCKLING OF ORTHOTROPIC PLATES, WITH SPECIAL REFERENCE TO PLYWOOD, W. Thielemann, August 1950

TM 1287 DEPENDENCE OF THE ELASTIC STRAIN COEFFICIENT OF COPPER ON THE PRETREATMENT, W. Kuntze, August 1950

TM 1290 THE STRUCTURE OF AIRY'S STRESS FUNCTION IN MULTIPHY CONNECTED REGIONS, G. Grioli, July 1951

Applicable NASA Technical Translations

TT F-27 ON REISSNER'S THEORY OF THE BENDING OF PLATES, A. L. Goldenveizer, May 1960

Since the classical theory of the bending of thin plates is affected by a contradiction which is based on the noncorrespondence of the order of the differential equations with the number of boundary conditions, a method is given in this report for relaying of static boundary conditions (given boundary conditions are replaced by others which are statically equivalent) to remove the contradiction.

Not Applicable NASA Technical Translations

TT F-34 TEMPERATURE FLEXURE OF ELASTIC ELEMENTS, G. A. Slomyanskii, May 1960

TT F-59 MECHANISM OF THE OXIDATION OF NICKEL AND CHROMIUM ALLOYS, D. V. Ignatov and R. D. Shamgunova, March 1961

TT F-64 THE SINTERED COPPER POWDER, Ye. M. Savitskiy and A. I. Vlasor, June 1961

There were no applicable or non-applicable structures reports in the NASA X series of Technical Memorandum.

NASA-Langley, 1970 — 2 CR-1484