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PROGRESS REPORT OF THE NASA SPECIAL COMMITTEE ON MATERIALS RESEARCH FOR SUPERSONIC TRANSPORTS

By Richard H. Raring
NASA

and

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University of Michigan

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

Activities of the NASA Special Committee in Materials Research for Supersonic Transports during the first 19 months of its life are summarized. Detailed results from the several investigations of sheet materials for wings and fuselage made under the Committee cognizance are presented. Committee recommendations for further research are outlined.

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FOREWORD

In February 1961, the National Aeronautics and Space Administration, as one of its contributions toward the effort to design a supersonic transport, established the NASA Special Committee on Materials for Supersonic Transports. At a meeting held in November 1962, this Committee agreed to publish a report on its progress during the first 19 months of its life. For convenience, the report is presented in two parts. Part I was prepared by Mr. R. H. Raring of NASA Headquarters and presents general information on committee activities and status of research. Part II was prepared by J. W. Freeman, J. W. Schultz, and R. H. Voorhees of the University of Michigan. It presents data generated by the Committee programs and covers results of research carried out by a number of organizations.

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November 1962

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PART I - COMMITTEE ACTIVITIES

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INTRODUCTION

This progress report has been sponsored by the NASA Special Committee on Materials Research for Supersonic Transports (SST) with two chief purposes:

(1) to summarize recent and current research, most of which has not been previously published, on sheet materials for SST, and

(2) to serve as a progress report and record of the first 18 months of the Committee's activities.

The Committee is composed of representatives of those airframe companies, alloy producers, and government agencies most directly concerned with the SST. Its purposes are to provide advice on SST materials research, to make available to all interested parties an instrument for promoting and coordinating research, and to effect a faster and wider exchange of research results.

The Committee and its several ad hoc Panels, in close conjunction with representatives of research-sponsoring agencies and many research investigators, have devoted considerable effort to detailed planning of research. As a consequence of this unified planning, much of the current research on SST sheet materials is related and complementary. To the extent possible, therefore, results of the investigations coordinated through, or inspired by, the Committee are presented in an integrated form as part II of this report. It was judged that such a combined and single publication of results from separate but closely related studies would facilitate their distribution and use.

The identity of the laboratories and of individuals who conducted the research is preserved and acknowledged. The very substantial tasks of collecting the detailed data from the various sources, such as progress reports, Committee presentations, and private correspondence, and of arranging them in common format for tabulation and display, were performed by Professor James W. Freeman and his associates at the University of Michigan. Their accomplishment of this intricate undertaking in a systematic fashion is acknowledged with thanks.

COMMITTEE HISTORY AND SCOPE

Materials for SST has been a subject of concern and speculation by airframe companies for many years. However, substantial and specific research on SST materials had to await the evolvement of the approximate characteristics of the aircraft, especially its speed, life-time, flight profile, and operating environment. By late 1960, these characteristics began to crystalize sufficiently to enable materials engineers to estimate the materials requirements and to start the research and development needed to meet them (refs. 1 and 2).

At approximately the same time, official recognition was made of a wide and growing conviction that the cost of developing an SST within a reasonable time was beyond the technical and financial resources of any single company (ref. 3). Assistance and encouragement from the Government were needed to bring the diverse capabilities of the nation's industries and laboratories to bear on the many problems in a correctly orientated, efficient, and coordinated fashion. In reference 3 the Federal Aviation Agency (FAA), the Department of Defense (USAF), and the NASA recommended that their organizations jointly start a "vigorous effort . . . immediately in order to have an operational aircraft in the 1970 time period." Under these recommendations, the FAA was to assume leadership and to provide the chief financial backing, while the Air Force and the NASA were to provide technical support. These recommendations were accepted and have been put into practice.

As one of its contributions to this national SST endeavor, the NASA in February 1961, established the Special Committee on Materials Research for Supersonic Transports. To hold the Committee to a manageable size, membership was limited to representatives of the three government agencies involved, the large-airframe companies, and the chief producers of those alloys having the most potential for SST airframes. However, the rightful concern with the affairs of the Committee of all sectors of the industrial and scientific community that could make contributions to, or be significantly affected by, the Committee's actions was recognized. Minutes of meetings are being sent to all interested organizations; counsel and suggestions from nonmember organizations in the form of presentations at meetings or written reports are accepted and often solicited; in several instances nonmembers have been invited to join with Committee Panels appointed to study specific matters in depth.

When the Committee was established and its scope defined, it was recognized that a Mach 3 transport differed so radically from all previous transport aircraft that serious problems would arise with virtually all its materials; for example, sheet, extrusions, forgings, hydraulic fluids, lubricants, fuels, glazing, engine parts, tires, etc. Nevertheless, the Committee decided to limit the scope of detailed study to investigations of sheet materials for wings and fuselage. This decision was made because (1) sheet materials were believed to be the major materials problem and (2) practical realism clearly dictated that a Committee working on detailed matters must be specialized to be effective. With the exception of the recent establishment of a Committee Panel to study the possible existence and severity of the problems of materials for heavy sections, such as forgings and extrusions, the Committee has restricted its attention to sheet materials.

COMMITTEE PROCEDURE

During the first 19 months of its life, the Committee has held seven meetings. Much of the meeting time, especially during the earlier meetings, was occupied by detailed reports from representatives of government agencies and industry on recent and current work directed at, or closely related to, SST materials. This familiarization of the Committee with research in progress, which was as comprehensive as practicable, was a recognized prerequisite to informed discussion and rational decisions on needed additional work. After identification by the Committee of the most critical problem areas, Committee Panels are appointed for further and more detailed study of specific problems.

Panel reports, containing documentated background and detailed recommendations, are submitted to the entire Committee membership for review and action. Recommendations that received approval of the Committee are submitted to joint NASA-FAA-DOD task groups established to shape an overall and balanced SST effort that includes all major research areas, for example, engines, structures, operations, fuels, and such, as well as materials. The Committee recommendations are also available, in a less detailed but widely distributed form, as meeting minutes for the information of all interested parties.

STATUS OF RESEARCH UNDER COMMITTEE COGNIZANCE

Preliminary Screening Test

A few months before the first meetings of the Committee, the NASA in its own laboratories and under contract, started a series of "screening" investigations designed to produce data on which to base comparison of the many alloys that were being advocated for SST. It should be understood that these studies were neither intended nor expected to result in design data, or even to lead to material selection. Their purpose, rather, was to enable materials engineers to make rational eliminations from the many alloys that were being seriously suggested. Lessening the number of candidate alloys was recognized as a necessary first step in the planning of subsequent and more concentrated work on a minimum number of materials. This decision becomes clear from the fact that 27 different alloys, not including the variations in heat-treatment on temper of individual alloys, are included in the preliminary screening. Some of the first tasks of the Committee were assisting in the selection of alloys to be screened, the establishment of conditions of test, and the interpretation of results as they accumulated.

Since the Committee's guidelines, as fixed by references 1 and 2, prescribe a cruising speed of Mach 3, which would result in surface temperatures as high as 650° F, and likely 1200° F in the engine area, it was clear from the outset the chief attention should concentrate on stainless steels, titanium alloys, and superalloys. The scope of the screening program was affected also by the guideline dealing with overall timing of the SST. Reference 3 sets a time goal which led to the conclusion that only those alloys whose development was virtually completed and whose producibility and availability were assured should be screened. In some instances, however, alloy producers engaged in the final stages of development of new alloys or in minor alterations of existing alloys have extended or modified the test methods they use to characterize their new materials so as to conform with the conditions of the screening test program. Such private endeavors were encouraged by the Committee and the results have been included in its reviews of screening data.

These preliminary screening tests are now nearing completion. The accumulated results as of September 1962 are presented in detailed form in part II of this report.

Stress Corrosion Screening Tests

Studies by a Committee Panel on Corrosion of SST alloys led to the conclusion that screening-type tests to determine susceptibility to stress corrosion of the candidate alloys should be extended beyond the scope of the stress-corrosion investigator of the preliminary screening, results of which are reported in part II. This recommendation was accepted, and an FAA-sponsored Air Force contract with the Douglas Aircraft Company was established in April 1962 to extend stress-corrosion studies. Under this contract, leading candidate alloys are being evaluated in natural-exposure tests at El Segunda and Kure Beach, in laboratory salt-spray and alternate-immersion corrosion tests.

Creep Tests

The likelihood of significant creep occurring in the SST cannot be predicted with satisfactory certainty. This uncertainty arises from the nearly total lack of creep data at the temperatures and the steady-state creep rates of chief interest. A Committee Panel made an assessment of the importance of creep in SST by extrapolating, with the more common time-temperature, creep-ruptured parameters, available creep data from higher-temperature, shorter-time tests. The conclusions, which the Panel recognized as being based on questionable extrapolation, indicated that creep could be a matter of concern with titanium alloys, but likely would not be with steels or superalloys. Consequently, two actions have been taken:

(1) Under an NASA contract, the Convair Division of the General Dynamics Company is developing a creep machine with superior sensitivity and temperature stability, capable of measuring very low steady-state creep rates. The need for such creep data is evident from the fact that the SST airplane will be designed for a 30,000-hour minimum life, and that total permissible creep strain in some parts will be as low as 0.1 percent.

(2) Under an Air Force Contract, General Dynamics, Fort Worth, will carry on creep tests at stress levels, temperatures, and times representative of SST operating conditions. Alloys to be tested will be: Ti-8Al-1Mo-1V double annealed; Ti-6Al-4V annealed; AM 350 SCT-850; PH 15-7 Mo RH 1100; and René 41 20% CR 16 hr. at 1400° F.

Fracture Toughness

In the screening program, notch tests are conducted with the 1-inch-wide edge-notch or the 2 inch-wide center fatigue-notched specimens. The Committee considered that the notch testing should be expanded to include larger specimens, more nearly representative of aircraft structures. A Committee Panel appointed to study this matter recommended additional notch-toughness studies, using larger specimens. Since work with larger and more complex specimens is more costly and slower than with small screening specimens, it was recommended that a minimum number of alloys be used. Guidance from the screening tests in the selection of materials for the larger tests was expected.

These Panel recommendations received Committee endorsement and form the basis of an FAA-sponsored Air Force contract made with the Douglas Aircraft Company in April 1962. Under this contract 8-inch-wide specimens with center fatigue cracks are being tested at temperatures ranging from -110° F to 1400° F. Variables to be studied will include crack length, strain rate, thickness, and exposure time at 650° F. The alloys used will be: Ti-8Al-1Mo-1V 1400° F duplex annealed; Ti-6Al-4V annealed; René 41 20% CR 16 hr. age at 1400° F; air-melted AM 350 SCT-850; and PH 15-7 Mo RH 1100.

Coatings

Interest in protective coatings for SST materials arises for two reasons. First, there are some nonstainless steels with excellent potential for SST, which are not seriously considered because they would rust in service. A practicable protective coating could overcome this fatal deficiency of what might otherwise be an optimum material. Second, there is concern about discoloration that will appear on the fuselage and wings of an SST made with stainless steels and titanium alloys.

On several occasions, the Committee discussed the merits of various types of coatings for SST, always with the conclusion that not enough is known about individual coatings to judge feasibility of coating. It was concluded that a detailed survey of all promising coating processes, together with laboratory tests representing SST operating conditions, was needed. To satisfy this need, the NASA has engaged the Southern Research Institute to conduct such a survey and investigation.

Fatigue

Comparison of alloys on the basis of their ability to resist fatigue under SST operating conditions is seriously hindered by the lack of pertinent data. This state of affairs was early recognized by the Committee, and fatigue tests were included in the original screening program. However, mention of the screening fatigue is made here, rather than above with the preliminary screening tests, because of its relationship with other fatigue investigation, and because the fatigue screening had not progressed sufficiently for inclusion in the screening summary of part II of this report.

In the SST fatigue testing program at the Langley Research Center, candidate alloys are held at 550° F for various times, up to three years, without stress. After exposure, fatigue life of both notched and unnotched specimens will be determined at 70° F with mean tension stresses of 25, 000 psi for titanium alloys and at 40, 000 psi for steels. Alloy will include Ti-6Al-4V in both the annealed and the heat-treated conditions; Ti-4Al-3Mo-1V (aged); Ti-8Al-1Mo-1V (mill annealed); PH 15-7 Mo; AM 350 CRT 20%; AM 350 double aged; and AISI type 301 50% cold rolled.

In addition to these fatigue screening tests, the Langley Research Center will determine the rate of fatigue crack extension in 8-inch-wide center-notch specimens. The breaking strength of specimen after various amounts of fatigue crack extension will be measured in static tension at -110° F, 70° F, and 550° F. Alloys will include those listed in the previous paragraph plus Ti-8Al-1Mo-1V duplex annealed and René 41.

Under NASA contracts made in the summer of 1962, the Battelle Memorial Institute will determine the fatigue properties at 650° F, 70° F, and -110° F of Ti-8Al-1Mo-1V duplex annealed and AM 350 20% CRT. The Chance Vought Aircraft Company will conduct fatigue tests of specimens containing mechanical joints and also welded specimens representative of aircraft parts. These two investigations will use common materials, from the same mill lots.

RATING OF SST ALLOYS

Selection of a material for a specific use, like all selection, entails compromise. One single material is never the best in all significant aspects. It is, therefore, the responsibility of the materials engineer to find or to develop the overall-optimum material through profitable compromise, that is, the acceptance of a disadvantage with an accompanying and overbalancing advantage. Such trade-offs, seldom easy to make on a sound and rational basis, become especially critical and difficult when they entail far-reaching decisions on materials for an entirely novel application. Such is the case in selection of SST materials today.

At its second meeting, the Committee set out to devise a rationale for rating and selection of SST materials, to be founded on a formal procedure for the objective and quantitative evaluation of materials in terms of the important and precisely defined parameters. To accomplish this, a special Panel of the Committee has devised an SST materials rating procedure which has, in the process of its evolution, received critical examination by the entire Committee and by engineers of the staffs of several airframe companies. Neither the Committee nor the Panel is entirely satisfied with this rating process in its present form. Nevertheless, it is presented here because it represents a best attempt to organize and rationalize the sometimes imprecise and prejudice-prone process of material selection.

In table I, the parameters that the rating process takes into account are defined. Notice that many of these specialized definitions are shaped to the unique requirements of a Mach 3 airplane. The parameters are of three kinds identified as: discriminating, nondiscriminating, and go-no-go.

The discriminating parameters are those which represent characteristics of a material to which quantitative values can be given. It is on the basis of thse parameters that trade-offs can be made. They are: strength, toughness, thermal stress, fatigue, stability, formability, cost, stiffness, and as-welded strength.

The nondiscriminating parameters, that is, availability and producibility, do not allow comparison or quantitative discrimination among materials.

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Obviously, they represent requirements which must be met if a material is to be considered at all.

The go-no-go parameters represent characteristics of a material to which quantitative values can be assigned, but which must meet a certain fixed minimum value. Merit in excess of this minimum would be of limited usefulness, and such excess merit would not likely offset any inferiority in terms of discriminating parameters. Thus the go-no-go parameters do not lend themselves to compromise, or to quantitative and relative rating.

TABLE I. - MATERIAL RATING PARAMETERS FOR SUPERSONIC TRANSPORTS

(a) Discriminating Parameters

1. Strength	The average of the short-time ultimate tensile strength and compression yield strength at room temperature and 650° F divided by the material density.
2. As-welded strength	Ratio of the ultimate as-welded tensile strength to the ultimate design tensile strength of the parent metal.
3. Fatigue	Fatigue strength (10^5 cycles of axial tension, $R = 0$, and a stress concentration factor of $K_t = 2.5$) at room temperature divided by density.
4. Stiffness	The average Young's Modulus in tension between 70° F and 650° F divided by the material density.
5. Thermal stress	Average coefficient of thermal expansion between 70° F and 650° F times Young's Modulus at 650° F divided by compression yield strength at 650° F.
6. Toughness	Minimum values of notched over unnotched tensile strength ratio in the temperature range -110° F to 650° F. The choice of ASTM machined edge notched specimen or 8-inch fatigue cracked specimen should be based on the amount of test data available. Only one type of specimen (either notched or cracked) should be used in the rating procedure. If the amount of data for notched and cracked specimen is approximately the same, the cracked specimen is recommended.
7. Stability	Ratio of the notch-strength after exposure to the notch-strength before exposure.
8. Cost	The product of the cost (dollars per pound) of 10, 000 pounds of sheet material (0. 050 inch × 36 inch × 96 inch) and 10^5 divided by the strength parameter (refer to strength).

(b) Nondiscriminating Parameters

1. Availability	Relative supply of raw material and equipment for production by 1965.
2. Producibility	Producers' capability to offer raw material in form of sheet, foil, and plate.
3. Formability	Uniform elongation of 3% in 2-inch gage length.

(c) Go-No-Go Parameters

1. Corrosion	Resistance to general corrosion and stress corrosion for supersonic transport environment and life.
2. Weldability	Can be fusion welded with freedom from voids and cracks.
3. Brazability	Capability as a brazed-sandwich panel to retain the properties of the basic material.

After the value of each parameter for a given material is determined on the basis of the special definitions, its overall rating is arrived at with the aid of Rating Table shown in blank form in table II. Only the discriminating parameters are used in the quantitative part of the operations governed by the Rating Table procedure; values of the other parameters must be satisfactory. In the Rating Table, Weighting Factors are assigned to each discriminating parameter. These Weighting Factors reflect the relative importance of the parameters, and, in effect, make the trade-offs. Obviously, the assignment of the Weighting Factors is one of the critical steps, and by far the most controversial and subjective one, in the entire rating procedure.

To exercise the Rating Table, a material's Rating Number, ranging from 1 (for the poorest) to 5 (for the best), is determined on the basis of the parameter definitions. This Rating Number is multiplied by the Weighting Factor; the product is the Relative Rating Number. The sum of the Relative Rating Numbers is then divided by the sum of the Weighting Factors used; the quotient is the final Material Rating Number and appears in the last column. If the rating process is right in concept and execution, the material with the highest Material Rating Number is the optimum material.

TABLE II. - RATING CHART FOR SST MATERIALS

MATERIAL	GO-NO-GO ✱ SCREENING			RELATIVE RATING NUMBER (○ RATING NUMBER X *WEIGHTING FACTOR)								MATERIAL RATING NUMBER
ALLOY AND CONDITION	CORROSION	WELDABILITY	BRAZABILITY	STRENGTH (5)*	TOUGHNESS (5)	STIFFNESS(5)	STABILITY (5)	FATIGUE (4)	AS WELDED STRENGTH (4)	THERMAL STRESS (3)	COST (1)	Σ REL RATING NO. / Σ SIGMA RATING FACTORS
RENE 41												
A286												
INCONEL W												
WASPALLOY												
L605												
D979												
N155												
V36												
INCO 718												
INCO 901												

*WEIGHTING FACTOR (RANGE = 1 POOREST TO 5 BEST)
○ RANGE = 1 POOREST TO 5 BEST

✱ CODE = S = SATISFACTORY
U = UNSATISFACTORY

Several attempts to arrive at a relative rating of the candidate alloys that would be acceptable to the Committee have been defeated, chiefly due to lack of completely sufficient and reliable data from which to calculate parameter values. As more data become available from current investigations, this hindrance will gradually be overcome.

RECOMMENDATIONS FOR ADDITIONAL MATERIALS RESEARCH

Suggestions for additional research on SST materials are received by the Committee from its members and from other sources. These suggestions are studied by a special panel to judge merit, importance, overlap with current work or with other suggestions, etc; arranged in order of priority; and put into form suitable for Committee consideration and possible action. The recommendations of the panel for additional SST materials research, as modified and accepted by the Committee in November 1962, follow:

1. Realistic Proof Tests of SST Materials

Objective: The object of this project would be to establish the ability of two or three skin-material alloys to withstand realistic environments for the design life of SST. This study would serve as a proof test and check on analytical results derived from earlier and more general tests.

Work Outline: The most promising alloys, selected on the basis of current screening tests would be subjected to simulated SST service conditions and tested at various time intervals.

Materials - Each of the alloy classes (steels, titanium alloys, and superalloys) are suggested. Selection should be subjected to careful review at the time of work initiation.

Specimens - Should include smooth tensile, center hole tensile, joined samples (resistance and fusion welded, brazed, bolted, and rivited, as appropriate) evaluated by strength and ductility tests.

Simulated Environment - Specimens should be subjected to the stress, temperature, and time cycles representative, to the degree practicable, of SST. Gust, maneuver, landing, taxi, take-off, and thermal stresses should be included in spectrum. Times, equivalent to 30, 000 hours of SST operation, compressed to the degree possible, should be used.

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Results: Results would be in terms of degradation with simulated SST service.

2. Large Scale Fracture Toughness Tests

Expansion of the current research based on the Report of the Notch Test Panel, dated 22 September 1961, submitted to the Committee at the September 19-22 Meeting, is recommended. This work should be expanded to include larger specimens (to about 24 in. wide), which can provide designers with data that will be more representative and reliable than the 8-inch-wide specimens of the current work. Materials of heavier section than the 0.050-inch gage in current work should be included. Tests should permit determination of plain-strain fracture toughness $\left(K_{Ic}\right)$.

3. Screening of Materials for Fusion and Resistance Welding

It would be desirable to use fusion and resistance welding in fabricating many sections of the SST structure to insure maximum joint efficiency or fuel tightness. It has been found that weld metal in some high-strength alloys as PH steel, when hardened to maximum strength, is inclined to be brittle. Prolonged heating following welding may aggravate these effects. In performing a general screening of potential SST structural alloys, evaluation of welding characteristics must be included.

Objective: To evaluate the potential SST structural methods with respect to ability to retain adequate fatigue resistance, fracture toughness, and ductility in welded joints.

Development Program: It is not possible to evaluate fully the welding characteristics of the proposed SST materials since knowledge about the optimum welding technique for some of the alloys is inadequate. Therefore, it will be necessary to bring the welding techniques for each alloy to a comparable state of development for evaluation purposes. This will be done for only those alloys showing reasonably good welding characteristics. Fusion welding is preferable for the SST fabrication, but for those alloys showing poor fusion weld characteristics, other methods such as electron beam welding will be used.

Weld Testing: Welded test specimens should be tested at room temperature. Each type of specimen should have a minimum of three specimens per test temperature. The following welded specimens should be used for the screening program:

a. Tension specimens
b. Shear specimens
c. Bend specimens

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d. Fatigue specimens
e. Fracture toughness

The specimens should have a standard configuration. Material thickness should be comparable to SST skin materials. The semistandard 8-inch-wide center-notch specimen with transverse welds is recommended for the fracture toughness phase.

Results: The proposed program would provide an evaluation of welding characteristics of candidate structural materials for the SST.

4. Evaluation of Effects of Stressed Exposure at Temperature on Fatigue Properties at Room and Elevated Temperature

Materials: Leading SST alloys at time of start of work.

Specimens: Center hole tension-tension fatigue specimens.

Test Conditions: After exposure to SST operating temperature, for 100, 500, and 1,000 hours, with and without stress, fatigue tests should be made at room temperature, 400° F, and 650° F. Random loading representative of the stress spectrum of SST should be used.

Results: In terms of loss of fatigue strength, compared with original material.

5. Simplified Environmental Proof Test of SST Materials

The incorporation of a corrosive environment in the more complicated temperature, stress, cycle proof tests recommended in (1) above necessitates a test rig so complex and difficult to manage that results might be suspect. Consequently, a separate proof test with a simpler specimen and a less complex spectrum is recommended.

Specimen: Simple tension specimens, and specimens joined by realistic methods such as welding, brazing, and mechanical devices.

Test Time: To 30,000 hours or failure.

Materials: Leading SST materials at start of work.

Test Conditions: Alternate immersion in, or exposure to, sea-water solution coupled with representative temperature. Simple tension-tension fatigue tests should be used.

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6. Screening of Materials for Honeycomb Sandwich Construction

Honeycomb sandwich construction will be advantageous in many areas of the supersonic transport. However, the proposed SST materials differ in their suitability for use in this type of construction. The main problems associated with using these materials in sandwich construction are their reaction to brazing alloys, the compatibility of their heat treat requirements with brazing temperatures, and their corrosion resistance characteristics.

Objective: The objective of this study would be to evaluate the suitability of the proposed SST materials for use in honeycomb sandwich construction.

Metallurgical Evaluation: Since bonding techniques have not been established for most of the materials being considered for the SST, the first step in the program would be a bonding development program. The development program should determine the best brazing alloys and brazing cycles to be used for a particular material. If the material does not lend itself to brazing techniques, methods such as diffusion bonding and resistance welding should be investigated. The bonding techniques selected should be proven by a metallurgical analysis and tests for strength, thermal stability, and corrosion resistance.

Honeycomb Sandwich: After the bonding and metallurgical development phase has been completed, the resulting bonding techniques should be used to fabricate honeycomb sandwich specimens. The honeycomb specimens should be tested in the following manner:

a. Flatwise tension and compression-through thickness.
b. Core shear with beam or plate specimen.
c. Edgewise compression (short column).
d. Thermal conductance-through the thickness.

A minimum of three specimens per test condition should be required. The tests should be run at room temperature and 650° F. Materials of gage 0.015 - 0.020 in steels and 0.020 - 0.025 in titanium are suggested. Core densities of 6 pounds per cubic foot and 3/4-inch-thick panels are suggested. The proposed program would accomplish the following objectives:

a. Provide a basis for the choice of SST materials.
b. Provide knowledge about some of the fabrication problems and strength properties of honeycomb sandwich for the SST.

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7. Evaluation of Materials for Thick Sections

Virtually no operating experience and very few laboratory data are available to guide selection of materials for thick-section parts, such as landing-gear. Many alloys have been suggested; consequently, it is recommended that a preliminary screening program be conducted, followed by a more intense study of long-time stability of a few alloys chosen on the basis of the screening.

Screening Alloys Suggested: AISI 4340; Hy-Tuf; 300 M; HP9Ni-4Co; PH 15-5 or PH 13-8 stainless steel; Ti-6Al-6V 2Sn or Ti-6Al-4V; 18 Ni Maraging Steel at 200 ksi and 250 ksi tensile strength; Inconel 718; and AM-355.

Screening Tests:

1. Treatment to optimize toughness, as determined by precracked charpy specimens, in 8-inch square billets, or smaller if required to simulate realistic practice, should be ascertained.
2. K_c determined by ASTM - recommended center notch specimens, as a function of thickness, should be determined.
3. K_{Ic} should be determined, using both fatigue-cracked round specimens and center-notch plate specimens.
4. Effects of exposure representative of SST operating conditions should be investigated by use of precracked charpy specimens.
5. Strain-rate effects should be explored using a precracked specimen and a strain ratio of 0.01 per sec or faster.
6. Effects of variable humidity at various temperatures on plain-strain fracture should be explored.

Long Time Stability: Three alloys, selected from results of the above screening tests, should be exposed for 3,000, 10,000, and 30,000 hours at 450° F and 650° F under stress of 67,000 psi for steel and 40,000 psi for Ti. Following exposure K_c and K_{Ic} should be determined at 480° F or 650° F, and at -100° F.

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CONCLUSION

It will be evident from examination of the factual matter of this TN that research on SST sheet materials, although substantially advanced during the past 18 months, has not yet reached a stage propitious for making final material selections. Nor does the overall SST timing as envisioned by reference 3 require such final selection at this writing. Findings of the several investigations mentioned earlier in this report, which are expected to accumulate at an accelerating rate during the first half of 1963, should permit sounder judgments based on more complete and trustworthy data. The Committee's conclusions, reached at the Committee's most recent meeting in November 1962, are therefore presented here as interim conclusions, based on incomplete results and subject to modification in the light of more data from current efforts.

1. A Mach 3 supersonic transport is feasible as far as sheet material for wings and fuselage is concerned. However, it is not evident that either titanium alloys, stainless steels, or a superalloy alone will be best; in all likelihood optimum design will call for more than one type of material (i.e., titanium, stainless steel, or superalloy) and more than one alloy of each type.

2. On the basis of available data, the following alloys are considered to be the most promising ones: steels - AM 350, AM 355, PH 14-8 Mo; titanium alloys - Ti-8Al-1Mo-1V, Ti-6Al-4V; superalloys - René 41, Waspaloy, and Inconel 718.

3. None of the above-listed alloys shows significant degradation in strength or toughness after exposure to representative SST stress and temperature for 1,000 hours.

4. Failures of some titanium alloys and stainless steels in laboratory stress-corrosion tests at representative SST temperatures and in the presence of solid salt, both with and without high humidity, indicate that further studies are needed to determine the gravity of this phenomenon.

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2. Supersonic Transport Group, Bur. Flight Standards: Supersonic Transports - A Preliminary Study of Airworthiness, Operations, and Maintenance Standards. FAA, Mar. 1961.

3. Anon: Commercial Supersonic Transport Aircraft Report. Dept. of Defense, NASA, and FAA, June 1961.

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PART II - RESULTS OF SUPERSONIC TRANSPORT MATERIALS SCREENING PROGRAM

By J. W. Freeman, J. W. Schultz,
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PART II - RESULTS OF SUPERSONIC TRANSPORT MATERIALS SCREENING PROGRAM

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INTRODUCTION

Most of the data presented in this report came from a program designed specifically to screen alloys which appeared to be candidate skin materials for the construction of the wings and fuselage of a Mach 3 supersonic transport (SST). Estimates are that SST metal skin temperatures will vary from -70° F during subsonic flight to 550° F at Mach 3 cruise conditions. The estimated necessary service life for this aircraft is 30, 000 to 50, 000 hours. The basic requirement for candidate materials is a combination of the highest possible strength, adequate resistance to catastrophic crack propagation, and adequate corrosion resistance. It was considered most important that these properties be maintained during the prolonged exposure to maximum operating temperatures.

The testing program devised to screen materials to establish those with promising basic properties has been described by Espey, Bubsey, and Brown.[1] A test temperature range of -110° to 650° F was used to obtain data for unnotched (smooth) specimens and for specimens with sharp edge notches. Short-time tensile tests were used exclusively. To estimate the influence of prolonged exposure at maximum operating temperatures, smooth and sharp notch specimens were held for 1000 hours at 650° F under a stress of 40, 000 psi prior to testing.

The temperature and corrosion requirements limited candidate materials to titanium alloys, high-strength stainless steels, and superalloys. Still, many existing alloys had to be considered in the screening program. The number of materials to be screened was further multiplied by the need to optimize treatments of alloys for SST service

For the superalloys, screening program test and exposure temperatures were increased to as high as 1200° F, to establish maximum temperatures of usefulness.

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[1]G. B. Espey, R. T. Bubsey, and W. F. Brown, Jr. "A Preliminary Report on the NASA Sheet Alloy Screening Program for Trisonic Transport Skins." Paper presented at the ASTM Annual Meeting in the session on Fracture Testing on June 24, 1962.

Stress-corrosion of candidate skin materials is cause for considerable concern. Consequently, attention has been given to the effects of dry salt coatings at maximum operating temperatures, and extensive data on this aspect are included in the report. Limited additional data for other conditions of stress-corrosion are also included.

Most of the screening data were obtained by NASA through in-house research at Lewis Research Center and sponsored research at Syracuse University and The University of Michigan. NASA also sponsored a stress-corrosion testing program at the Materials Research Laboratory. Other laboratories contributed data on alloys originally included in the NASA screening program, as well as on other promising alloys. For alloys not originally included in the program, the Special Committee required that screening-type data be provided before consideration would be given.

Certain "follow-on" programs were indicated as a result of the activities of the Special Committee. One area of considerable concern is determination of the possibility of alteration of strength and crack resistance as a result of prolonged exposure to stress at SST temperatures. No proven way of extrapolation is available. To supply information applicable to this problem, the Applications Laboratory, ASD, U.S. Air Force is sponsoring research programs involving exposure for time periods up to 30,000 hours at Joliet Testing Laboratories, Inc. and at The University of Michigan. Preliminary data from these programs are included. NASA is also conducting research on the effects of prolonged exposure at the Langley Research Center. A very large program is in progress at the Douglas Aircraft Company involving follow-on tests and additional stress-corrosion testing under the sponsorship of the FAA through ASD. Only very limited data from this program were available for this report.

The companies represented on the Special Committee have various programs of their own in progress. Applicable data supplied by these organizations are included.

In addition to establishing factual test data, most of the research programs have included investigations intended to provide information of a more general and basic nature. Available data of this type have been included in this report.

Little or no data existed in the literature defining properties for SST applications. Only data pertinent to this type of application have been included in this report. No effort has been made to extract "handbook"[2] type data from the literature for the alloys considered.

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[2] The Air Weapons Materials Application Handbook, Metals and Alloys, ARDC TR 59-66.

The individual research programs on which this part of the report is based are described along with a summary of the major results of the research. Original test data are presented in a separate section for each alloy.

ORGANIZATIONS CONTRIBUTING DATA

NASA In-House Research
- Langley Research Center
- Lewis Research Center

NASA Sponsored Research
- Materials Research Laboratory, Inc.
- Syracuse University
- The University of Michigan

Applications Laboratory, Aeronautical Systems Division, U.S. Air Force Sponsored Research
- Joliet Testing Laboratory, Inc.
- The University of Michigan

Allegheny Ludlum Steel Corporation
Armco Steel Corporation
Boeing Airplane Company (Transport Division)
Crucible Steel Company of America
Douglas Aircraft Company, Inc. (Aircraft Division)
The International Nickel Company, Inc. (Huntington Alloy Products Division)
Lockheed Aircraft Corporation (California Company)
North American Aviation, Inc. (Los Angeles Division)
Northrup Corporation (Norair Division)

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RESEARCH PROGRAMS

Basic Screening Program

Longitudinal and transverse smooth and sharp edge-notch specimens were used in the basic screening program. The specimens were similar to those recommended by the ASTM Special Committee on Fracture Testing of High Strength Materials[3,4] and are illustrated on the following page. Minor variations in specimen dimensions occurred between laboratories, but reduced section length to width ratios and notch geometries were always about the same for smooth and notch specimens respectively.

The evaluation of alloys in the screening program was carried out as follows:

(1) Determination of the ultimate tensile strength, 0.2 percent offset yield strength, and elongation from -110° to 650°F.

(2) Determination of the notch strength to obtain a measure of fracture toughness.

(3) Expose both smooth and notched specimens at 650°F for 1000 hours using net section stresses of 40,000 psi on the steels and superalloys and 25,000 psi on the titanium alloys, and subsequently conduct tensile tests at -110° to 650°F.

Both longitudinal (parallel to rolling direction and transverse (perpendicular to rolling direction) specimens were tested because past experience with high-strength sheet materials had demonstrated that extreme directionality in properties can occur, especially when cold rolling is used to increase strength.

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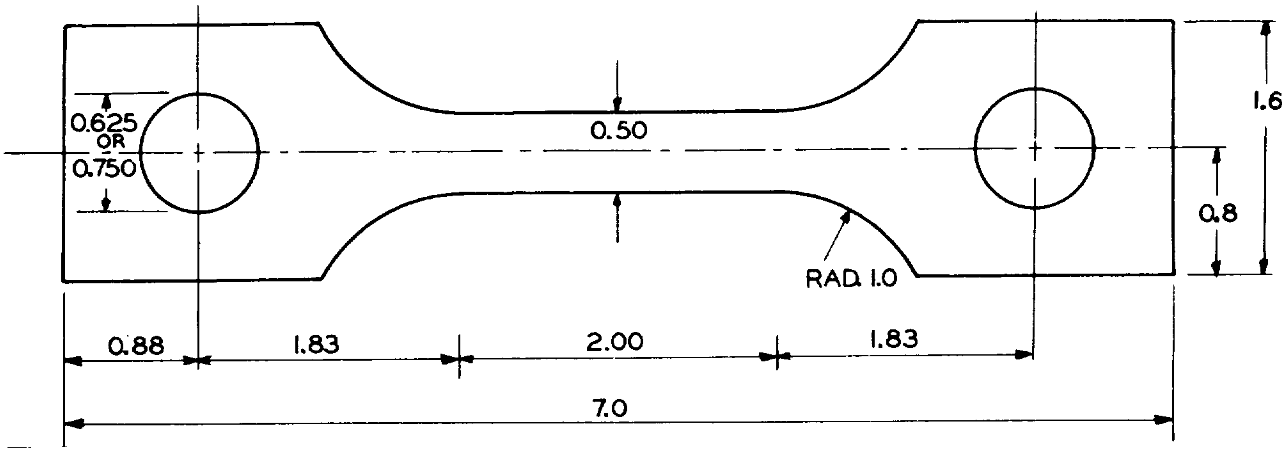
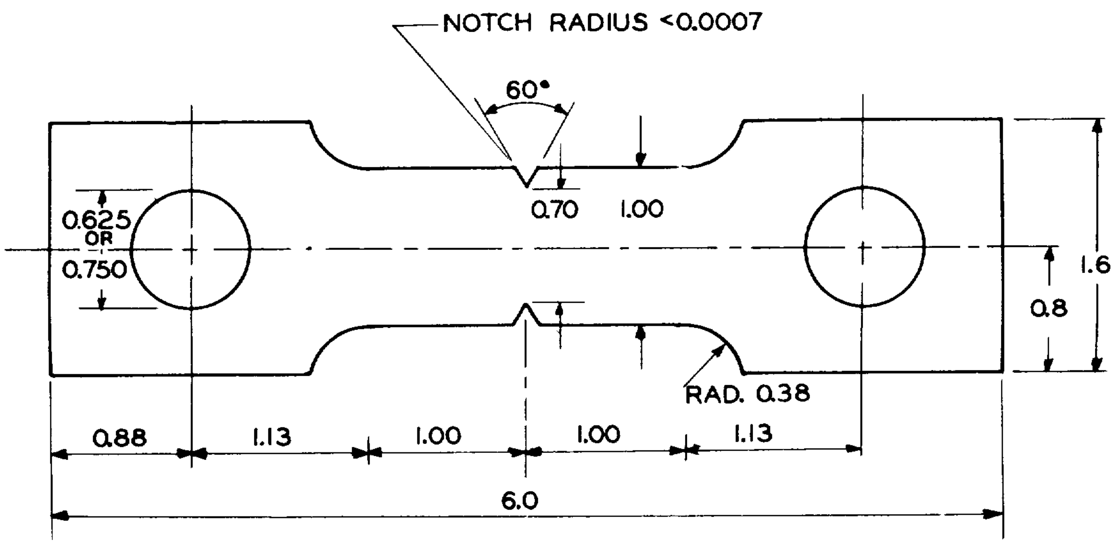
[3] "Fracture Testing of High Strength Sheet Materials: A report of a Special ASTM Committee", ASTM Bulletin No. 243, p. 29-40, Jan. 1960 and No. 244, p. 18-28, Feb. 1960.

[4] "Fracture Testing of High Strength Sheet Materials", Third Report of a Special ASTM Committee, ASTM Materials Research and Standards, Vol. 1, No. 11, p. 877-885, Nov. 1961.



a) Unnotched specimen



b) Specimen with sharp edge notches

Typical specimens used for screening tests. (All dimensions in inches)

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A sheet thickness of 0.025 inch was established as an arbitrary compromise.

A minimum temperature of -110°F was selected as convenient for testing purposes and, furthermore, insured that any evidence of a ductile to brittle transition temperature close to the minimum operating temperature would be uncovered. The exposure temperature of 650°F was selected rather than the average skin temperature of 550°F with the object of accelerating structural changes and corrosion which might occur during prolonged service at 550°F. One thousand hours was purely arbitrary as the longest practical time for screening purposes. The exposure stresses were roughly approximate to those resulting from a one g load on the airplane. Sharply notched specimens were exposed to simulate the effect of the presence of a crack during service.

It was recognized that the screening program represented many simplifications from the conditions actually encountered in a SST. Its sole purpose, however, was to sort out the more promising materials. The more sophisticated testing to simulate an actual SST is to be conducted as part of a follow-on program for the more promising materials.

Deviations from Basic Screening Program

There were, in individual cases, deviations from the basic test program. For superalloys, testing and exposure temperatures were extended to 800°, 1000°, and 1200°F with the objective of defining the maximum temperature of usefulness. This information was needed for certain parts of the SST which would operate at higher temperatures than the skin, and to provide data for estimating the ability of materials to withstand the higher temperatures associated with a possible growth potential in aircraft speed. Other deviations from the screening program are noted with the individual data.

Deliberate variations in metallurgical variables were included for certain alloys. In most cases, this involved variations in the degree of cold reduction to enhance strength. For the superalloys, it was necessary to establish suitable aging treatments after cold work.

DATA PRESENTATION

Data are presented for the following alloys:

Titanium Alloys

- Ti-6Al-4V
- Ti-8Al-1Mo-1V
- Ti-4Al-3Mo-1V
- Ti-5Al-2.75Cr-1.25Fe

High Strength Stainless Steels

- AFC 77
- AISI Type 301 Stainless Steel (Cold Worked)
- AM 350
- AM 355
- AM 367
- PH 15-7 Mo
- PH 14-8 Mo

Superalloys

A-286	Inconel W	Rene' 41
D-979	Inconel X	Waspaloy
L-605	Inconel 718	V-36
N-155	R27	

The data for each alloy are presented individually. An introductory page for each alloy identifies the sources of the data, alloy producer, heat number, and composition for each data sheet. The major properties are then displayed graphically, a separate page being used for each alloy condition. Data sheets tabulating all individual test results follow. A numbering system is used on the graphs to identify each plotted point with a specific data sheet. Specialized data, e.g. tear test results, notch acuity effects, etc., have separate data sheets and are displayed graphically where practical.

In certain cases, the same lot of material was used by more than one laboratory supplying data. All the test results on the same lot of material, although obtained from several sources, were included on the same data sheet to clearly relate them to that particular lot..

There were obviously a number of ways the data could be displayed graphically. For screening type data, longitudinal and transverse properties are shown separately; and the properties after exposure, including exposure to solid salt, are plotted with the original properties. This provides a direct comparison of exposure effects, but makes the comparison of longitudinal and transverse properties somewhat difficult. However, all attempts to combine the two led to graphs which were too confusing to use.

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INDIVIDUAL LABORATORY PROGRAMS

The objectives, pertinent procedures, and major results of individual research programs are presented below.

First discussed are the three sub-programs of the basic screening program, conducted cooperatively by the NASA Lewis Research Center, The University of Michigan, and Syracuse University.

Then follows an outline of two pertinent stress-corrosion studies, one directly sponsored by NASA, and the other conducted by an aircraft manufacturer on sheet alloys of interest.

A third grouping covers a pair of research studies, initiated under Air Force direction to determine response of SST materials to creep exposures of 30, 000 hours duration.

Lastly are outlined a variety of programs carried out by alloy producers, aircraft manufacturers, and NASA Langley Research Center to supply information of the type requested by the NASA Special Committee on Materials Research for Supersonic Transports.

NASA Lewis Research Center Program

Principal Investigators: W. F. Brown, Jr., G. B. Espey, and R. T. Bubsey

This program was part of the over-all basic screening program carried out cooperatively with NASA sponsored programs at Syracuse University and The University of Michigan.

Objectives

The objectives of this program were to establish the influence of the degree of cold work and heat treatment on the mechanical properties and notch toughness of selected materials from -110° to 650°F and to determine the stability of these materials using exposures at 650°F.

The alloys investigated were:

Type Alloy	Alloy	Condition
Precipitation hardening stainless steel	AM350	Cold Rolled 20, 30 and 45 percent and tempered
Precipitation hardening stainless steel	AM355	Cold Rolled 20, 30 and 45 percent and tempered
Titanium Alloy	8Al-1Mo-1V	Annealed 1450°F
Superalloy	V-36	Cold Rolled 20, 30 and 50 percent
Superalloy	Inconel W	Cold Rolled 50 and 65 percent

The AM350 and AM355 materials were from consumable electrode vacuum melted (CEVM) heats.

Procedure

The materials were exposed and tested in both the longitudinal and transverse directions under the test conditions dictated by the basic screening program. The smooth and sharp edge-notch specimens used were those described in the Research Program section.

Tensile tests were conducted using a differential transformer type strain gage connected to an autographic recorder for smooth specimens. The loading rate at -110°F and room temperature was 4300 psi per second for smooth specimens and 2300 psi net section stress per second for notched specimens. At 650°F, the loading rate was 2800 psi per second for smooth specimens and 1500 psi net section stress per second for notched specimens. A bath of dry ice and ethyl alcohol was used to obtain the -110°F test temperature. Conventional resistance furnaces were used at elevated temperatures.

Exposures at 650°F were carried out in creep-testing machines. Four specimens were connected in series and heated by two 12-inch resistance furnaces stacked one on top of the other. An aluminum tube around the specimens promoted temperature uniformity. Temperatures varied less than ±5°F. One Chromel-Alumel thermocouple was tied to each end of smooth specimens or attached to notch specimens by spot welding approximately 0.25 inch from the notch plane. No creep readings were taken during exposure.

Principal Results

The strengths of all materials decreased with increasing temperature of testing. The notched strength of AM350, Inconel W and V-36 alloys also decreased so that N/S values at 650°F were either no higher or were lower than the values at -110°F and room temperature. The 8Al-1Mo-1V titanium alloy, on the other hand, increased markedly in notched strength with increasing temperature, so that the N/S values increased from -110° to 650°F. The data for AM355 were incomplete.

Increasing amounts of cold reduction generally raised the strength of smooth specimens, reduced ductility and reduced notched strength. N/S ratios, consequently, decreased with increasing reduction. For V-36 alloy, a cold reduction of 50 percent resulted in such low N/S values (0.3 to 0.4) that there was no further interest in the material even though smooth strengths were very high.

For AM350, tempering at 950°F resulted in somewhat lower strengths, higher ductility and higher N/S ratios than tempering at 700° or 825°F. Aging Inconel W after cold reduction slightly raised smooth strengths.

AM350 was subject to transformation to martensite as a result of straining. Increasing amounts of cold reduction increased the degree of transformation before testing and reduced the amount during testing. Consequently, the ratio of yield to tensile strength increased with the amount of cold reduction.

The investigators analyzed their data to show that the use of ratios of notched strength to yield strength rather than to tensile strength avoids difficulties in interpreting data[1]. For instance, it avoids the indication of increasing toughness with increasing amounts of cold work indicated by notched to tensile strength values for AM350 transforming to martensite while, in fact, toughness must decrease with amount of reduction.

In general, exposure under stress for 1000 hours prior to testing had only a minor effect, if any, on properties. Differences between longitudinal and transverse specimens, either before or after exposure, varied with test temperature and prior history. The effects on properties were such that the data had to be considered in detail to define the effects of prior exposure and orientation.

The University of Michigan (NASA) Program

Principal Investigators: J.P. Rowe, Jay W. Schultz, and J.W. Freeman

This program was part of the over-all basic screening program carried out cooperatively with the Lewis Research Center of NASA and Syracuse University under sponsorship of NASA.

Objectives

This program was designed to investigate by screening type tests the possibilities of using superalloys in SST construction. Also, the upper temperature limit of usefulness of superalloys for SST applications was to be established to indicate possible use at points of higher temperature than skin temperatures. This information would also serve as a background for possible growth potential to speeds greater than Mach 3.

The alloys investigated were:

Alloys		Conditions
A286	-	Cold worked 30, 50, 65 and 80 percent and aged
Rene' 41	-	Annealed, cold worked 20 and 35 percent and aged
Waspaloy	-	Annealed, cold worked 20 and 40 percent and aged
D979	-	Cold worked 30, 50 and 65 percent after annealing at 1850°F and cold worked 80 percent after annealing at 1950°F and aged
N155	-	Cold worked 40, 55 and 65 percent
L605	-	Cold worked 25 and 45 percent
AM350-CRT	-	Air melted

The materials were selected to indicate the effects of alloy types as well as to cover specific promising alloys.

(1) Rene' 41 and Waspaloy are high strength Ti+Al precipitation hardened alloys which differ in metallurgical characteristics imparted by high and low molybdenum contents.

(2) D979 is a very high strength Ti+Al precipitation hardened alloy containing tungsten.

(3) A286 is a relatively low-alloyed Ti+Al precipitation hardened alloy.

(4) N155 and L605 were included as representative of superalloys not subject to precipitation hardening but capable of being cold worked to high strengths.

(5) AM350-CRT was mainly included to provide data for comparison purposes with other laboratories.

Procedure

For the precipitation hardening alloys, it was necessary to conduct brief aging experiments to select promising aging conditions after cold work.

Room temperature tests were used to estimate the aging treatment giving the optimum strength and notch-strength ratio.

The non-precipitation hardening alloys were tested in the cold worked condition. Pilot tests were used to eliminate conditions of cold work for which screening tests would not provide useful data.

All notch tests employed the ASTM type sharp edge-notch specimen mentioned previously. The notch roots were finished on a shaper by manually drawing a carbide tool through them. The root radii (measured with a 50X optical comparator) varied from 0.0005 to 0.0007 inch.

The materials were exposed and tested in both the longitudinal and transverse directions under the conditions dictated by the basic screening program. For exposures, short cuts reduced an excessively large testing program; only when the properties of a material appear promising were tests conducted over the entire temperature range of -110° to 650°F.

Alloys and specific treatments of alloys which showed promising properties in the initial screening program were further tested at 800°, 1000°, and 1200°F. Exposures were also carried out at these temperatures for 1000 hours under 40,000 psi, and tensile tests subsequently conducted at room temperature and at the exposure temperature. As data were accumulated and the pattern of properties established, exposures were jumped from 650° to 1000°F.

Tensile tests at -110°F were conducted in a mixture of dry ice and acetone, and at elevated temperature in an electric resistance furnace. Temperatures varied less than ±3°F from the nominal test temperature along the gage length and during the tests. The time for heating and adjusting the temperature distribution was about one hour. Temperatures were measured by Chromel-Alumel thermocouples wired to the center and to each end of the gage length of specimens. Notched specimens had one thermocouple wired to the center. Smooth samples were loaded at about 0.01 inch per inch per minute to about 2-percent strain and then the strain rate was increased to 0.05 inch per inch per minute. Notched samples were loaded at a rate of 1000 psi net section stress per second.

Strain measurements were made for all tensile tests of smooth specimens. For most of the room temperature tests, a microformer type extensometer was used. For other tests, a modified Martens type extensometer was clamped to the gage section. The sensitivity of the extensometers was 0.000005 inch per inch.

Exposures were carried out in simple beam loaded creep units. About four hours were used for heating and temperature adjustment. Creep measurements were made on all smooth specimens. The extensometer was the same as that used in the tensile tests.

After exposure, tensile tests were conducted without further machining or surface treatment with the exception of a few tests where sharp notches were machined after exposure.

The load was applied through a special pin connection attached to a universal joint.

Principal Results

The screening program yielded the following results:

(1) Generally, the data showed a decrease in strength and notch-tensile strength ratio as the temperature was increased from -110°F. The main exception was Rene' 41 for which the notch-tensile strength ratios remained fairly constant.

(2) Exposure generally did not change subsequent tensile properties.

(3) Cold working resulted in marked increases in strength. A further increase for superalloys containing Ti+Al could be obtained by proper aging after cold working.

(4) Longitudinal and transverse specimens showed little difference except for severely cold worked materials.

(5) Elongations either did not change or else decreased with increasing test temperature.

(6) Cold work reduced notch-tensile strength ratios and elongations.

(7) Creep has not been significant in the exposure testing. A slight decrease in length was observed in most alloys at 650°F. This diminished with increasing testing temperature.

(8) The few tests with notches machined after exposure have not given much different results than those for specimens exposed with the notches present.

Although notch-tensile strength ratios were generally unaffected by exposure, certain other results cause concern:

a) Two transverse notched specimens of Rene' 41 cold reduced 35 percent and aged two hours at 1500°F fractured during exposure at 1000°F under 40,000 psi at 743.3 and 941.9 hours.

b) During tensile tests at 800° and 1000°F, longitudinal smooth specimens of D979 cold reduced 50 percent and aged 16 hours at 1100°F fractured below the yield strength in a brittle manner at pin holes, fillets, and in the gage section under collars. This also occurred during tensile tests at 1000°F after exposure at that temperature.

The D979 cold reduced 65 and 80 percent failed in a brittle manner in room temperature tensile tests after aging treatments. These conditions were subsequently eliminated from the screening program.

c) Notched specimens of L605 cold reduced 25 percent failed during exposure at 1000°F in short time periods.

d) A notched specimen of A286 cold reduced 30 percent and aged 16 hours at 1300°F fractured at 214 hours during exposure, but a repeat specimen did not fracture in 1000 hours. A286 cold reduced 80 percent and aged at 1100°F for 16 hours fractured prematurely during tensile tests at 650° and 800°F. Exposure at 650°F embrittled this material in subsequent tensile tests at 650° and 800°F.

Syracuse University Research Institute Program

Principal Investigators: V. Weiss, R. Sell, and C. Chave

The program was part of the over-all basic screening program carried out cooperatively with the Lewis Research Center of NASA and The University of Michigan under sponsorship of NASA.

Objectives

In addition to basic screening tests, specimens of some alloys were tested with fatigue cracked edge notches to study the effect of notch sharpness. Some data were obtained for exposure without stress. A limited amount of data was obtained for changes in the radii of notch roots during exposure. The effect of the stress concentration factor of the notch is also being studied for root radii from <0.001 to 0.187 inch (K_t values from >17.31 to 1.83).

The following alloys were investigated:

Alloy	Conditions
AISI Type 301 Stainless Steel	Cold reduced 34, 51 and 60 percent
PH15-7Mo Stainless Steel	RH1050 and CH900
Ti-6Al-4V Titanium	Annealed and solution treated plus aged
Ti-4Al-3Mo-1V Titanium	Annealed
Ti-5Al-2.75Cr-1.25Fe Titanium	Annealed and solution treated plus aged
Ti-8Al-1Mo-1V Titanium	Duplex annealed

Procedure

The ASTM type specimen with machined sharp edge notches was used for screening tests. A 10-percent starter notch was used for the fatigue-cracked edge notches.

Dry ice and acetone were used to obtain -110°F. Other tests were conducted in air, with resistance furnaces for elevated temperature tests. Exposures were carried out in creep-rupture units, using two or three specimens in tandem in furnaces modified to obtain uniform temperature distribution.

Principal Results

Ti-6Al-4V alloy appeared to be the most promising of those studied. Ti-5Al-2.75Cr-1.25Fe annealed and Ti-4Al-3Mo-1V annealed also appeared promising.

On the basis of notch-tensile strength ratios being less than 0.4, AISI Type 301 stainless steel cold reduced 51 percent, PH15-7Mo CH900 and Ti-5Al-2.75Cr-1.25Fe solution treated and aged seem unacceptable for SST construction.

Measured notch root radii changes from exposure were:

Material	Stress at 650°F for 1000 hours	Root Radii Before Exposure	Root Radii After Exposure	Change
Ti-6Al-4V solution treated and aged	25,000	0.0005	0.0005	0.0000
	25,000	0.0005	0.0007	0.0002
PH15-7Mo RH1050	40,000	0.0010	0.00125	0.00025
	40,000	0.0011	0.00125	0.00015

The effects of unstressed exposure versus exposure under stress varied with the alloy and its treatments. Effects generally were not large, with no difference for the Type 301 stainless steels.

The notched strengths for fatigue cracks versus machined notches also varied with the alloy. There was no difference for the Type 301 stainless steels. The cracked specimens were slightly stronger for PH15-7Mo RH1050. For most of the titanium alloys, the fatigue cracked specimens were weaker.

The notch-tensile strength ratio for annealed Ti-6Al-4V at room temperature was slightly higher than 1 out to a K_t of 9 to 10 and then fell slightly below 1. The ratio fell below 1 at a K_t of 7 down to about 0.7 at a K_t of 17 for the solution-treated and aged condition. Little difference existed between longitudinal and transverse specimens. For PH15-7Mo CH900, the longitudinal specimens developed a notch-tensile strength ratio of less than 1 at a K_t of about 5 and fell to a ratio of 0.8 at the sharpest notch. The transverse specimens all had notch-tensile strength ratios of less than 1 and the ratios decreased sharply to 0.6 at a K_t of about 3 and about 0.45 for the sharpest notch. On the other hand, K_t had little effect on PH15-7Mo RH1100, being close to 1 out to the sharp notch with the transverse specimens being only slightly lower than the longitudinal.

Program of Materials Research Laboratory, Inc.

Principal Investigators: R. L. Kirchner and E. J. Ripling

This program was carried out as part of the over-all NASA program in cooperation with the NASA Lewis Research Center program.

Objectives

The initial objective of this program was to develop stress-corrosion data to compare exposure in the presence of natural sea salt with exposure in air. The procedure was generally the same as the basic screening program with the addition of sea salt prior to exposure.

The alloys used in the investigation were from the same lots as those used in the Lewis Research Center and Syracuse University screening programs. They were as follows:

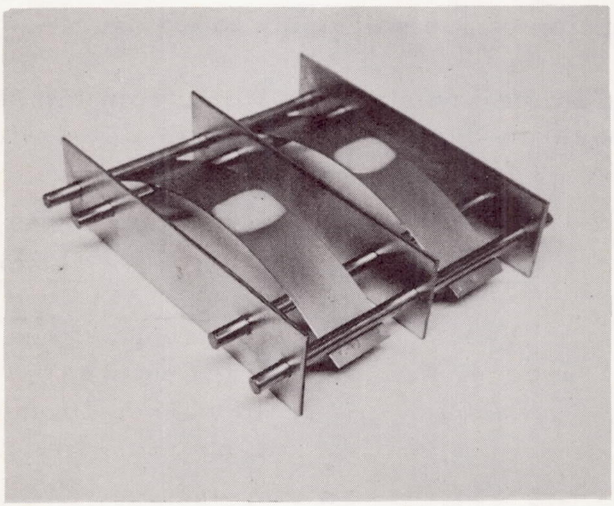
Type of Alloy	Alloy	Condition
superalloy	V-36	cold worked 30 percent
superalloy	Inconel W	cold worked 65 percent
stainless steel	AM350	cold worked 20 and 45 percent and tempered 3 hrs. at 825° and 950°F
titanium	Ti-6Al-4V	annealed
titanium	Ti-8Al-1Mo-1V	annealed

The titanium alloys were found to be severely embrittled by salt exposure in laboratory tests; but service experience has indicated that these alloys perform satisfactorily in applications where salt collects on the metal as long as the surface is subjected to a fast air stream. Hence, the program was expanded to determine if tests in a stagnant laboratory atmosphere are representative of the environment probable for skin materials of an SST. The mechanism of stress-corrosion cracking is being investigated through the electrochemical characteristics of the titanium-salt reaction in order to evaluate the "working action" of a fast moving air stream.

Procedure

Initially, all salt exposures were made using only sharp-notched specimens of the ASTM recommended design with sea salt applied to an area covering about ½-inch of length centered around the notch. Creep machines were used for these exposures with temperature variations being kept to ±2°F. Lewis Research Center data for unexposed and air-exposed specimens were used for comparison purposes.

After initial tests on the titanium alloys indicated severe embrittlement from salt exposure, a more extensive exposure program was instigated for these materials at 650°F. Bend test racks, as pictured below, were used to expose specimen blanks with and without salt coatings. These exposures were for 100 hours with the racks placed in stainless steel boxes to provide a stagnant atmosphere.



SALT COATED SPECIMENS MOUNTED ON TEST RACK

Surface stresses during exposure from 0 to 40,000 psi were calculated using calibrations at room temperature and modulii at 650°F. Tensile specimens were machined after exposure, removing stress variations at the edges of bend sheets.

The conductivity measurements were made in a porcelain tube to investigate the electrochemical characteristics of the titanium-salt reaction. Two discs of alloy were separated by about 0.1 inch of salt. At low temperatures, the conductivity was calculated by measuring current in a μa induced by a bias of 36 volts. At higher temperatures, an ohmmeter was used. The time of each determination was carefully controlled so that it took 50 minutes to bring the conductivity cells from room temperature to

1300°F. Both V-36 and Ti-6Al-4V electrodes were used. The conductivities measured with the titanium electrodes were lower than those measured with V-36 electrodes using sea salt and ASTM salt. This was probably due to TiO_2 forming on the electrode surfaces.

Principal Results

Using sharp notched specimens, V-36, Inconel W, and all conditions of AM350 showed no property losses as a result of exposure in the presence of dry sea salt coatings. Increasing the stress to 60,000 psi on Inconel W and AM350 cold reduced 20 percent and aged at 825° or 950°F induced no effect from the salt. Neither did increasing the exposure temperature to 850°F cause attack of the Inconel W by the salt.

All the Ti-6Al-4V sharp-notched specimens fractured in less than 400 hours under salt exposure at 650°F and 25,000 psi. Under the same exposure conditions, the three longitudinal Ti-8Al-1Mo-1V specimens fractured in less than 300 hours; while the two transverse specimens lasted 1000 hours. Failures in the notched specimens occurred away from the notch at the edge of the salt coating. Notched samples of Ti-8Al-1Mo-1V survived an exposure of 1000 hours at 450° and 500°F with very little alteration of properties due to salt.

Bend-test samples with salt on the tension side were exposed for 100 hours in a stagnant atmosphere at 650°F under stresses ranging from 0 to 40,000 psi. Longitudinal samples of Ti-6Al-4V were only moderately damaged, but transverse specimens were extensively damaged. Ti-8Al-1Mo-1V was damaged in both directions. The damage was much greater the higher the stress. Salt on the compression side of the specimens had no effect.

The failures at the salt edge away from the notch suggested galvanic corrosion. The lack of attack on unsalted specimens and on the specimens with salt on the compression side exposed in bend test racks cast doubt on the theory that chlorine release caused corrosion. In view of this, conductivity measurements were made on sea salt, ASTM salt (7 parts NaCl + 1 part $MgCl_2$), and NaCl. The sea salt was considerably more conductive at about 600°F than either of the other two, with NaCl being least conductive. Comparable conductives were achieved at the following temperatures:

Sea salt at 650°F
ASTM salt at 725°F
NaCl at 900°F

If the corrosion was electrochemical, it should be possible to move the location of attack from the edge of the salt deposit in notched specimens by developing a more uniform current flow through the entire salt coating. Superimposing 20 μa of current per square inch through the salt on Ti-6Al-4V transverse samples caused fracture in the plane of the notch after very short exposures at 650°F under 25,000 psi.

Sample anode - fractured in 20 hours
Sample cathode - fractured in 4.9 hours

Fracture did not initiate in the notch bottom but did initiate in the plane of the notches. The higher conductivity of the sea salt could account for the apparently greater attack than for the other salts.

Fractures were intergranular in the titanium alloys.

Program of North American Aviation, Inc.

Principal Investigator: G.A. Fairbairn, Group Leader, Metallic Materials Laboratory

Objectives

This is a program to evaluate the long term stress-corrosion resistance of six alloys at 650°F. Exposures are to be continued for 30,000 hours on five surface- and environmental conditions for the following alloys:

Type of Alloy	Alloy
Titanium	Ti-6Al-4V
	Ti-8Al-1Mo-1V
Stainless Steels	AM350
	PH15-7Mo
Superalloys	Rene' 41
	Inconel 718

The surface and environmental conditions are:

(1) Bare specimens as-heat treated

(2) Salt-Coated Specimens - Specimens dipped in a hot concentrated solution of 6 parts NaCl + 1 part $MgCl_2$ and dried.

(3) Brazed surface. The specimens were completely machined including notching and then placed in a retort with the braze alloy sheet. Brazing and heat treatment were carried out in the retort.

(4) Brazed surface coated with salt. After brazing, the specimens were coated as described under (2).

(5) Cyclic Tests. Salt-coated specimens prepared as in (2) are removed from the furnace every two weeks and placed in a humidity cabinet at 100°F for two weeks.

The titanium specimens were not heat treated after brazing, while the stainless steels and superalloys were re-heat treated. No attempt was made to clean out the salt or braze alloy which tended to accumulate in the notches. The edges of all braze-coated specimens were ground until clean base metal was obtained.

Procedure

Cantilever specimens 11.5 inches by 1.5 inches both unnotched and notched are being used. Notches were machined across the 1.5-inch direction at the point of maximum stress and near the weight suspension point at a low stress. A root radius of 0.005 inch in 0.010-inch deep 60°V notches is being used.

The loaded specimens in frames are placed in an air circulation furance having a temperature variation of 630°F near the door to 650°F in the center and rear portions. Due to air circulation, specimens continually vibrate with an amplitude of about 0.1 inch.

The maximum stress levels used varied within the following ranges:

	Ti-6Al-4V	Ti-8Al-1Mo-1V	PH15-7Mo
Unnotched, ksi	23.0-36.8	22.5-31.4	53.7-61.3
Notched, ksi	44.6-58.0	56.2-66.1	140.6-168.4

	AM350	Rene' 41	Inconel 718
Unnotched, ksi	50.0-59.1	48.8-57.4	34.0-40.8
Notched, ksi	129.3-160.3	126.8-147.2	92.4-105.5

Results to Date

The test data available at the 4700 hours of exposure when this report was written are included in the sections for the individual alloys. The most significant data are:

(1) Fractures have occurred as follows:

(a) Ti-8Al-1Mo-1V alloy specimens, salt coated and unnotched, fractured during continuous exposure at 2720 and 3980 hours. The surface appearance indicated extensive corrosion. A third specimen had not failed at 4700 hours.

(b) AM350M alloy specimens salt coated and unnotched, (cyclically exposed in the furnace for two weeks and in a humidity cabinet at 100°F for two weeks), fractured at 2880, 3290, 3290 and 3360 hours. The surfaces were heavily rusted and cracks other than those causing failure were present in two of the specimens.

(2) Appearance of other specimens is as follows:

(a) The bare titanium and stainless steel alloys show slight bluing.

(b) Salt coated stainless steels are colored from gold to brown. About 20 percent of the surface of unnotched specimens and 50 percent of the surface of notched specimens are coated with rust spots. The other specimens have darkened surfaces and a few rust-like spots. The salt coating appears spotty.

(c) The braze-coated specimens show slight darkening with no evidence of corrosion.

(d) The braze- and salt-coated titanium alloy specimens are dark brown. Titanium alloy specimens in the bottom layer of the frame and all stainless steels have about 50 percent of their surface covered with rust-like spots.

(e) The cyclically exposed ferrous and superalloys have a round surface and exhibit considerable rusting. Titanium alloy specimens are smooth with a blue-gray discoloration.

The University of Michigan (ASD) Program
(Contract AF33(616)-8334)

Principal Investigators: H. R. Voorhees and J. W. Freeman

Objectives

To determine the effects on mechanical properties of AM350 sheet from long-term exposure at the upper temperature expected in SST service. The program includes tests which seek to provide partial information at the earliest possible date, and to enable evaluation of possible extrapolation methods to predict creep in 30,000 hours from results of shorter tests.

Experimental Program

Test materials came from the same consumable-electrode vacuum-melted stock as that tested by the Lewis Research Center in its part of the basic screening program. All specimens were sampled in the rolling direction of the 0.025-inch thick sheet. After the required stresses were found to be too high, initial plans were dropped to establish the stress that would produce 0.5 percent creep strain in 30,000 hours at 550°F, and other types of tests were substituted.

Three types of specimens are now being exposed under 67,000 psi stress at 550°F:

(1) Unnotched specimens with 0.350-inch wide gage section 2 inches long;

(2) Notched specimens with $K_t = 3$;

(3) Unnotched specimens with 1-inch gage width, to receive sharp edge notches after the exposure.

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Exposure times of 2000, 5000, 12,000, and 30,000 hours were selected to define the time effect of exposures, if any, as well as to provide some interim data prior to completion of the longest exposures in 1965. After the exposures, tensile tests at 550°F will supplement those originally called for at room temperature, because data from the screening program indicate exposure effects may be most severe at the higher temperature.

Notched specimens with $K_t = 3$ are intended to simulate a severe design condition, while the sharp notches approximate cracks which might develop during service. A few exposures without stress were included by suspending an unloaded specimen in the exposure furnace alongside a stressed specimen.

A limited study of accelerated exposure used the 67,000 psi stress, but with times of 2000 hours at 600°, 200 hours at 650°, and 20 or 200 hours at 700°F.

Creep measurements are being made during exposure only for one unnotched section of specimens being exposed in tandem. With creep expected to be very small, the number of measurements should still suffice to demonstrate whether creep deformation would become a serious factor during service.

Results to Date

(1) The $K_t = 3$ notches raised net-section strengths of the unexposed material at room temperature and 550°F.

(2) The only change from sharp notches was a reduction of strength at 550°F for the SCT condition.

(3) Exposure at 550°F under stresses below, at, and above the yield strength had no effect on tensile properties at room temperature.

(4) The exposures at 600°, 650°, and 700°F did not change properties except possibly in one case. The ultimate strength of one CRT specimen exposed at 700°F for 200 hours and then tensile tested at 550°F was apparently higher than for unexposed material. This "accelerated" test foretold no expected change from 30,000 hours of exposure at 550°F.

Program of Joliet Testing Laboratory, Inc.
(Contract No. AF33(616)-8348)

Principal Investigators: W. F. Carew and C. F. Kinkel

Objectives

To examine effects of 30,000-hour exposures to stress and temperature on mechanical properties of AM350 SCT stainless steel, and annealed Ti-8Al-1Mo-1V sheet. An original intent to evaluate extrapolation procedures to predict long-time creep strains from shorter-time tests, was abandoned because initial tests suggested that stresses in the yield range would be needed to obtain 0.5 percent creep strain in 30,000 hours.

Procedure

Four unnotched specimens (with a 2-inch gage length 0.505-inch wide) and one notched specimen ($K_t = 3$) of each material are being exposed for 30,000 hours under 67,000 psi stress; the AM350 at 650°F, and the titanium alloy at 550°F. The notch used represents a severe design condition, rather than a crack such as was simulated by the notches of the screening program.

Most of the exposed specimens are to be tested at room temperature, and their short-time mechanical properties compared with those of the virgin material. Other specimens will be examined for metallurgical changes.

Creep is expected to be negligible at the 67,000 psi stress, but creep measurements are being taken for all unnotched specimens, using conventional platinum-strip extensometers viewed through windows in the furnace walls.

Principal Results

To date, the only results are for the original material, or for discontinued preliminary creep tests started at stresses in the yield range.

Related Programs from Which Data Have Been Included

Allegheny Ludlum Steel Corporation

Screening-type tests at -100°F and room temperature were run on AM367 sheet with a variety of annealing temperatures and subsequent maraging conditions. A few tests involved 500-hour exposures at 650°F under 40,000 psi. Most tests were for 0.025-inch sheet thickness, with some data for 0.050 or 0.062 inch. One lot of AM367 was evaluated after welding, with and without further heat treatments.

Complete screening tests in duplicate were reported for R-27 sheet (2050°F, WQ + 1400°F, 16 hrs. + 1200°F, 24 hrs.) tested at -320°, room temperature, 650°, and 800°F. These involved 1000-hour exposures at 650°F and 40,000 psi before some tests at room temperature and 650°F. Data are included for a few bend tests after three different treatments, and for room-temperature tensile properties of annealed specimens.

Armco Steel Corporation

Technical data are being developed for PH14-8Mo stainless steel over the temperature range likely to be encountered by a SST. Five conditions of the material are being evaluated to varying degrees. In addition to screening-program data, results are being obtained with center-notch fatigue-cracked specimens, and Allison bend parameters are being established.

A limited amount of unstressed exposures to 1000 hours at 500°F will be carried out.

Other phases of the program include effects of TIG welding, cold work, and stress-corrosion cracking at Kure Beach and by laboratory salt-fog tests.

The Boeing Company, Transport Division

Tear resistance was evaluated between -65° and 500°F for AM350 (SCT and CRT), and for AM355 (CRT) stainless steels, using specimens 24-inches wide by either 23 or 48-inches long. A machined center notch 8-inches long was transverse to the testing direction, Type I notches were 0.005-inch wide:

Type II, 0.030 inch except for the last 0.25 inch at each end, which was also 0.005-inch wide. Effect of strain rate was evaluated for the AM350 material.

Greased stiffener plates were lightly clamped against the specimen in an effort to minimize buckling as the "crack-growth jig" was loaded by a hydraulic system. An oscillograph recorded the load rate, measured by a 50 KIP dyne bar.

Critical crack lengths were determined by visual observation during slow crack extension, and by studying the fracture surfaces. Coupons machined from broken tear-test specimens were tested at the tear-test temperature. Strain rates in standard tensile tests were increased from 0.005 to 0.10 inch/inch after two percent strain had been reached.

Tabulated results include the stress intensity factor $k = \sigma_G \sqrt{a}\, \alpha$,

where σ_G = the gross area stress, psi

a = half the initial crack length

α = Irwin's correction factor for axial rigidity of the panel.

Other listed values are $\Delta\sigma_G / \Delta t$ and G_c.

Decreasing fracture toughness with increasing temperature for the CRT condition was attributed to structures with more than half austenite. A drop in toughness of AM350SCT at -65°F was stated as probably due to greater transformation to austenite in this condition.

AM355 CRT was extremely sensitive to load rate, with a decrease in the yield-zone width and in the critical crack length for increasing rates.

Crucible Steel Company of America

This program involves determination of technical data on AFC 77 steel sheet in the temperature range anticipated for a SST. Tables list results of basic screening data, as well as for fatigue-cracked center-notch specimens. Varied cold reductions and welding conditions, in conjunction with varied thermal heat treatments, are being studied in an effort to optimize treatments and properties.

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Douglas Aircraft Company, Inc., Aircraft Division

Tear-test results are tabulated for AM350 sheet, treated to the SCT-850°F condition after shearing and milling to panels 8.000-inches wide (in the rolling direction) by 24-inches long. A 0.006-inch wide starter slot 0.450-inch long was "Eloxed" across the center of each panel, and a 1.0-inch long crack then was developed at each end of the starter notch by fatigue.

Cracked panels were tension tested to failure, at a loading rate between 1000 and 5000 psi per second.

No report was made of the composition of the particular material or of crack measurements other than its original length.

The International Nickel Company, Huntington Alloy Products Division

Screening tests of Inconel 718 sheet were made for transverse specimens in two conditions of heat treatment. Some specimens had been exposed for 1000 hours at 650°F and 40,000 psi stress. Effects on room-temperature properties from sheet thicknesses between 0.027 and 0.050 inch received some attention.

NASA Langley Research Center

Tensile data at -110°F and at room temperature were determined for unnotched and sharp-edge notched specimens of two annealed titanium alloys (Ti-6Al-4V and Ti-8Al-1Mo-1V), and of PH15-7Mo stainless steel in the TH 1050 condition. Unstressed exposures of up to 10,000 hours at 550°F are included, with future tests to 22,000 hours planned. ASTM type notched specimens had a root radius of approximately 0.0005 inch.

Lockheed Aircraft Corporation, California Company

Crack-propagation data have been obtained at -65°, room temperature, and 600°F for a variety of alloys and treatments under consideration for use in SST. Some specimens were oriented parallel to, and others transverse to, the rolling direction of the sheet.

Terms employed in the tabulated results include the following:

F_G = gross area stress

$$dw/da = \frac{\text{change in the work necessary for crack propagation}}{\text{change in the surface area of the crack}}$$

F_{tu} = ultimate tensile stress

F_{ty} = 0.2% offset yield stress.

Control-coupon data define base properties of each of the materials.

Crack propagation specimens were 9-inches wide by 27-inches long. Fatigue cracks were initiated from "Elox" cuts produced across the center of the panel by an electrical arc cutting process.

Static crack growth was measured with a transit, using a 0.02-inch division scale clamped to the specimen immediately above the crack.

Tables in this report list results for the following materials:

Ti-6Al-4V (annealed; solution treated + aged)
Ti-4Al-3Mo-1V (925°F, 12 hrs.; 950°F, 24 hrs.)
AM350 (CRT 650; CRT 850; CRT 1050)
AM355 (six different conditions)
PH15-7Mo (RH 1075)
D979 (1850°F, AC + 1550°F, 6 hrs., + 1300°F, 16 hrs.)
Inconel 718 (Solution treated + 1400°F, 16 hrs.; cold rolled + 1400°F, 16 hrs.)
Rene' 41 (solution treated 1975°F + 1400°F, 16 hrs.)

Northrup Corporation, Norair Division

Tensile tests at room temperature, 1000°, and 1300°F were reported for unexposed longitudinal specimens of 0.040-inch thick Rene' 41, most with the heat treatment: 1975°F, ½ hr. + 1400°F, 16 hrs.

COMPARISON OF MATERIALS

Two groups of summary figures allow comparison of the numerous alloys and alloy conditions for which basic screening program data are presented in this paper. These figures will be found at the end of this report.

The first group of three figures presents, in bar graph form, the tensile properties reported for the basic screening program test temperatures of -110°F, room temperature, and 650°F. Tensile strength, yield strength, elongation, and sharp-notch strength are included for both longitudinal and transverse test directions. All test results for a given condition were averaged, whether from one or several sources. Results for 1000-hour exposures at 650°F are indicated wherever they differed from those without prior exposure.

The second group of six figures involves calculated parameters, notch-strength ratios and notch-strength ratios adjusted for density. The following comparisons are made at -110°F, room temperature, and 650°F:

(1) notch-tensile strength ratio versus tensile strength

(2) notch-tensile strength ratio versus tensile strength-density ratio

(3) notch-yield strength ratio versus yield strength

(4) notch-yield strength ratio versus yield strength-density ratio

The direct comparisons of tensile or yield strength at a given temperature are presented on the same sheet. Similarily, comparisons of tensile and yield strength, adjusted for density, are presented to permit visualization of the influence of density on the relative strength levels.

Each point on these figures was calculated using averaged tensile properties at the indicated temperature and room-temperature densities. An accompanying identification key indicates the type of material by a distinctive shape (▽ = titanium alloys, □ = stainless steels, ○ = superalloys) and a number which identifies the particular material and its heat-treatment condition. One can readily compare properties for the same material on the several plots by looking for the same identifying symbol and number. In these comparisons, transverse properties were used unless only longitudinal data were available.

National Aeronautics and Space Administration,
Washington, D.C., March 19, 1963

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TEST DATA

INDIVIDUAL LABORATORY PROGRAMS

Ti-6Al-4V

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Syracuse University Research Institute	Republic Steel Corporation	3930269
2	Materials Research Laboratory, Inc.	Republic Steel Corporation	3930269
3	Langley Research Center, NASA	Titanium Metals Corp. of America	M-9774
4	North American Aviation, Inc.	---------	
5	Lockheed Aircraft Corp., Calif. Co.	Titanium Metals Corp. of America	9004 D-709

Composition, percent

	Data Sheet	C	V	Al	N	Fe
	1 & 2	0.034	4.10	6.10	0.012	0.18
(9004)	5	0.024	4.0	6.0	0.016	0.11
(D-705)	5	0.026	4.0	6.1	0.016	0.10

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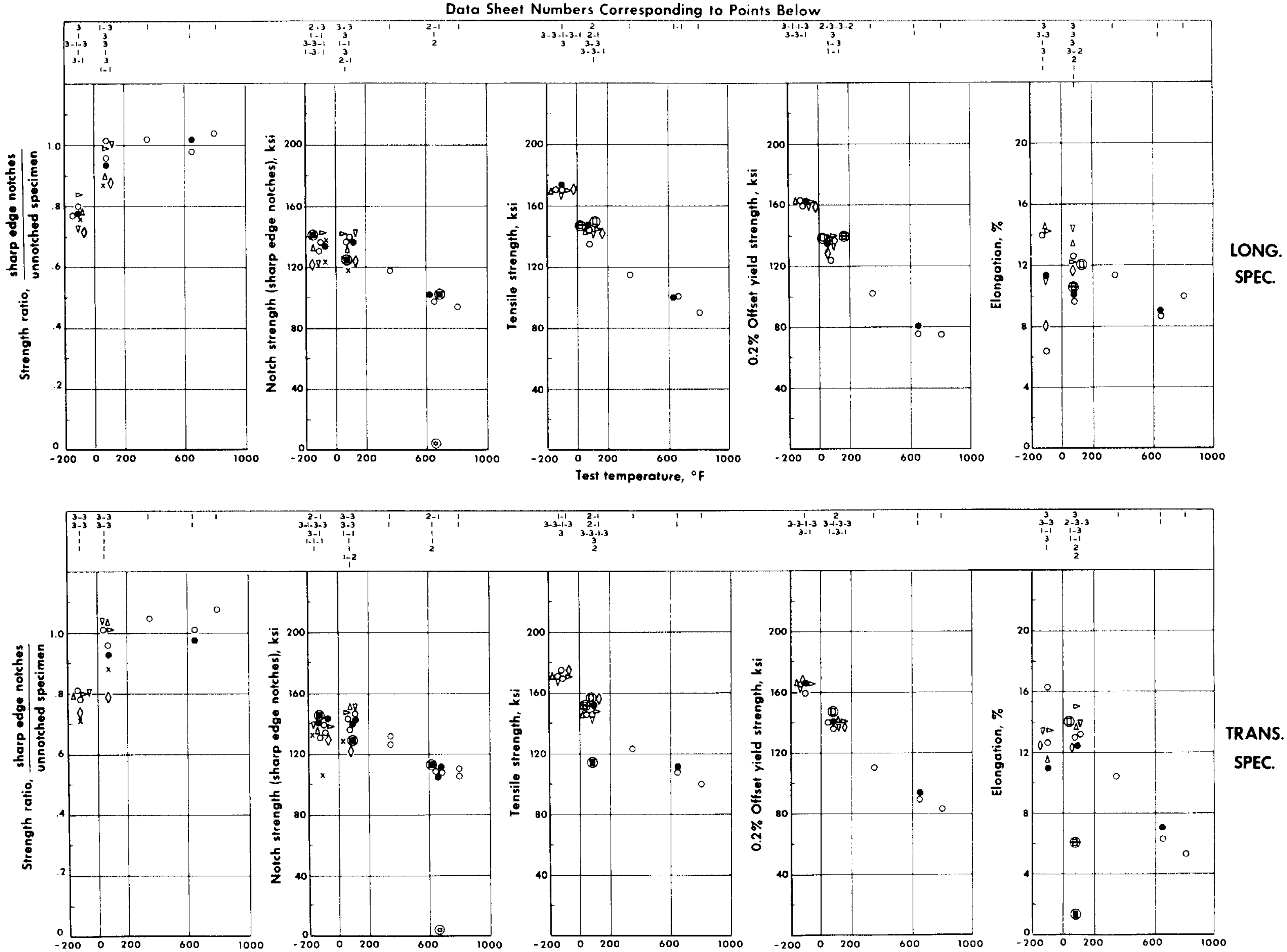


Conditions of prior exposure
△ 2000 hrs., 650°F, unstressed
▷ 4000 hrs., 650°F, unstressed
▽ 7000 hrs., 650°F, unstressed
● 1000 hrs., 650°F, 25 ksi (◊ unstressed)
○ Unexposed (× fatigue-cracked edge notches)

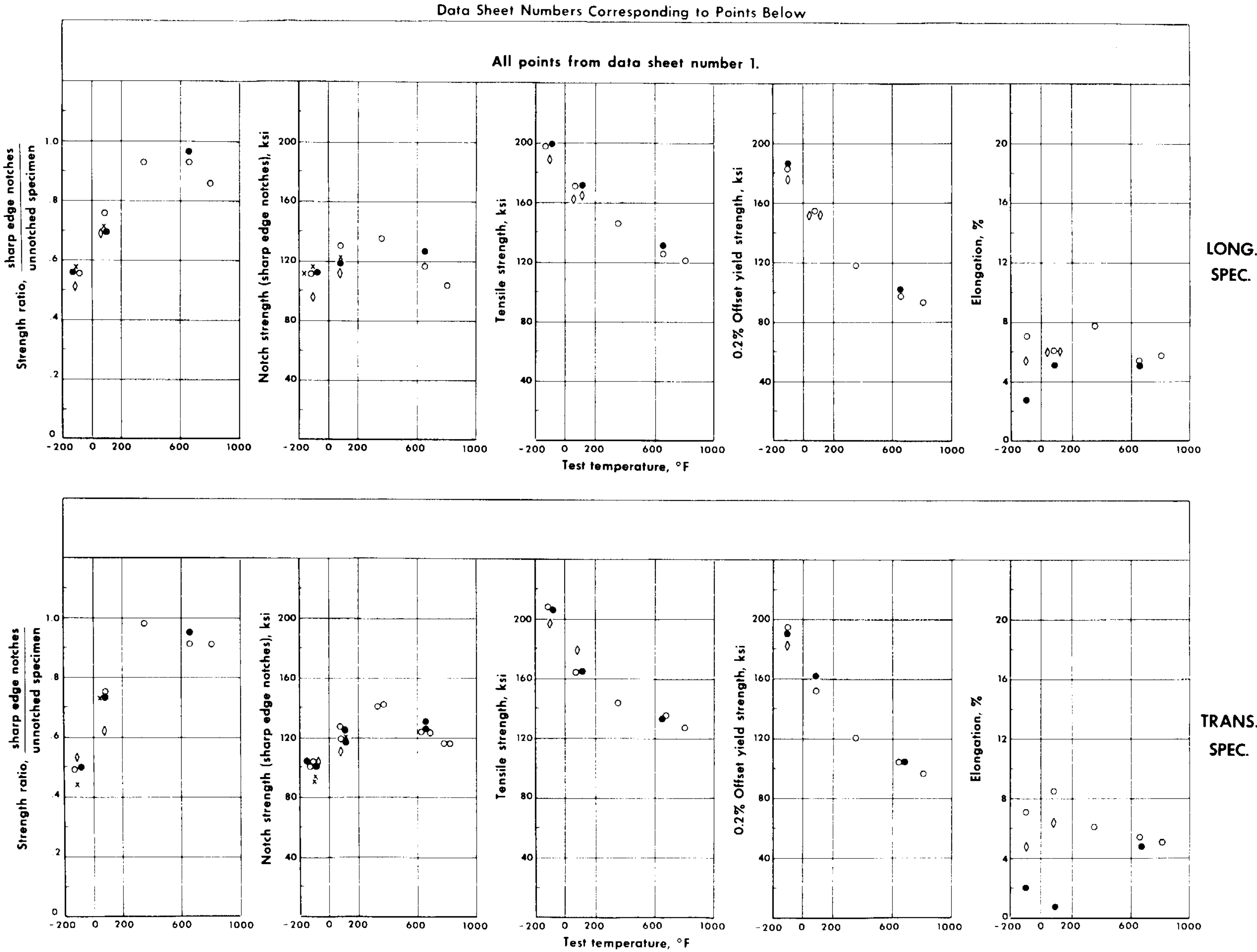
Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Ti-6Al-4V (Annealed)

[a]Specimens failed during salt exposure at 650°F, 25 ksi

Points from data sheets 2 and 3 are averages for all like tests.

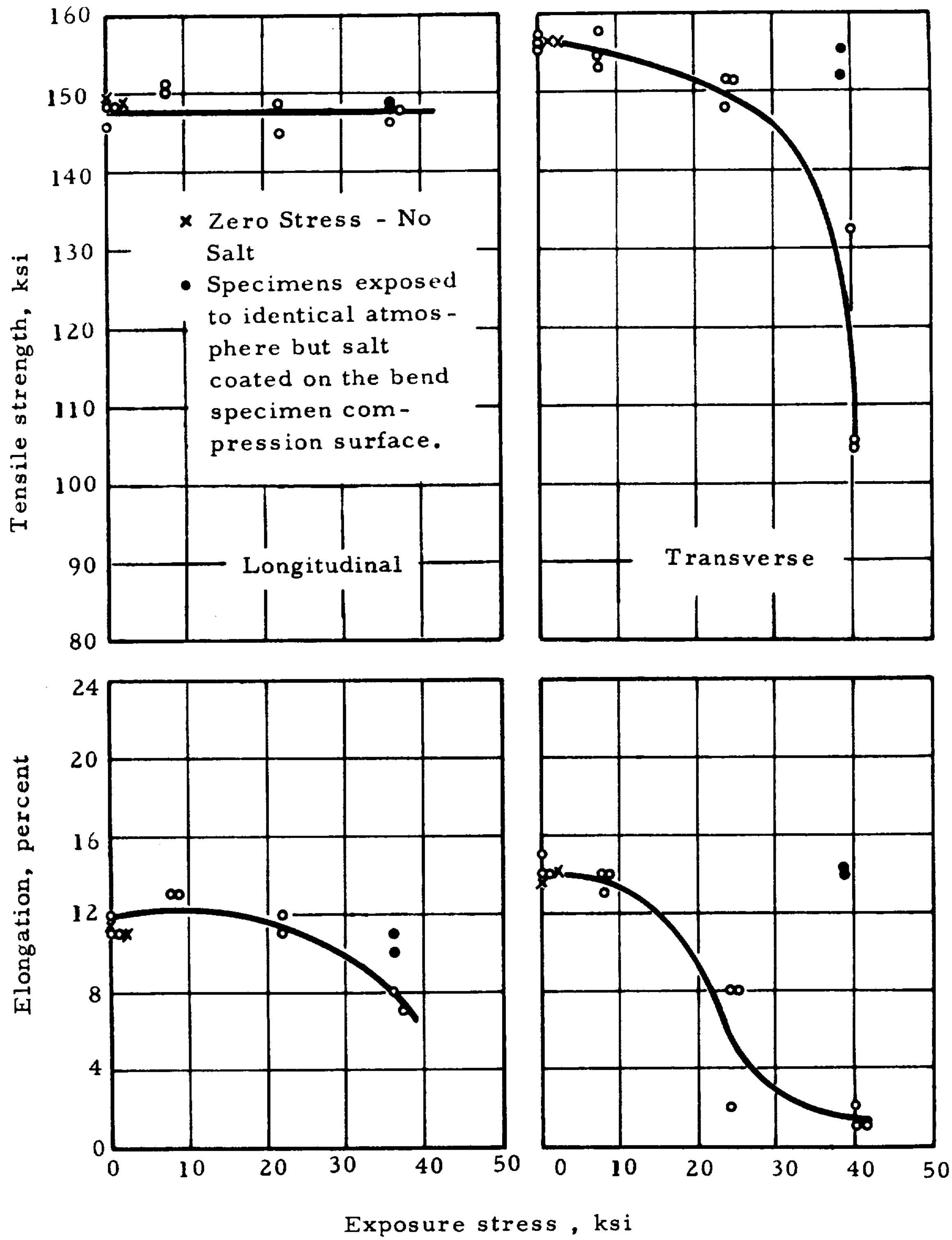
Coated with sea salt during exposure
1000 hrs., 450 or 500°F, 25 ksi
100 hrs., 650°F, 0-7.7 ksi
100 hrs., 650°F, 21.8-37.2 ksi
100 hrs., 650°F, 38.8-40.1 ksi



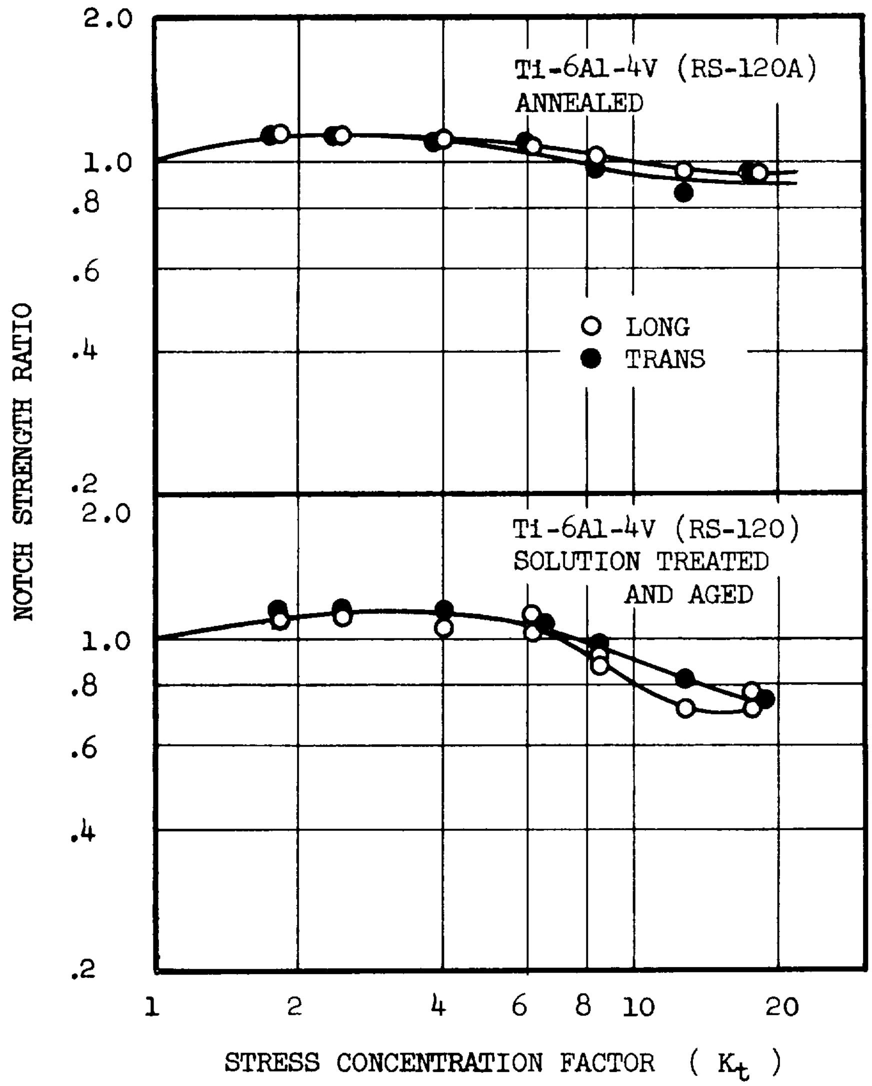
Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Ti-6Al-4V (Solution treated + aged)

Conditions of prior exposure
- ○ Unexposed (× fatigue-cracked edge notches)
- ● 1000 hrs., 650°F, 25 ksi
- ◊ 1000 hrs., 650°F, unstressed



Effect of exposure stress (surface stress in bending of strips coated with sea salt) on room-temperature tensile properties of annealed Ti-6 Al-4 V sheet exposed 100 hours at 650°F. (Data Sheet No. 2)



Notch strength ratio at room temperature versus stress concentration factor (K_t) for Ti - 6 Al -4 V (RS-120A) . A single point designates the average of two test points having close values. (Data Sheet No. 1)

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Alloy Designation: Ti-6Al-4V (RS-120A) Contributor: Syracuse University Research Institute Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure Stress ksi	Prior exposure Time, hr.	Test Temp. °F	Unnotched Tensile strength, ksi L[d]	Unnotched Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength, ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches Tensile strength, ksi L	Sharp edge notches Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	[e]Edge-Cracked Specimens Tensile Str. (C), ksi L	Tensile Str. (C), ksi T	Strength Ratio, C/S L	Strength Ratio, C/S T
Annealed																			
None			-110	170.5	169.5	163.5	159	6.4	1.5	12.6	1.5	136.6	131.2	} 0.80	0.78	137	106	} 0.76	0.71
None			-110	---	---	---	---	---	---	---	---	---	134.6			123	133		
650	0	1000	-110	171	175.5	161.5	168	8.0	1.5	12.5	1.5	122.5	130.5	0.72	0.74				
650	25	1000	-110	173	175	163	166.3	11.3	1.5	11.0	1.5	134.5	142.8	} 0.78	0.81				
650	25	1000	-110	---	---	---	---	---	---	---	---	---	140.5						
None			Room	135	146	124.5	136	9.7	1.5	13.0	1.5	137.2	137.2	} 1.02	0.96	118	129	} 0.87	0.88
None			Room	---	---	---	---	---	---	---	---	---	142.9			---	---		
650	0	1000	Room	142.6	157.5	129	137	11.7	1.5	12.4	1.5	125	123.7	0.88	0.79				
650	25	1000	Room	146.8	152	135	140	10.0	1.5	12.5	1.5	137.6	143	} 0.94	0.93				
650	25	1000	Room	---	---	---	---	---	---	---	---	---	139.5						
None			350	115.5	123.5	102.5	110.5	11.4	1.5	10.4	1.5	118	132	} 1.02	1.05				
None			350	---	---	---	---	---	---	---	---	---	127						
None			650	101	107.8	76	89.7	8.7	1.5	6.4	1.5	99	109.6	} 0.93	1.01				
None			650	---	---	---	---	---	---	---	---	---	107.5						
650	25	1000	650	100.5	111.2	80.5	93.8	9.0	1.5	7.0	1.5	102.5	106	} 1.02	0.98				
650	25	1000	650	---	---	---	---	---	---	---	---	---	112.5						
None			800	91.4	100	75.4	83.6	10.0	1.5	5.4	1.5	94.5	110	} 1.04	1.08				
None			800	---	---	---	---	---	---	---	---	---	105.8						
Solution treated + Aged																			
None			-110	197.5	208	182.5	194.5	7.0	1.5	7.0	1.5	111.5	103.5	} 0.56	0.49	116.5	90.5	} 0.58	0.44
None			-110	---	---	----	---	---	---	---	---	---	100.5			111.5	93		
650	0	1000	-110	189	197	176	182.5	5.4	1.5	4.7	1.5	96	103.8	0.51	0.53				
650	25	1000	-110	199	206	185.5	190	2.7	1.5	2.0	1.5	112.5	100.5	} 0.57	0.50				
650	25	1000	-110	---	---	---	---	---	---	---	---	---	104						
None			Room	171	164.2	155	151.5	6.0	1.5	8.4	1.5	130	127	} 0.76	0.75	122	120	} 0.71	0.73
None			Room	---	---	---	---	---	---	---	---	---	119.1			---	---		
650	0	1000	Room	165	---	151.5	---	6.0	1.5	---	---	112	111	} 0.69	0.62				
650	0	1000	Room	162	179	152.5	---	6.0	1.5	6.4	1.5	---	---						
650	25	1000	Room	171.5	165	---	162	5.0	1.5	0.7	1.5	119.5	125	} 0.70	0.73				
650	25	1000	Room	---	---	---	---	---	---	---	---	---	116.5						
None			350	145.8	143.8	118.5	120	7.7	1.5	6.0	1.5	135	141	} 0.93	0.98				
None			350	---	---	---	---	---	---	---	---	---	142						
None			650	126.3	135.2	97.4	104.7	5.4	1.5	5.3	1.5	117	124	} 0.93	0.91				
None			650	---	---	---	---	---	---	---	---	---	123						
650	25	1000	650	131.3	133.2	101	105	5.0	1.5	4.7	1.5	126.8	124.8	} 0.97	0.95				
650	25	1000	650	---	---	---	---	---	---	---	---	---	130						
None			800	121	127.3	92.9	95.9	5.7	1.5	5.0	1.5	103.8	116.4	} 0.86	0.91				
None			800	---	---	---	---	---	---	---	---	---	115.5						

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation
[e] Specimen 1.00 in. wide notched 0.05 in. deep, then fatigued to 0.70 in. between the roots of the edge cracks.

Alloy Designation: Ti-6Al-4V Contributor: Materials Research Laboratory, Inc. Data Sheet No.: 2
Heat Treatment: Annealed Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES AFTER SALT EXPOSURES[c]

Prior exposure[a] (in bending) Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	L	T	L	T
450	25	1000	-110	-----	-----	-----	-----	----		----		138.2	-----						
500	25	1000	-110	-----	-----	-----	-----	----		----		138.4	145.2						
500	25	1000	-110	-----	-----	-----	-----	----		----		147.0	-----						
450	25	1000	Room	-----	-----	-----	-----	----		----		-----	125.0						
500	25	1000	Room	-----	-----	-----	-----	----		----		126.4	131.9						
650	0	100	Room	145.8	155.2	132.0	144.8	11		14									
650	0	100	Room	148.6	155.7	138.6	144.9	11		15									
650	0	100	Room	148.7	157.0	139.1	150.0	12		14									
650	0	100	Room[f]	148.6	156.6	139.1	147.0	11.5		14									
650	0	100	Room[f]	149.6	156.8	137.3	149.1	11.5		13.5									
650	7.6	100	Room	151.0	-----	144.5	-----	13		----									
650	7.6	100	Room	149.9	-----	140.7	-----	13		----									
650	7.7	100	Room	-----	157.8	-----	-----	----		14									
650	7.7	100	Room	-----	154.6	-----	-----	----		13									
650	7.7	100	Room	-----	153.0	-----	-----	----		14									
650	21.8	100	Room	144.8	-----	139.6	-----	12		----									
650	21.8	100	Room	148.4	-----	141.8	-----	11		----									
650	23.8	100	Room	-----	148.0	-----	-----	----		2									
650	24.0	100	Room	-----	153.0	-----	-----	----		8									
650	24.0	100	Room	-----	153.0	-----	-----	----		8									
650	36.0	100	Room	146.2	-----	138.4	-----	8		----									
650	36.2	100	Room[g]	148.7	-----	138.6	-----	10		----									
650	36.2	100	Room[g]	148.0	-----	137.1	-----	11		----									
650	37.2	100	Room	147.8	-----	-----	-----	7		----									
650	38.8	100	Room[g]	-----	150.2	-----	145.0	----		14									
650	38.8	100	Room[g]	-----	155.3	-----	146.0	----		14									
650	39.8	100	Room	-----	132.8	-----	-----	----		1									
650	40.0	100	Room	-----	104.7	-----	-----	----		2									
650	40.1	100	Room	-----	105.9	-----	-----	----		1									
450	25	1000	650	-----	-----	-----	-----	----		----		-----	112.8						
500	25	1000	650	-----	-----	-----	-----	----		----		102.2	-----						
650	25	1000	650									(h)	(h)						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Solid coating of natural sea salt f - No salt; same atmosphere of air and reaction products as for other specimens.
[g] Salt on the compression side only; all other bend tests had salt on the tension side only.
[h] Two longitudinal specimens failed during exposure at 63.0 and 187.2 hrs; three transverse specimens failed at 23.2, 275.8, and 394.7 hrs., respectively.

Alloy Designation: Ti-6Al-4V Contributor: NASA, Langley Research Center Data Sheet No.: 3
Heat Treatment: Annealed Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	L	T	L	T
None			-110	172.0	171.0	162.5	167.0	14.0		18.0		138.5	139.3	0.77	0.81				
None			-110	169.0	171.0	159.0	164.0	----		14.5		124.8	139.0						
550	0	2000	-110	171.0	172.0	164.0	166.0	----		9.0		131.8	139.5	0.78	0.79				
550	0	2000	-110	168.2	171.0	161.5	166.0	14.5		14.0		134.2	131.5						
550	0	4000	-110	171.0	171.5	163.0	164.0	14.5		14.0		144.0	142.5	0.84	0.80				
550	0	4000	-110	170.0	172.0	162.5	167.0	14.0		13.0		143.5	134.0						
550	0	7000	-110	169.0	169.0	161.5	162.5	11.0		----		127.6	139.0	0.73	0.82				
550	0	7000	-110	169.5	169.0	161.0	161.5	----		13.5		121.0	137.7						
None			Room	145.0	145.5	138.5	141.0	12.5		13.0		144.5	152.5	0.96	1.01				
None			Room	145.5	146.7	136.9	139.0	13.0		13.5		135.0	141.8						
550	0	2000	Room	143.8	145.0	138.4	140.7	13.0		13.5		130.5	150.1	0.90	1.03				
550	0	2000	Room	144.2	145.8	137.4	142.8	14.0		14.0		131.5	150.6						
550	0	4000	Room	144.9	147.5	140.5	141.0	12.0		15.0		141.9	151.2	0.99	1.01				
550	0	4000	Room	144.6	147.1	138.0	142.0	12.5		15.0		143.5	145.2						
550	0	7000	Room	144.5	145.0	134.0	138.0	14.0		14.0		146.5	150.5	1.01	1.04				
550	0	7000	Room	142.0	145.5	135.5	138.5	15.0		13.5		142.5	153.0						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation

Alloy Designation: Ti-6Al-4V Contributor: North American Aviation, Inc. Data Sheet No.: 4

Heat Treatment: 1100°F, 4 hrs.; brazed at 1725°F, air cooled Sheet Thickness, inches 0.050

SHORT-TIME TENSILE PROPERTIES[d]

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens						Sharp edge notches			
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi	Yield strength,[b] ksi	Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi L T	Strength ratio, N/S L T	L T	L T
BEFORE BRAZING													
None			Room	161.9	151.2	11							
None			Room	160.9	150.4	12							
None			Room	159.8	152.3	10							
BRAZED SPECIMENS													
None			Room	142	130.5	15							
None			Room	144	128	13.6							
None			Room	157	116.5	16.1							

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified. [d]Test direction not stated

STRESS-CORROSION TESTS

Cantilever beam tests at 650°F in circulating air furnace.

Salt coated by dipping in hot concentrated 6 parts NaCl + 1 part $MgCl_2$ and drying.

Smooth and Notch Specimens Tested - 60°V-notches, 0.010-inch deep with 0.005-inch root radius, machined across flat surface at point of maximum stress and at a point of very low stress.

Test Condition	Maximum Stresses Smooth (ksi)	Maximum Stresses Notched (ksi)	Status at 4700 Hours(a)
Bare Surface - continuously exposed	36.9, 36.0, 36.5	58.0, 58.0	Slightly blued
Salt Coated - continuously exposed(b)	34.0, 35.2, 34.4	51.4, 53.4	Some surface darkening and few rust-like spots
Braze Coated - continuously exposed	28.7, 20.2, 29.6	47.4, 46.6	Slight darkening
Braze+Salt Coated - continuously exposed	33.1, 29.9, 30.9	44.6, 46.6	Dark brown and rust-like spots on specimens at bottom of furnace
Salt Coated - 2 weeks at 650°F + 2 weeks in humidity cabinet at 100°F intermittently	34.5, 33.3, 35.1 33.8	----------	Blue-gray color

(a) All unbroken at 4700 hours
(b) At 4700 hours, the salt coating appeared spottv

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Alloy Designation: Ti-6Al-4V Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 5
Heat Treatment: As noted below Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data				Control Coupon Data		
				Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
Annealed										
Room	L	0.0240	8.99	16850	78.0	1.59	1004	138.1	146.7	14.2
Room	L	0.0236	9.00	15600	73.6	1.50	840			
Room	L	0.0236	9.00	11600	54.7	2.56	845			
Room	L	0.0243	8.99	12020	55.1	2.43	806			
Room	T	0.0230	8.99	20600	99.5	1.18	1046	149.4	155.3	11.5
Room	T	0.0225	8.99	18700	92.6	1.36	1054			
Room	T	0.0226	9.00	13600	67.0	2.38	1018			
Room	T	0.0235	8.99	13120	62.2	2.20	802			
600	L	0.0216	9.00	14900	76.6	1.47	1054	86.3	104.3	9.0
600	L	0.0252	9.00	16100	71.0	1.35	829			
600	L	0.0237	9.00	11850	55.6	2.58	1041			
600	L	0.0236	8.98	12000	56.6	2.54	1060			
600	T	0.0226	9.00	16600	81.6	1.27	968	93.4	107.1	6.8
600	T	0.0240	9.00	17600	81.5	1.37	1045			
600	T	0.0223	9.00	12650	63.0	2.57	1255			
600	T	0.0223	9.00	11800	57.5	2.75	1136			
Solution Treated and Aged										
Room	L	0.0248	9.00	20850	93.4	1.48	1211	167.2	174.0	8
Room	L	0.0240	9.02	18200	84.1	1.36	898			
Room	L	0.0246	9.01	13200	59.6	2.45	863			
Room	L	0.0238	9.02	12100	56.4	2.32	725			
Room	T	0.0247	9.02	18100	81.2	1.35	860	161.7	169.7	6
Room	T	0.0239	9.00	16500	76.7	1.45	828			
Room	T	0.0237	9.02	10700	50.0	2.42	621			
Room	T	0.0235	9.00	10600	50.1	2.39	614			
600	L	0.0228	9.00	14900	72.6	1.45	892	114.0	135.6	6
600	L	0.0231	9.00	15500	74.6	1.45	941			
600	L	0.0238	9.00	11400	53.2	2.85	1031			
600	L	0.0238	9.00	11450	53.5	2.43	859			
600	T	0.0250	9.00	19600	87.1	1.40	1256	106.0	129.5	5
600	T	0.0241	8.97	18400	85.1	1.42	1218			
600	T	0.0237	9.02	10400	48.6	2.53	753			
600	T	0.0241	9.00	10900	50.6	2.40	759			

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Ti-8Al-1Mo-1V

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Lewis Research Center, NASA	Titanium Metals Corp. of America	V-1551
2	Materials Research Laboratory, Inc.	" " " " "	V-1551 V-1848
3	Langley Research Center, NASA	" " " " "	V-1551 V-1555
4	Joliet Metallurgical Laboratories, Inc.	" " " " "	D-1237
5	Joliet Metallurgical Laboratories, Inc.	" " " " "	V-1555
6	North American Aviation, Inc.	-------	---

Composition, percent

Heat Number	C	Fe	N	H	Al	Mo	V	Ti
V-1551	0.032	0.09	0.013	0.0055	7.8	1.1	1.1	Bal
V-1555	0.026	0.09	0.015	0.009	7.8	1.1	1.0	Bal
D-1237	0.027	0.11	0.014	0.007	7.7	1.2	1.0	Bal

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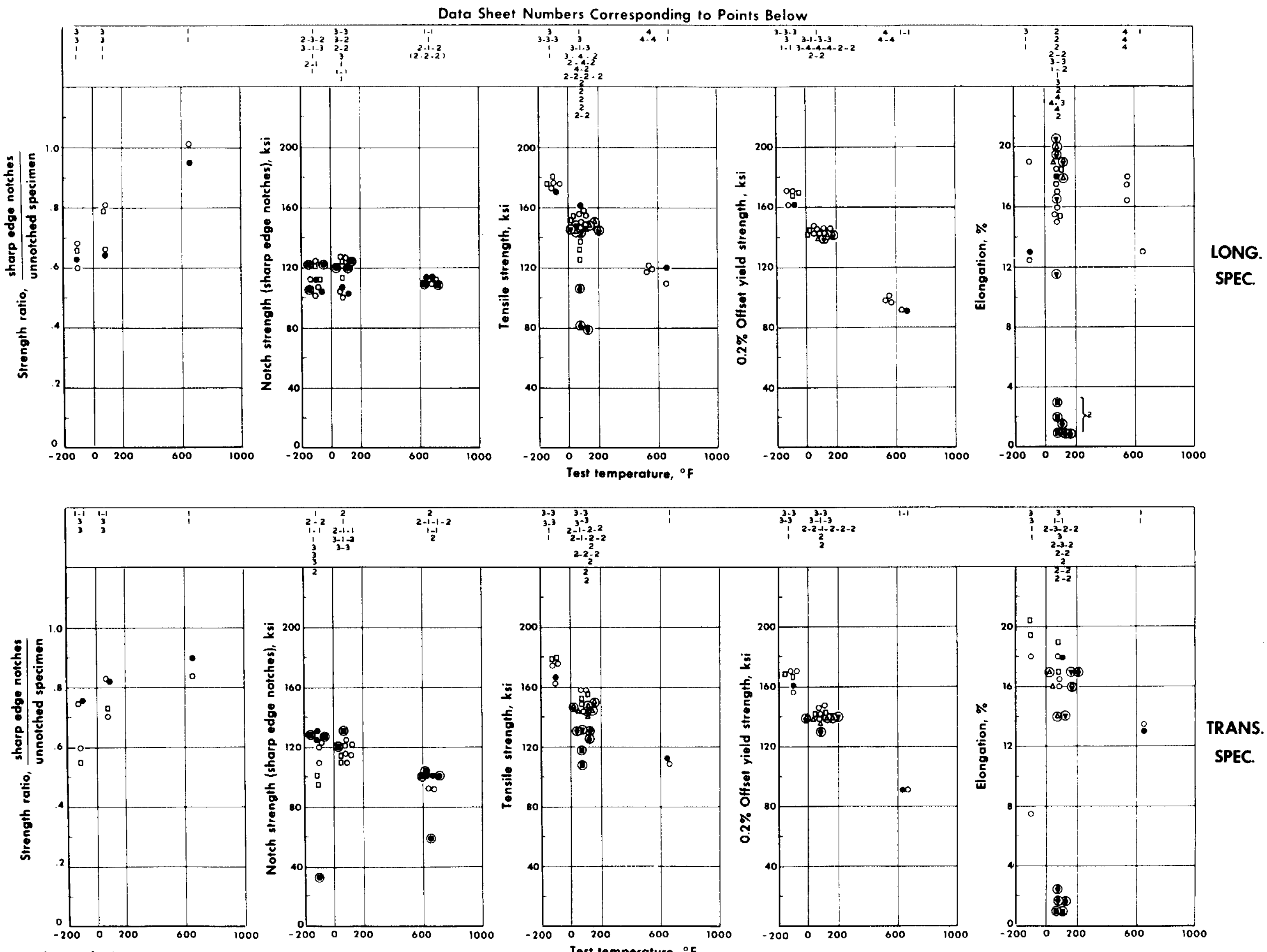


Conditions of prior exposure

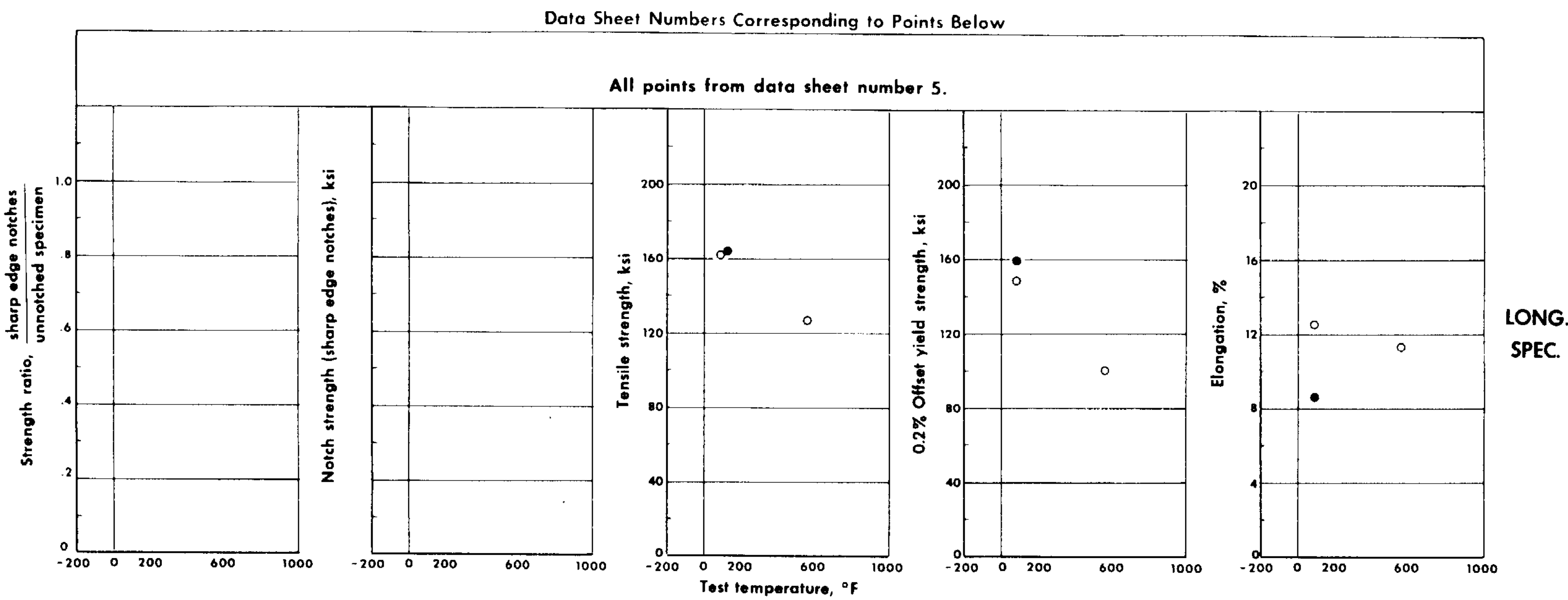
- ○ Unexposed
- ● 1000 hrs., 650°F, 25 ksi
- ▵ 100 hrs., 650°F, unstressed
- □ 2000 hrs., 550°F, unstressed

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Ti-8Al-1Mo-1V (Annealed)

Coated with sea salt during exposure

- 1000 hrs., 650°F, 25 ksi
- 100 hrs., 650°F, 29 ksi (18 ksi, 5.5 ksi, unstressed)
- 1000 hrs., 25 ksi, 550°F (500°F)
- 100 hrs., 650°F, 25 ksi (salt on compression side)

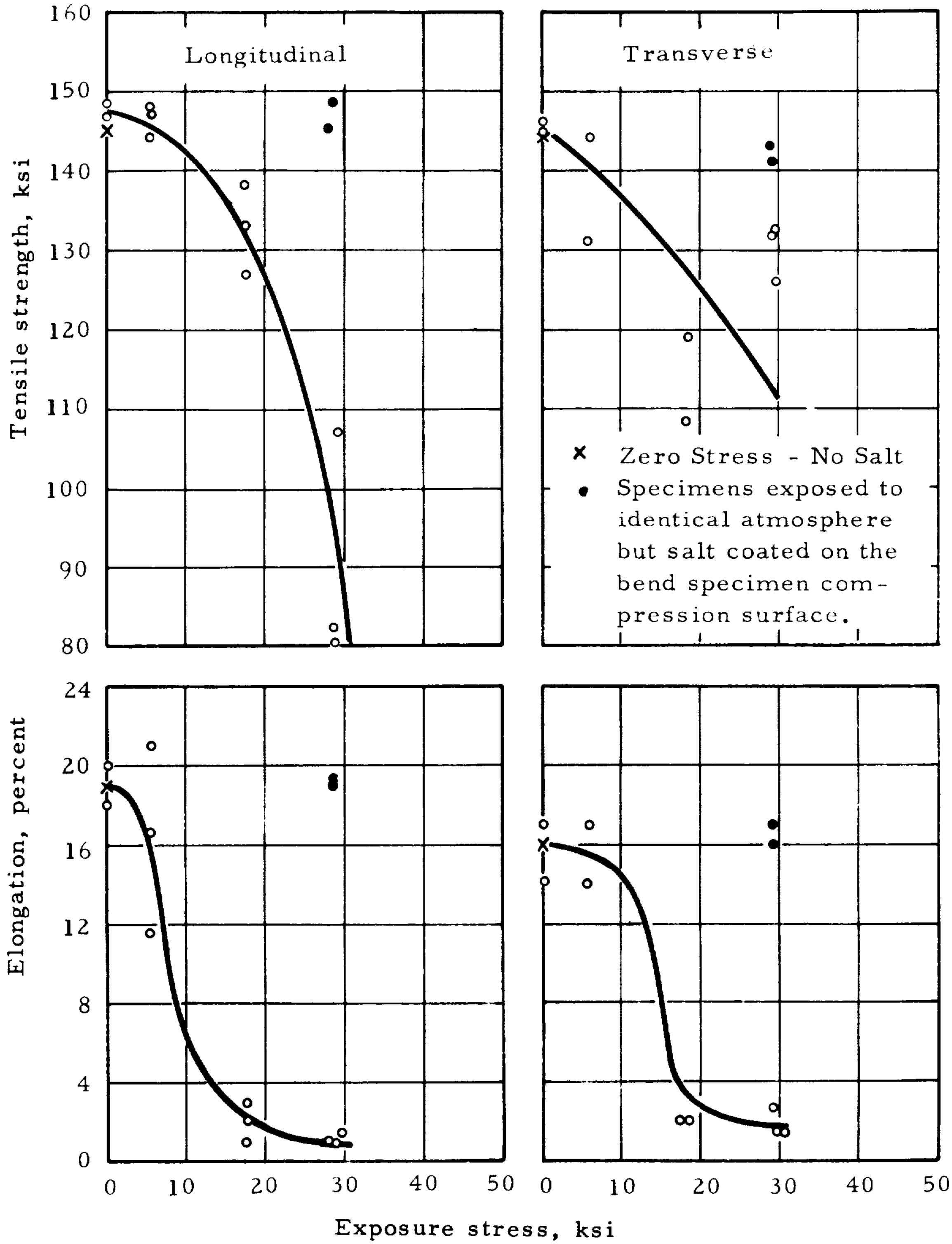


Tensile-test results in the longitudinal direction for sheet tested before and after exposure.

Conditions of prior exposure
- ○ Unexposed
- ● 500-1200 hrs., 550°F, 100-120 ksi (0.112-0.894% plastic deformation during exposure)

Ti-8Al-1Mo-1V (1850° A.C. + 8 hrs. 1100°)

Points are averages for 3-6 tests



Effect of exposure stress (surface stress in bending of strips coated with sea salt) on room-temperature tensile properties of annealed Ti-8 Al-1 Mo-1 V sheet exposed 100 hours at 650°F. (Data Sheet No. 2).

Alloy Designation: Ti - 8Al - 1Mo - 1V Contributor: NASA Lewis Research Center Data Sheet No.: 1
Heat Treatment: Mill Anneal 1450°F, 8 hrs. Sheet Thickness, inches 0.020

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
				Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
Temp. °F	Stress ksi	Time, hr.		L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			-110	173.9	163.2	162.3	157.3	12.5		7.5		102.2	120.3	0.60	0.75				
None			-110	-----	-----	-----	-----	----		----		106.9	123.2						
650	25	1000	-110	171.0	167.3	161.7	160.5	13		18		112.1	129.5	0.63	0.76				
650	25	1000	-110	-----	-----	-----	-----	----		----		104.5	124.5						
None			Room	156.4	144.4	146.3	.38.9	17.5		18		101.1	121.9	0.66	0.83				
None			Room	-----	-----	-----	-----	----		----		104.4	116.6						
650	25	1000	Room	162.3	148.9	147.8	141.7	18		18		107.2	120.9	0.64	0.82				
650	25	1000	Room	-----	-----	-----	-----	----		----		101.8	124.5						
None			650	109.7	110.0	91.7	91.2	13		13.5		110.0	92.3	1.01	0.84				
None			650	-----	-----	-----	-----	----		----		112.5	91.4						
650	25	1000	650	119.6	112.1	90.6	91.0	(e)		13		113.8	101.6	0.95	0.90				
650	25	1000	650	-----	-----	-----	-----	----		----		114.5	100.8						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Broke outside gage marks

Alloy Designation: Ti-8Al-1Mo-1V Contributor: Materials Research Laboratory, Inc. Data Sheet No.: 2
Heat Treatment: Annealed Sheet Thickness, inches 0.018

SHORT-TIME TENSILE PROPERTIES AFTER SALT EXPOSURES[e]

Prior exposure[a] (in bending)			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
				Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
Temp. °F	Stress ksi	Time, hr.		L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
650	0	100	Room	146.8	146.0	141.9	140.0	20		14									
650	0	100	Room	148.1	144.9	-----	139.8	18		17									
650	0	100	Room[f]	145.0	141.1	139.9	137.0	19		--									
650	0	100	Room[f]	-----	144.1	-----	140.0	--		16									
650	5.5	100	Room	146.8	-----	-----	-----	20.5		----									
650	5.5	100	Room	144.2	-----	-----	-----	16.5		----									
650	5.6	100	Room	148.0	-----	-----	-----	11.5		----									
650	5.7	100	Room	-----	131.0	-----	-----	----		14									
650	5.8	100	Room	-----	144.2	-----	140.8	----		17									
650	17.5	100	Room	132.9	-----	-----	-----	1		----									
650	17.5	100	Room	126.8	-----	-----	-----	2		----									
650	17.5	100	Room	137.9	-----	137.9	-----	3		----									
650	18.0	100	Room	-----	119.0	-----	-----	----		2									
650	18.3	100	Room	-----	108.4	-----	-----	----		2									
650	28.5	100	Room	82.5	-----	-----	-----	1		----									
650	28.8	100	Room	80.4	-----	-----	-----	1		----									
650	29.2	100	Room	107.0	131.8	-----	-----	1.5		2.5									
650	29.6	100	Room	-----	125.8	-----	-----	----		1.5									
650	29.7	100	Room	-----	132.7	-----	131.1	----		1.5									
650	28.0	100	Room[g]	145.2	-----	141.4	-----	19.5		----									
650	28.5	100	Room[g]	148.5	-----	141.9	-----	19		----									
650	28.8	100	Room[g]	-----	141.0	-----	140.8	----		17									
650	29.2	100	Room[g]	-----	143.2	-----	139.1	----		16									
650	25	1000	-110	-----	-----	-----	-----	----		----		-----	32.3						
550	25	1000	-110	-----	-----	-----	-----	----		----		122.0	-----						
500	25	1000	-110	-----	-----	-----	-----	----		----		122.8	128.8						
500	25	1000	-110	-----	-----	-----	-----	----		----		106.1	127.2						
550	25	1000	Room	-----	-----	-----	-----	----		----		120.4	-----						
500	25	1000	Room	-----	-----	-----	-----	----		----		125.4	131.2						
500	25	1000	Room	-----	-----	-----	-----	----		----		120.1	120.4						
650	25	1000	650	-----	-----	-----	-----	----		----		(h)	58.2						
550	25	1000	650	-----	-----	-----	-----	----		----		-----	100.8						
500	25	1000	650	-----	-----	-----	-----	----		----		109.1	103.6						
500	25	1000	650	-----	-----	-----	-----	----		----		109.5	101.8						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Solid coating of natural sea salt f - No salt; same atmosphere of air and reaction products as for other specimens
[g] Salt on the compression side only; all other bend tests had salt on the tension side only. [h] Three longitudinal specimens failed at 120, 240, and 283 hrs., respectively, during exposure.

Alloy Designation: Ti-8Al-1Mo-1V　　Contributor: NASA, Langley Research Center　　Data Sheet No.: 3
Heat Treatment: Annealed　　Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			-110	176.0	175.0	171.0	170.0	19.0		----		112.0	109.8	}0.68	0.60				
None			-110	176.0	176.0	171.0	170.0	----		----		125.5	99.2						
550	0	2000	-110	176.0	179.0	167.5	167.5	----		20.5		121.0	101.0	}0.66	0.55				
550	0	2000	-110	181.0	180.0	170.0	168.5	----		19.5		113.5	96.5						
None			Room	155.5	159.0	145.5	146.0	18.5		16.5		127.5	110.0	}0.81	0.71				
None			Room	157.0	159.0	146.0	148.0	17.0		16.0		126.5	114.0						
550	0	2000	Room	155.0	156.0	144.0	144.0	15.5		19.0		114.5	110.5	}0.78	0.73				
550	0	2000	Room	153.0	153.0	142.0	142.5	18.5		17.0		126.0	114.0						

Alloy Designation: Ti-8Al-1Mo-1V　　Contributor: Joliet Metallurgical Laboratories, Inc.　　Data Sheet No.: 4
Heat Treatment: Annealed 1450°F　　Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			Room	149.1		143.0		15.5											
None			Room	150.7		143.2		15.0											
None			Room	147.2		142.9		16.0											
None			550	120.3		101.9		18.0											
None			550	118.8		98.5		16.5											
None			550	122.2		97.3		17.5											

Alloy Designation: Ti-8Al-1Mo-1V　　Contributor: Joliet Metallurgical Laboratories, Inc.　　Data Sheet No.: 5
Heat Treatment: 1850°F, 5 min., AC + 1100°F, 8 hrs. AC　　Sheet Thickness, inches 0.064

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Total plastic deformation during exposure, %	Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches					
Temp. °F	Stress ksi	Time, hr.			Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S			
					L[d]	T	L	T	L		T		L	T	L	T	L	T
None				Room	162.0		148.4		13.0									
None				Room	162.3		148.0		11.5									
None				Room	163.3		149.9		13.0									
550	120.0	859.8	0.894	Room	162.9		162.0		7.0									
550	117.5	503.4	0.834	Room	165.2		162.9		9.0									
550	115.0	431.8	0.580	Room	164.0		161.6		9.0									
550	115.0	1195.4	0.400	Room	163.1		159.5		8.5									
550	112.5	500.5	0.196	Room	163.1		160.2		8.5									
550	100.0	1150.2	0.112	Room	166.7		152.9		9.5									
None				550	127.5		99.7		11.5									
None				550	127.1		102.4		11.0									
None				550	127.7		99.6		11.5									

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.　[b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.　[d] L = longitudinal orientation T = transverse orientation

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Alloy Designation: Ti-8Al-1Mo-1V Contributor: North American Aviation, Inc. Data Sheet No.: 6

Heat Treatment: Unbrazed - no heat treatment; Brazed at 1725°F, air cool Sheet Thickness, inches 0.020 smooth 0.050 notched

SHORT-TIME TENSILE PROPERTIES[d]

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi	Yield strength,[b] ksi	Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Sharp edge notches: Tensile strength, ksi (L / T)	Strength ratio, N/S (L / T)	(L / T)	(L / T)
					BEFORE BRAZING								
None			Room	152.4	144.2	17.5							
None			Room	152	143.4	17.5							
None			Room	150.5	143.6	16							
None			Room	153.5	143	7.7							
None			Room	156.5	143	12.8							
					BRAZED SPECIMENS								
None			Room	144	138	14							
None			Room	138	130	14							
None			Room	138	131	13							

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]Test direction not stated

STRESS-CORROSION TESTS

Cantilever beam tests at 650°F in circulating air furnace.

Salt coated by dipping in hot concentrated 6 parts NaCl + 1 part $MgCl_2$ and drying.

Smooth and Notched Specimens Tested - 60°V-notches, 0.010-inch deep with 0.005-inch root radius, machined across flat surface at point of maximum stress and at a point of very low stress.

Test Condition	Maximum Stresses: Smooth (ksi)	Maximum Stresses: Notched (ksi)	Fracture Time (hours)	Surface Condition at 4700 hrs.
Bare Surface - continuously exposed	31.3, 29.7, 32.0	66.6, 66.5	a	Slight bluing
Salt Coated - continuously exposed(b)	27.2	---------	3980	
	28.7	---------	2720	
	29.4	---------	a	
		60.1, 59.5	a	Some darkening and few rust-like spots
Braze Coated - continuously exposed	26.6, 32.1, 22.5	58.2, 58	a	Slight darkening
Braze + Salt Coated - continuously exposed	24.4, 22.7, 25.6	59.6, 56.2	a	Dark brown color with rust-like spots on specimens at bottom of furnace
Salt Coated - 2 weeks at 650°F + 2 weeks in humidity cabinet intermittently	27.9, 27.9, 29.8 28.7	----------	a	Smooth blue-gray color

(a) Unbroken at 4700 hours
(b) At 4700 hours, the salt coating appeared spotty

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Ti-4Al-3Mo-1V

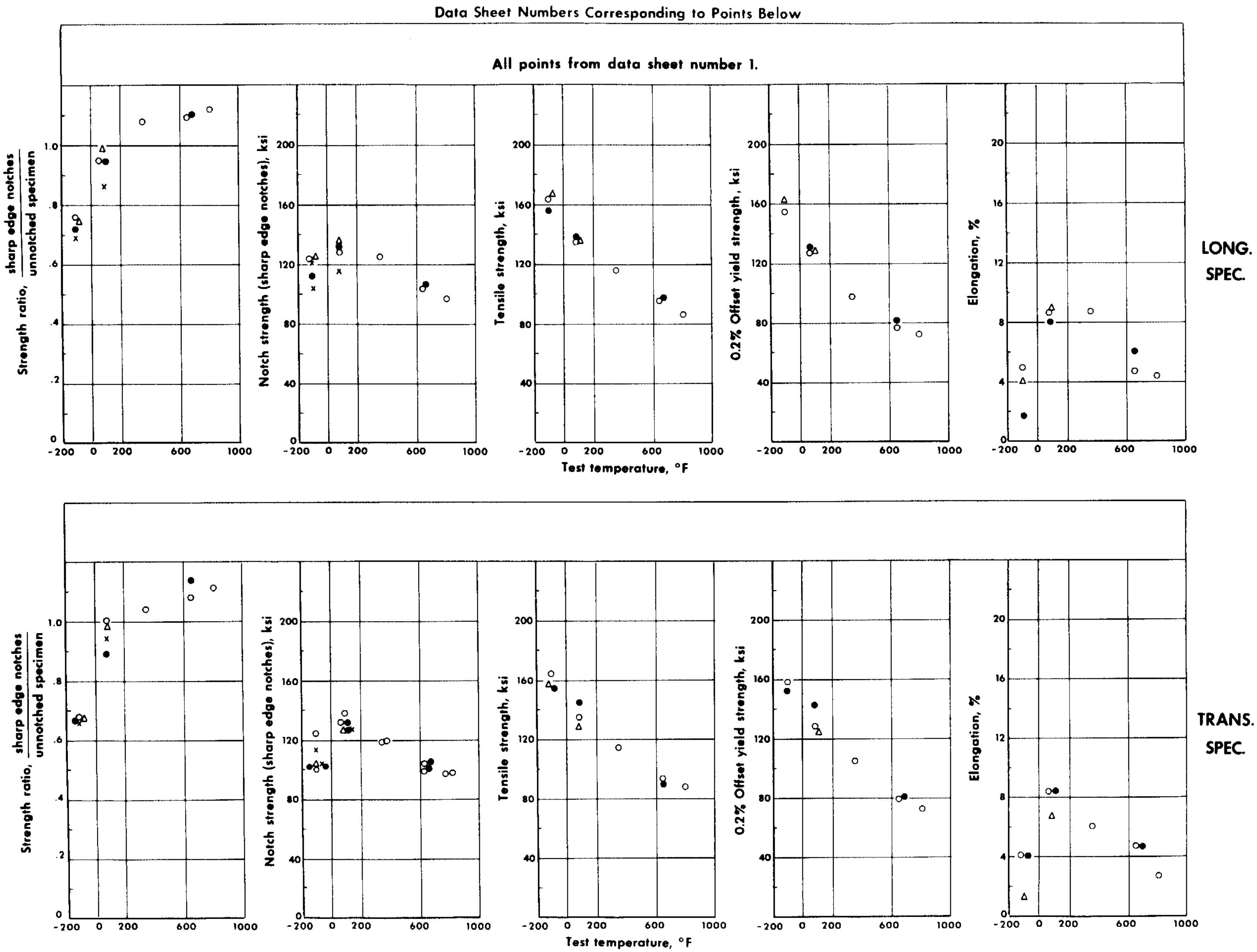
INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Syracuse University Research Institute	Republic Steel Corp.	3930265
2	Lockheed Aircraft Corp., Calif. Co.	Titanium Metals Corp. of America	8593

Composition, percent

Data Sheet	C	Mo	V	Al	N	H	Ti
1	0.031	3.16	1.05	4.30	0.004	0.003	Bal
2	0.018	3.2	0.9	4.2	0.013	0.007	Bal

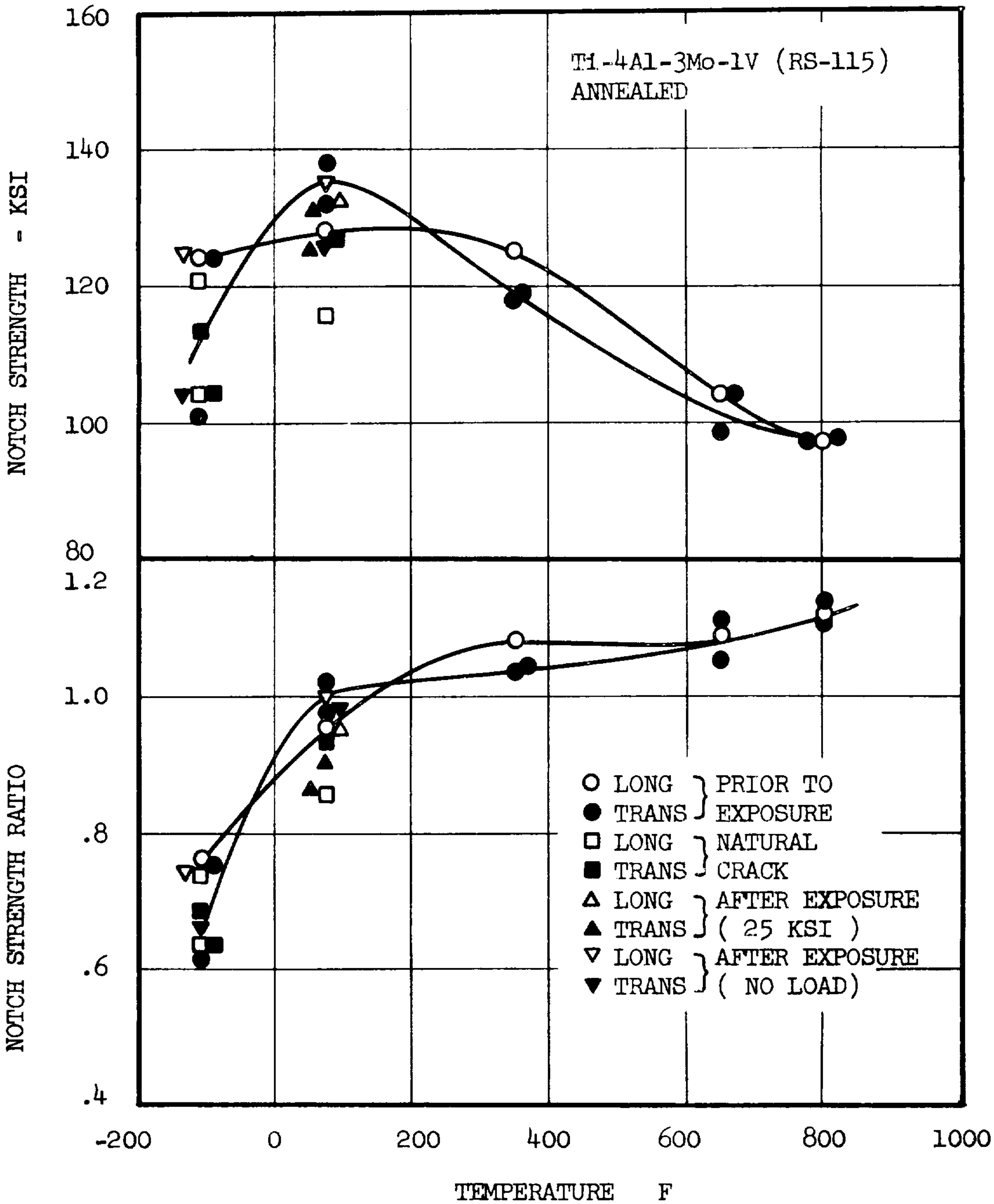
73



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Conditions of prior exposure
○ Unexposed (× fatigue-cracked edge notches)
● 1000 hrs., 650°F, 25 ksi (Δ unstressed)

Ti-4Al-3Mo-1V (Annealed)



Effect of testing temperature on the notch strength and notch strength ratio of annealed Ti-4 Al-3 Mo-1 V (RS-115) sheet before and after prior exposure. (Data Sheet No. 1).

Alloy Designation: Ti-4Al-3Mo-1V(RS-115) Contributor: Syracuse University Research Institute Data Sheet No.: 1
Heat Treatment: Annealed Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches				[e]Edge-Cracked Specimen			
Temp. °F	Stress ksi	Time, hr		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S		Tensile Str. (C), ksi		Strength Ratio, C/S	
				L[d]	T	L	T	L	L	T	T	L	T	L	T	L	T	L	T
None			-110	165	164.5	154.5	158	5.0	1.5	4.1	1.5	124	101	0.76	0.68	104	113.6	0.69	0.66
None			-110	---	---	---	---	---	---	---	---	---	124			121	104.6		
650	0	1000	-110	167	157	162.8	---	4.01	1.5	1.34	1.5	125	104.7	0.75	0.67				
650	25	1000	-110	155.5	154.5	---	152	1.67	1.5	4.01	1.5	112	103	0.72	0.67				
650	25	1000	-110	---	---	---	---	---	---	---	---	---	103						
None			Room	134.5	135	127	128	8.7	1.5	8.4	1.5	128	132	0.95	1.00	115.6	127	0.86	0.94
None			Room	---	---	---	---	---	---	---	---	---	138			---	---		
650	0	1000	Room	136	128	128.7	123.8	9.04	1.5	6.7	1.5	135	126	0.99	0.98				
650	25	1000	Room	139	145	131.3	142.5	8.03	1.5	8.38	1.5	132.5	131	0.95	0.89				
650	25	1000	Room	---	---	---	---	---	---	---	---	---	126						
None			350	115.5	114	97.7	105	8.7	1.5	6.0	1.5	125	118.5	1.08	1.04				
None			350	---	---	---	---	---	---	---	---	---	119						
None			650	95.5	93.5	76.2	79.4	4.7	1.5	4.7	1.5	104	98.5	1.09	1.08				
None			650	---	---	---	---	---	---	---	---	---	104						
650	25	1000	650	96.8	89.7	81.2	80.3	6.0	1.5	4.7	1.5	106.5	100.6	1.10	1.14				
650	25	1000	650	---	---	---	---	---	---	---	---	---	105						
None			800	86.5	88	73.1	72	4.4	1.5	2.7	1.5	97	97	1.12	1.11				
None			800	---	---	---	---	---	---	---	---	---	98						

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation
[e]Specimen 1.00 in. wide notched 0.05 in. deep, then fatigued to 0.70 in. between the roots of the edge cracks.

Alloy Designation: Ti-4Al-3Mo-1V Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 2
Heat Treatment: As noted below Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data				Control Coupon Data		
				Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
12 hrs. at 925°F										
Room	T	0.0200	8.98	6370	35.5	1.32	161	186.6	202.8	4.5
Room	T	0.0203	8.98	5160	28.3	2.29	189			
24 hrs. at 950°F										
Room	L	0.0262	9.00	7300	30.9	1.19	106	178.5	196.4	3.0
Room	L	0.0260	9.00	9200	39.3	1.17	167			
Room	L	0.0260	9.00	5360	22.9	2.41	125			
Room	T	0.0268	8.98	9300	38.6	1.29	172	190.1	207.2	5.0
Room	T	0.0260	8.99	10000	42.7	1.10	178			
Room	T	0.0268	8.98	9460	39.2	2.14	308			
Room	T	0.0256	8.98	7430	32.3	2.32	229			
600	L	0.0260	9.02	11120	47.4	1.40	372	118.7	152.1	3.5
600	L	0.0250	8.97	11430	51.0	1.42	437			
600	L	0.0254	9.00	8670	37.9	2.45	441			
600	L	0.0246	9.00	8450	38.2	2.46	450			
600	T	0.0248	8.98	12180	57.7	1.30	498	133.2	161.8	3.5
600	T	0.0254	8.98	13650	59.9	1.56	652			
600	T	0.0249	8.98	10550	47.2	2.53	696			
600	T	0.0258	8.98	10370	44.8	2.66	666			

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Ti-5Al-2.75Cr-1.25Fe

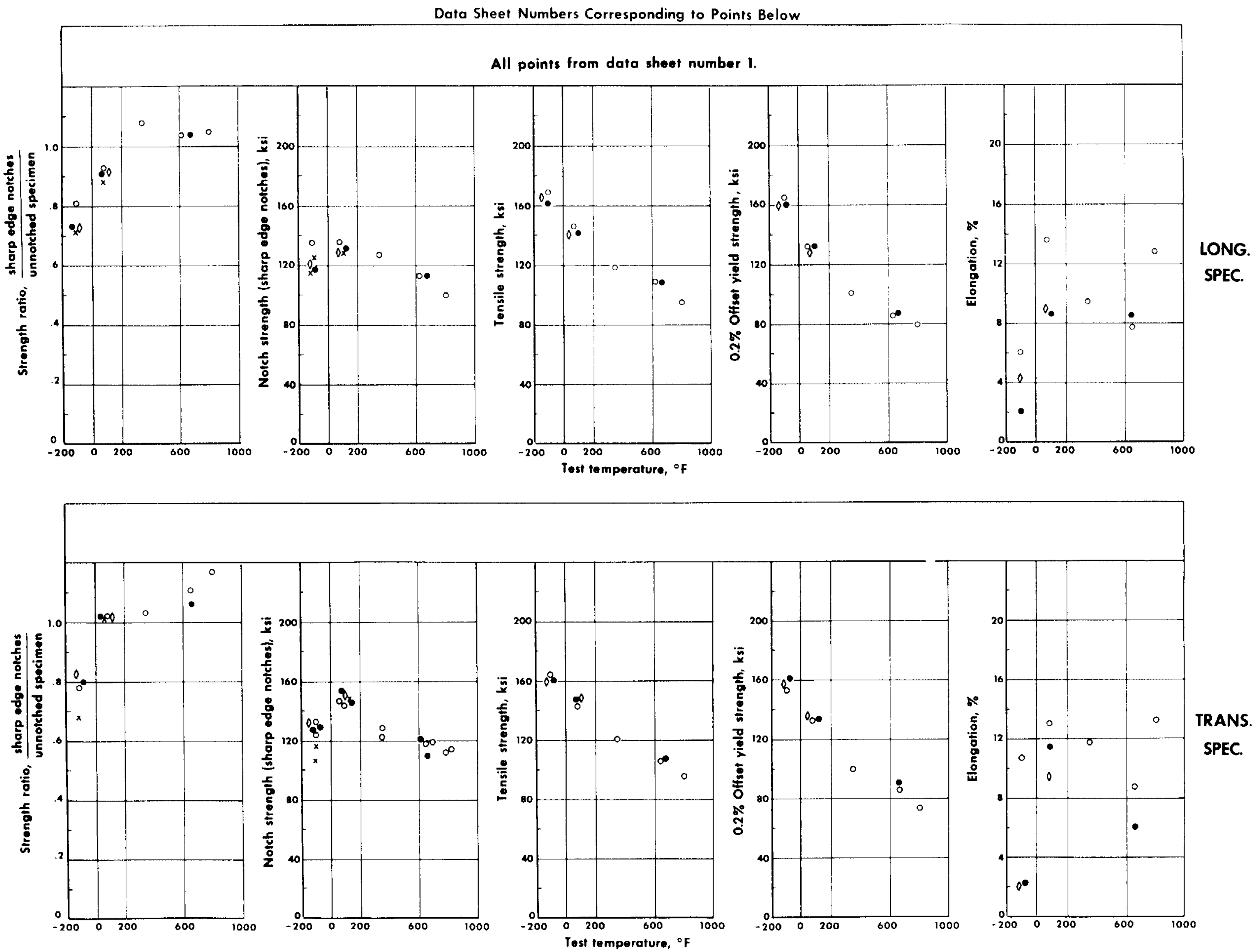
INDEX OF MATERIALS

Data Sheet	Organization Contributing Data	Alloy Producer	Heat Number
1	Syracuse University Research Institute	Republic	3930017

Composition, percent

Data Sheet	C	Cr	Al	N	Fe	Ti
1	0.030	3.10	5.10	0.011	1.30	Bal

77

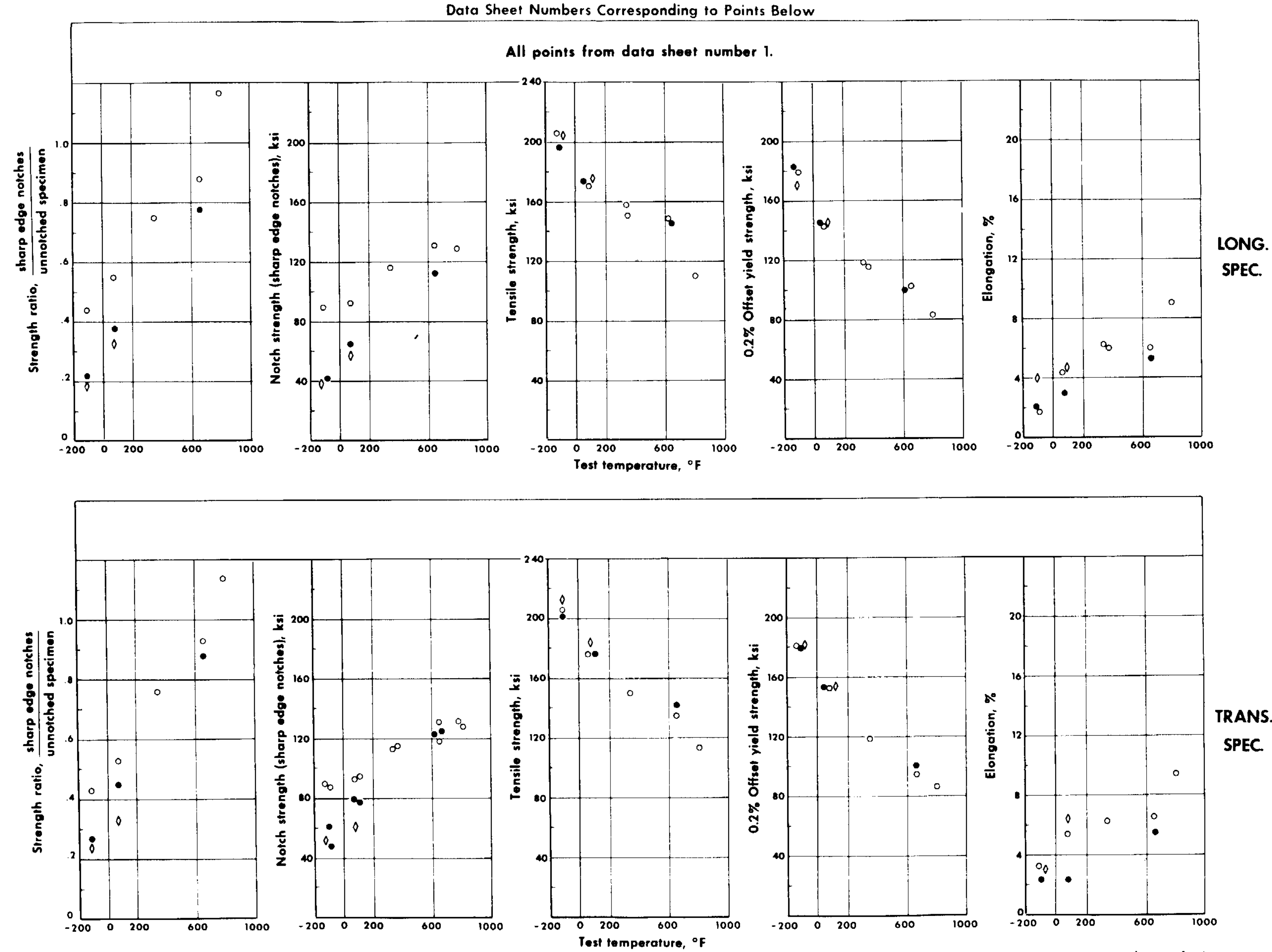


Conditions of prior exposure
○ Unexposed (× fatigue-cracked edge notches)
● 1000 hrs., 650°F, 25 ksi
◊ 1000 hrs., 650°F, unstressed

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Ti-5Al-2.75Cr-1.25Fe (Annealed)

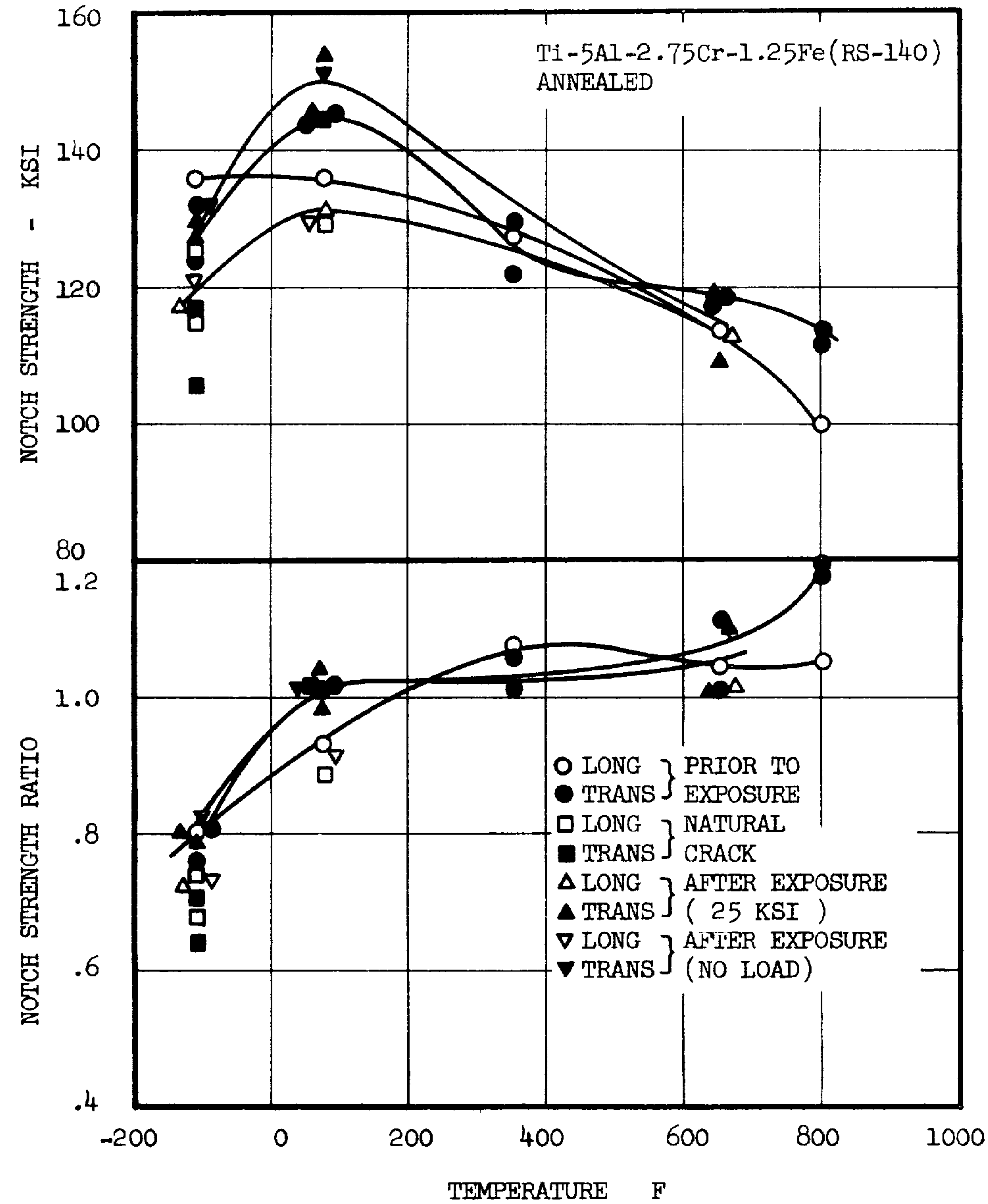
78



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Ti-5Al-2.75Cr-1.25Fe (Solution treated + aged 6 hrs. 900°)

Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 25 ksi
- ◊ 1000 hrs., 650°F, unstressed



Effect of testing temperature on the notch strength and notch strength ratio of annealed Ti-5 Al-2.75 Cr-1.25 Fe (RS-140) sheet tested before and after exposure. (Data Sheet No. 1)

(RS-140)

Alloy Designation: Ti-5Al-2.75Cr-1.25Fe Contributor: Syracuse University Research Institute Data Sheet No.: 1
Heat Treatment: As noted Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches				Edge-cracked specimens[e]			
Temp °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S		Tensile str.(C), ksi		Strength ratio, C/S	
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
Annealed																			
None			-110	169	164	165.5	153	6.0	1.5	10.7	1.5	136	124	0.81	0.78	125.5	106	0.71	0.68
None			-110	-----	-----	-----	-----	----	---	----	---	-----	132.2			115	116.4		
650	0	1000	-110	165.5	159.5	160	157.3	4.35	1.5	2.01	1.5	121.5	132	0.73	0.83				
650	25	1000	-110	161	161.5	161	161	2.01	1.5	2.34	1.5	117.3	129.5	0.73	0.79				
650	25	1000	-110	-----	-----	-----	-----	----	---	----	---	-----	127.2						
None			Room	146	143	132	132.5	13.6	1.5	13.0	1.5	136	146	0.93	1.02	129	145	0.88	1.01
None			Room	-----	-----	-----	-----	----	---	----	---	-----	144.5			-----	-----		
650	0	1000	Room	141.5	148.3	128	135.2	9.05	1.5	9.38	1.5	129.5	151	0.92	1.02				
650	25	1000	Room	143.5	147	132.2	133.5	8.7	1.5	11.5	1.5	131	144.8	0.91	1.02				
650	25	1000	Room	-----	-----	-----	-----	----	---	----	---	-----	154						
None			350	118.3	120.5	100.8	99.7	9.4	1.5	11.7	1.5	127.4	122	1.08	1.03				
None			350	-----	-----	-----	-----	----	---	----	---	-----	128.5						
None			650	109	106	85.3	85.9	7.7	1.5	8.7	1.5	113.5	117.6	1.04	1.11				
None			650	-----	-----	-----	-----	----	---	----	---	-----	118.2						
650	25	1000	650	109	107.5	86.8	90	8.38	1.5	6.0	1.5	113	109	1.04	1.06				
650	25	1000	650	-----	-----	-----	-----	----	---	----	---	-----	119						
None			800	95.2	95.6	79.7	73.5	12.8	1.5	13.2	1.5	100	112.5	1.05	1.17				
None			800	-----	-----	-----	-----	----	---	----	---	-----	114						
Solution treated + Aged 6 hrs, at 900°F																			
None			-110	206	206	179.5	181	1.7	1.5	3.3	1.5	90	90	0.44	0.43				
None			-110	-----	-----	-----	-----	----	---	----	---	-----	87.5						
650	0	1000	-110	205	213	170.5	182	4.0	1.5	3.0	1.5	39	52	0.19	0.24				
650	25	1000	-110	196	202	183	180.5	2.0	1.5	2.3	1.5	42.3	49	0.22	0.27				
650	25	1000	-110	-----	-----	-----	-----	----	---	----	---	-----	61						
None			Room	171	176.5	143.5	153	4.4	1.5	5.4	1.5	93.4	93.4	0.55	0.53				
None			Room	-----	-----	-----	-----	----	---	----	---	-----	94.5						
650	0	1000	Room	177.5	184	146.5	154	4.7	1.5	6.4	1.5	58	61.3	0.33	0.33				
650	25	1000	Room	172.8	176.5	145.5	153.5	3.0	1.5	2.3	1.5	65.4	79.9	0.38	0.45				
650	25	1000	Room	-----	-----	-----	-----	----	---	----	---	-----	77.8						
None			350	158	150	118.5	118.5	6.2	1.5	6.2	1.5	116.5	114	0.75	0.76				
None			350	151	-----	115.5	-----	6.0	1.5	----	---	-----	115						
None			650	148.5	134	102	94.2	6.0	1.5	6.5	1.5	131	131.5	0.88	0.93				
None			650	-----	-----	-----	-----	----	---	----	---	-----	118						
650	25	1000	650	145	142	99	100	5.4	1.5	5.4	1.5	112.5	122.5	0.78	0.88				
650	25	1000	650	-----	-----	-----	----	----	---	----	---	-----	125.6						
None			800	110.5	113.6	83	86.1	9.0	1.5	9.4	1.5	129.5	131.5	1.17	1.14				
None			800	-----	-----	-----	-----	----	---	----	---	-----	128.5						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Specimen 1.00 in. wide notched 0.05 in. deep, then fatigued to 0.70 in. between the roots of the edge cracks.

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AISI 301 STAINLESS STEEL

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Syracuse University Research Institute	American Steel & Wire	3V0065
2	Lockheed Aircraft Corp., Calif. Co.	Crucible Steel Company	122594

Composition, percent

Data Sheet	C	Mn	P	S	Si	Ni	Cr	Fe
1	0.06	1.34	0.029	0.013	0.56	7.31	17.72	Bal
2	0.10	1.23	0.038	0.024	0.52	7.17	17.62	Bal

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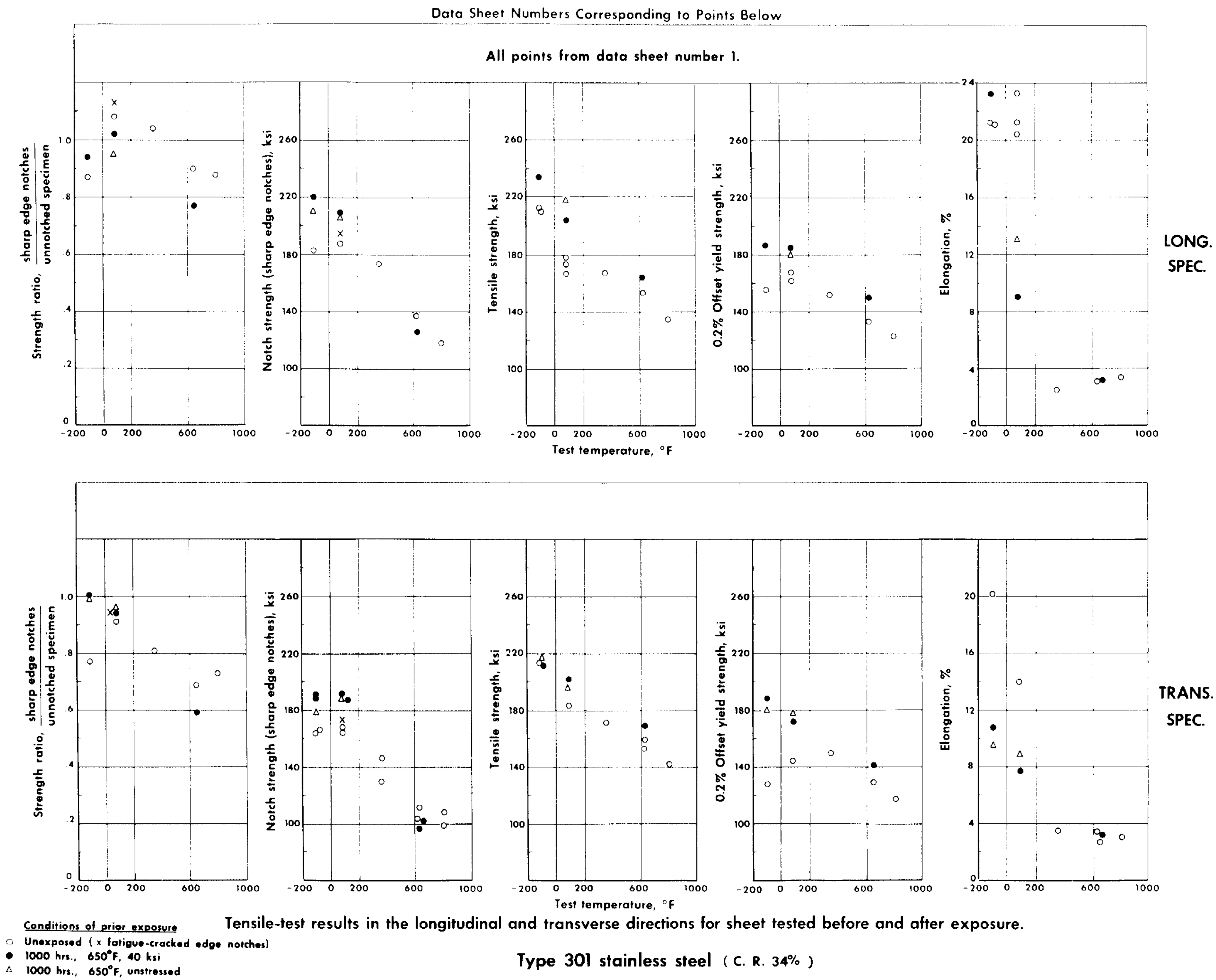
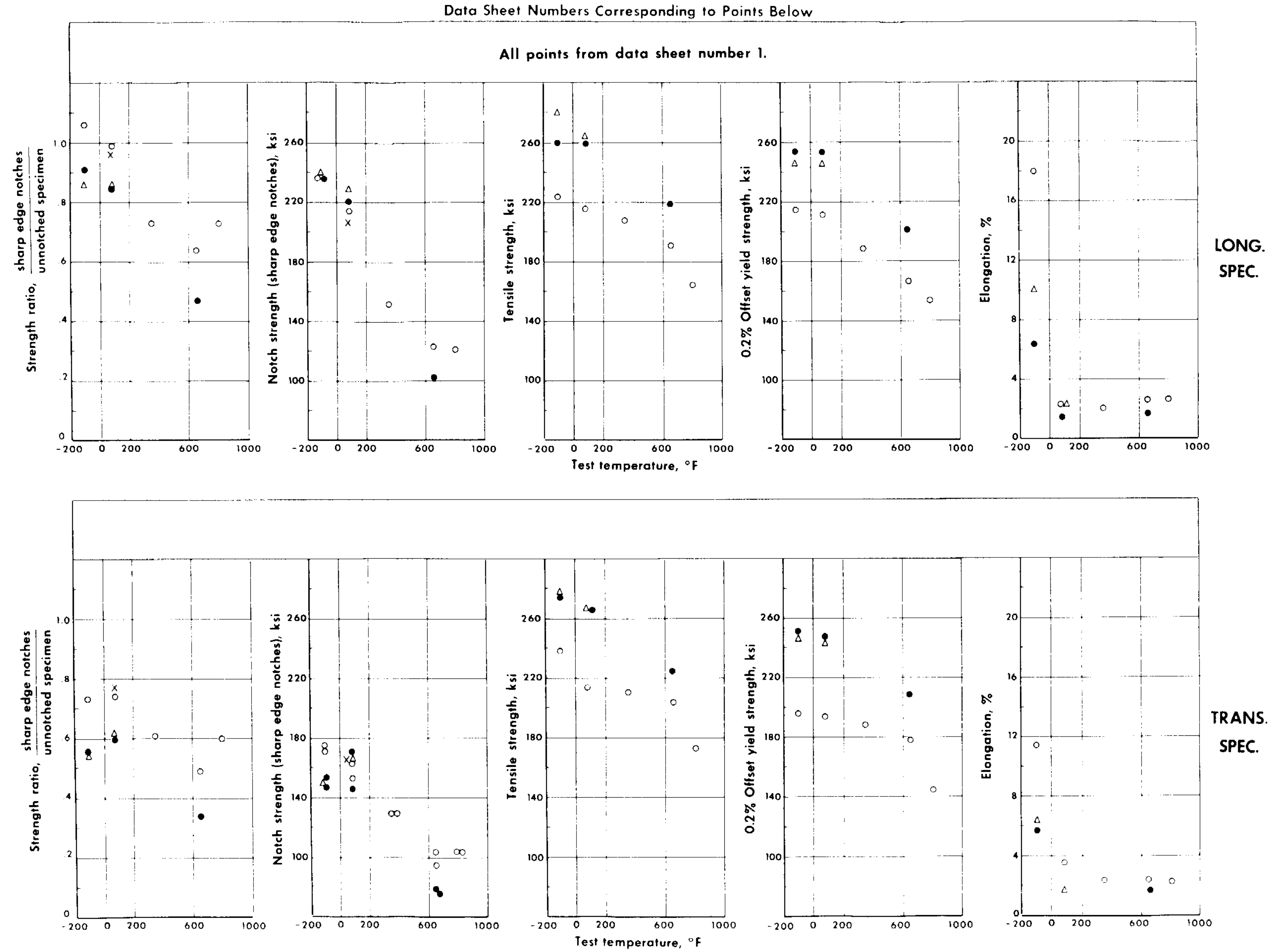


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Type 301 stainless steel (C. R. 34%)



Conditions of prior exposure
- Unexposed (× fatigue-cracked edge notches)
- ● 1000 hrs., 650°F, 40 ksi
- △ 1000 hrs., 650°F, unstressed

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Type 301 stainless steel (C. R. 51%)

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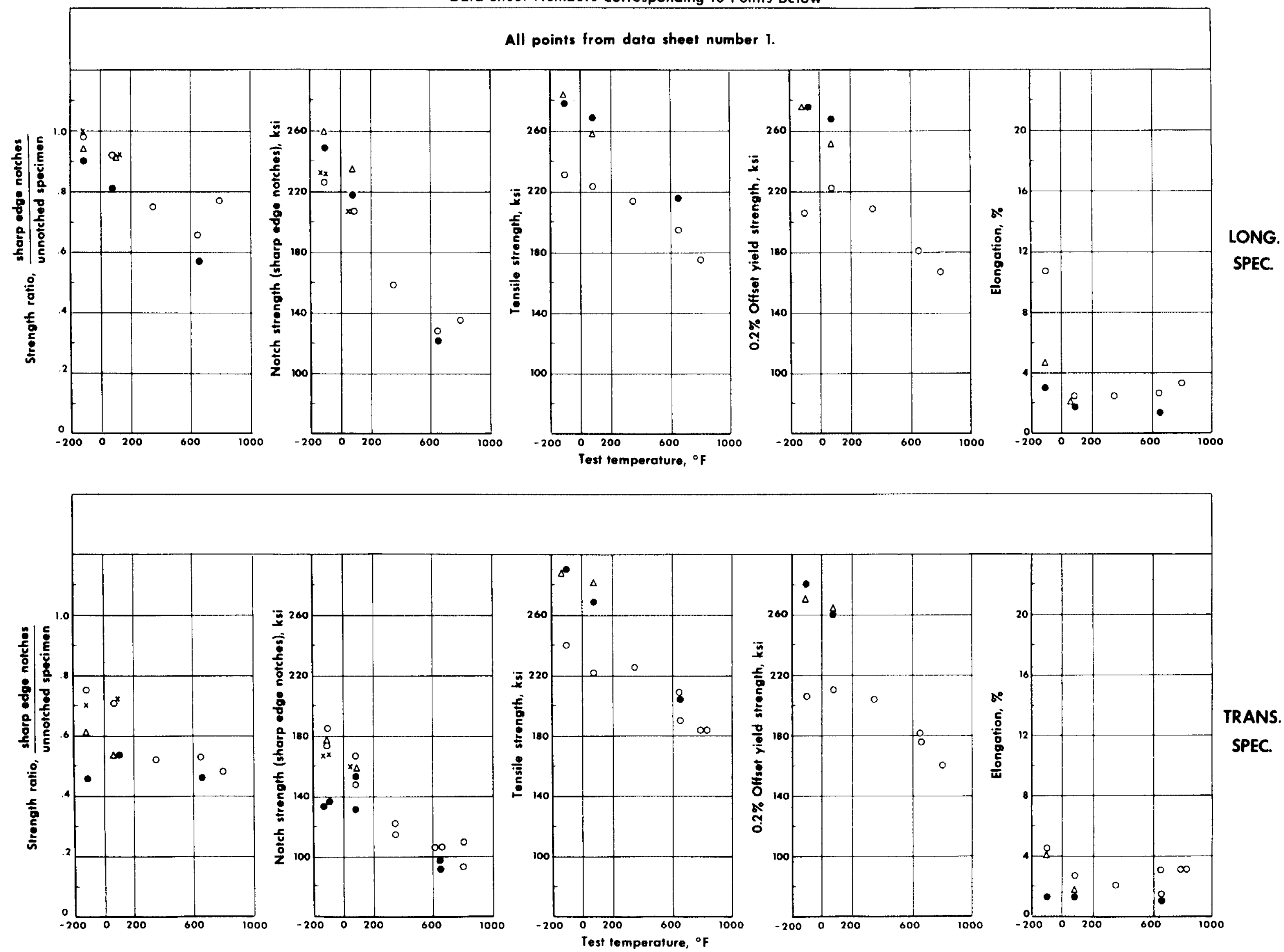
Data Sheet Numbers Corresponding to Points Below

All points from data sheet number 1.



Conditions of prior exposure
- ○ Unexposed (× fatigue-cracked edge notches)
- ● 1000 hrs., 650°F, 40 ksi
- △ 1000 hrs., 650°F, unstressed

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Type 301 stainless steel (C. R. 60%)

Alloy Designation: AISI 301 Stainless Steel   Contributor: Syracuse University Research Institute   Data Sheet No.: 1
Heat Treatment: As noted below   Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	[e] Edge Cracked Specimens: Tensile Str. (C), ksi L	Tensile Str. (C), ksi T	Strength Ratio, C/S L	Strength Ratio, C/S T
Cold reduced 34%																			
None			-110	211.5	212.5	-----	127.0	21.2	1.5	20.1	1.5	183.0	164.5	0.87	0.77				
None			-110	211.0	-----	155.5	-----	21.0	1.5	----	---	-----	164.0						
650	0	1000	-110	-----	216.0	-----	179.5	----	----	9.4	1.5	210.0	178.0	----	0.99				
650	40	1000	-110	234.0	210.1	186.0	187.7	23.2	1.5	9.7	1.5	220.0	187.4	0.94	1.00				
650	40	1000	-110	-----	-----	-----	-----	----	----	----	---	-----	190.0						
None			Room	173.4	182.6	166.7	143.7	20.4	1.5	13.9	1.5	187.4	167.5	1.08	0.91	194.5	172.0	1.13	0.94
None			Room	166.5	-----	-----	-----	23.2	1.5	----	---	-----	164.0						
None			Room	177.8	-----	161.0	-----	21.2	1.5	----	---	-----	-----						
650	0	1000	Room	218.0	195.0	179.5	177.0	13.0	1.5	8.7	1.5	206.0	188.0	0.95	0.96				
650	40	1000	Room	204.0	201.0	184.0	171.0	9.0	1.5	7.6	1.5	209.0	190.0	1.02	0.94				
650	40	1000	Room	-----	-----	-----	-----	----	---	----	----	-----	187.0						
None			350	166.5	171.0	151.5	149.0	2.4	1.5	3.4	1.5	172.6	146.0	1.04	0.81				
None			350	-----	-----	-----	-----	----	---	----	----	-----	130.0						
None			650	153.0	152.5	132.5	-----	3.0	1.5	3.3	1.5	137.5	102.9	0.90	0.69				
None			650	-----	158.5	-----	128.5	----	---	2.6	1.5	-----	110.5						
650	40	1000	650	163.6	169.2	149.0	140.0	3.1	1.5	3.1	1.5	126.0	96.2	0.77	0.59				
650	40	1000	650	-----	-----	-----	-----	----	---	----	---	-----	102.0						
None			800	134.5	142.0	121.5	117.0	3.3	1.5	3.0	1.5	117.5	108.0	0.88	0.73				
None			800	-----	-----	-----	-----	----	---	----	---	-----	98.0						
Cold reduced 51%																			
None			-110	223.5	238.0	215.0	196.5	18.0	1.5	11.4	1.5	237.0	176.0	1.06	0.73				
None			-110	-----	-----	-----	-----	----	---	----	---	-----	171.0						
650	0	1000	-110	280.0	278.0	245.5	246.5	10.0	1.5	6.4	1.5	240.0	150.0	0.86	0.54				
650	40	1000	-110	260.0	275.0	253.5	251.0	6.4	1.5	5.7	1.5	237.0	153.0	0.91	0.55				
650	40	1000	-110	-----	-----	-----	-----	----	---	----	---	-----	147.5						
None			Room	216.0	214.0	211.5	194.0	2.3	1.5	3.6	1.5	214.5	163.0	0.99	0.74	207	165.1	0.96	0.77
None			Room	-----	-----	-----	-----	----	---	----	---	-----	153.0						
650	0	1000	Room	265.0	267.0	245.5	244.0	2.3	1.5	1.7	1.5	229.0	165.5	0.86	0.62				
650	40	1000	Room	260.0	266.0	254.0	246.5	1.5	1.5	----	---	221.0	146.0	0.85	0.60				
650	40	1000	Room	-----	-----	-----	-----	----	---	----	---	-----	170.5						
None			350	208.0	210.5	188.5	187.5	2.0	1.5	2.4	1.5	152.0	128.5	0.73	0.61				
None			350	-----	-----	-----	-----	----	---	----	---	-----	129.0						
None			650	191.0	204.0	167.0	178.0	2.6	1.5	2.4	1.5	123.0	103.0	0.64	0.49				
None			650	-----	-----	-----	-----	----	---	----	---	-----	95.6						
650	40	1000	650	219.0	225.0	201.5	208.5	1.7	1.5	1.7	1.5	103.0	75.7	0.47	0.34				
650	40	1000	650	-----	-----	-----	-----	----	---	----	---	-----	78.2						
None			800	165.0	173.0	153.8	145.2	2.6	1.5	2.3	1.5	121.1	104.2	0.73	0.60				
None			800	-----	-----	-----	-----	----	---	----	---	-----	104.0						
Cold reduced 60%																			
None			-110	231.0	240.0	206.0	205.5	10.7	1.5	4.5	1.5	226.5	184.5	0.98	0.75	232.0	167.5	1.00	0.70
None			-110	-----	-----	-----	-----	----	---	----	---	-----	173.5			231.5	167.0		
650	0	1000	-110	284.0	288.0	276.0	270.0	4.7	1.5	4.0	1.5	260.0	177.0	0.94	0.61				
650	40	1000	-110	278.0	290.0	276.3	280.0	3.0	1.5	1.3	1.5	248.5	135.0	0.90	0.46				
650	40	1000	-110	-----	-----	-----	-----	----	---	----	---	-----	134.2						
None			Room	223.5	222.0	222.5	210.0	2.4	1.5	2.7	1.5	206.5	167.2	0.92	0.71	206.2	159.2	0.92	0.72
None			Room	-----	-----	-----	-----	----	---	----	---	-----	148.2						
650	0	1000	Room	258.0	281.0	251.0	264.0	2.0	1.5	1.7	1.5	235.0	158.0	0.91	0.53				
650	40	1000	Room	269.0	269.0	267.5	259.5	1.7	1.5	1.3	1.5	218.0	153.0	0.81	0.53				
650	40	1000	Room	-----	-----	-----	-----	----	---	----	---	-----	132.0						
None			350	213.5	225.0	207.5	203.5	2.4	1.5	2.0	1.5	159.0	121.5	0.75	0.52				
None			350	-----	-----	-----	-----	----	---	----	---	-----	114.0						
None			650	194.5	190.0	180.0	175.5	2.6	1.5	1.4	1.5	128.5	106.2	0.66	0.53				
None			650	-----	208.5	-----	181.0	----	---	3.0	1.5	-----	106.0						
650	40	1000	650	216.0	204.0	-----	-----	1.3	1.5	1.0	1.5	122.0	97.5	0.57	0.46				
650	40	1000	650	-----	-----	-----	-----	----	---	----	---	-----	90.5						
None			800	174.5	183.8	166.7	160.0	3.3	1.5	3.0	1.5	135.0	62.4						
None			800	-----	183.8	-----	-----	----	---	3.0	1.5	-----	93.1	0.77	0.48				
None			800	-----	-----	-----	-----	----	---	----	---	-----	109.5						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Specimen 1.00 in. wide notched 0.05 in. deep, then fatigued to 0.70 in. between the roots of the edge cracks.

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AM350

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Lewis Research Center, NASA	Allegheny Ludlum	W23327-1
2	Materials Research Laboratory, Inc.	" "	W23327-1
3	The University of Michigan (ASD)	" "	89746
4	The University of Michigan (NASA)	" "	23327
5	Joliet Metallurgical Laboratories, Inc.	" "	45790
6	North American Aviation, Inc.	-----	----
7	Douglas Aircraft Company	-----	89329
8 & 9	Boeing Company, Transport Div.	Allegheny Ludlum	----
10	Lockheed Aircraft Corporation, Calif. Co.	Allegheny Ludlum	69762
		Wallingford	79289

Composition, percent

Data Sheet	C	Mn	P	S	Si	Cr	Ni	Mo	N	Fe
1, 2, 3	0.084	0.65	0.009	0.007	0.21	16.50	4.29	2.94	0.10	Bal
4	0.086	0.80	0.018	0.014	0.42	16.83	4.25	2.90	0.083	Bal
5	0.10	0.76	0.018	0.016	0.21	16.51	4.30	2.73	0.091	Bal
(69762) 10	0.10	0.92	0.024	0.011	0.26	16.87	4.50	2.82	0.10	Bal
(79289) 10	0.089	0.84	0.020	0.020	0.42	16.37	4.30	2.60	0.083	Bal
8, 9	0.095	0.85	0.024	0.014	0.30	16.98	4.33	2.80	0.09	Bal

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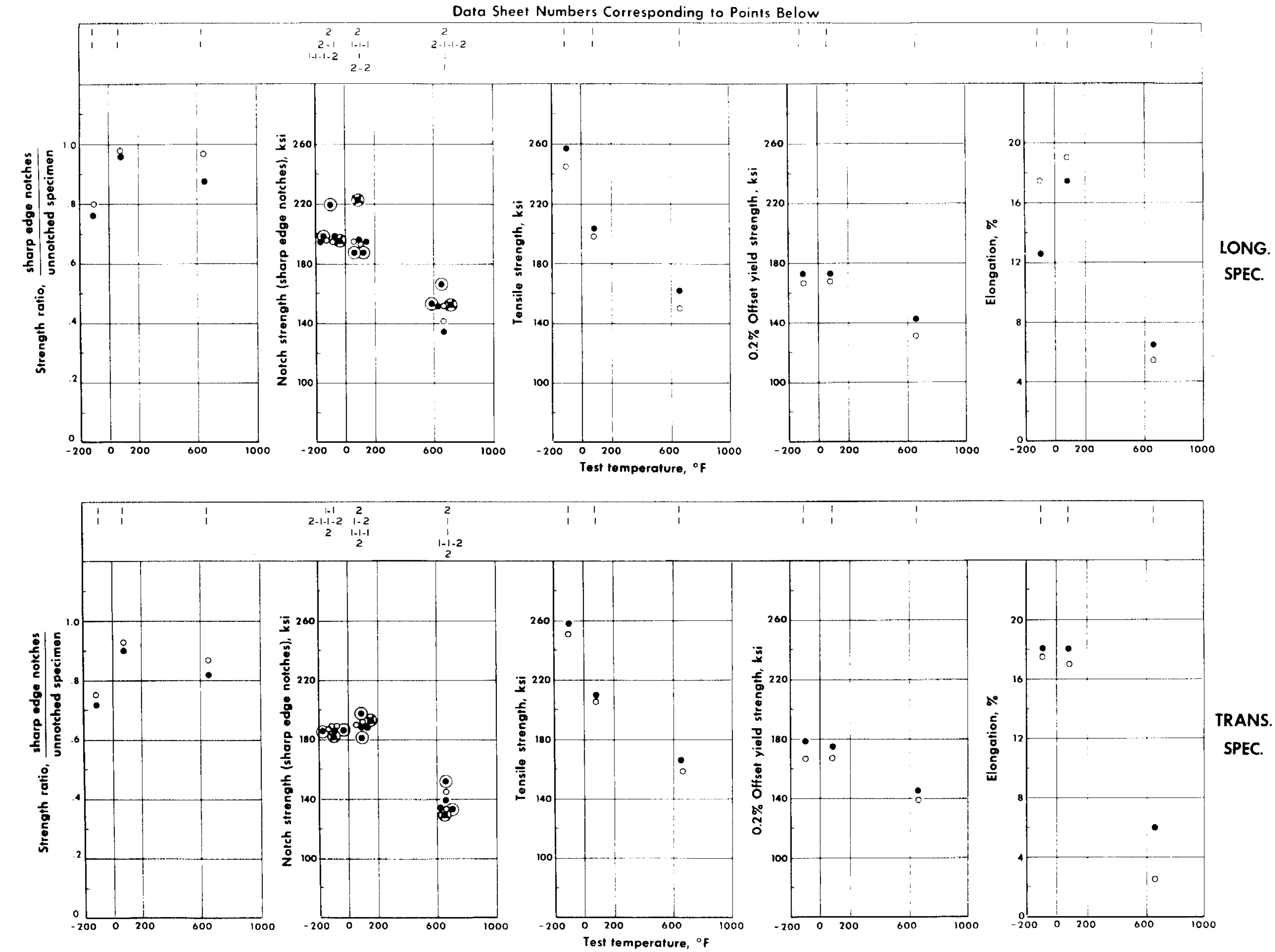
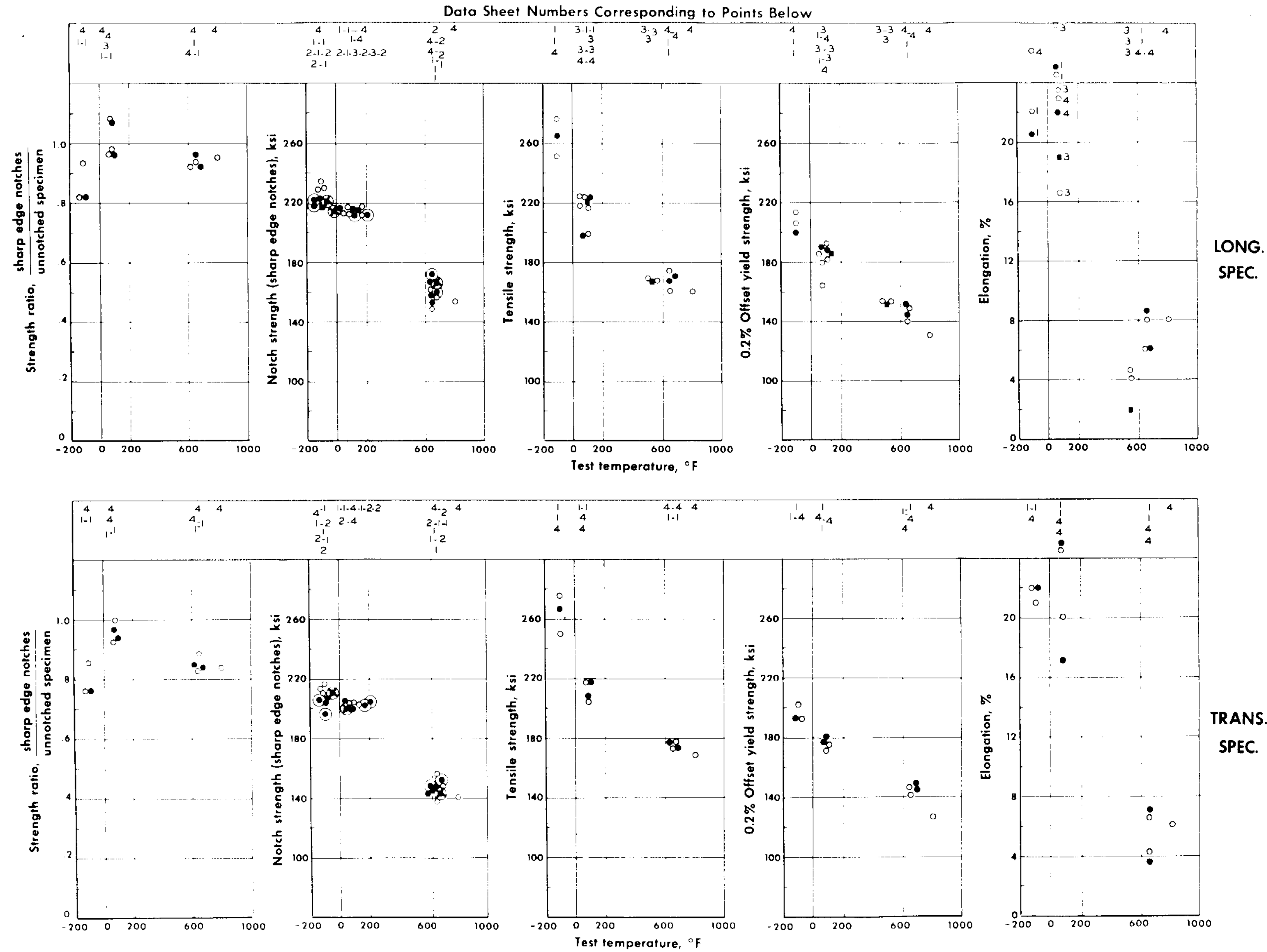


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

AM350 (C. R. 20% + 3 hrs. 950°)

Coated with sea salt during exposure
- 1000 hrs., 650°F, 40 ksi
- 1000 hrs., 650°F, 60 ksi

Conditions of prior exposure
- Unexposed
- 1000 hrs., 650°F, 40 ksi

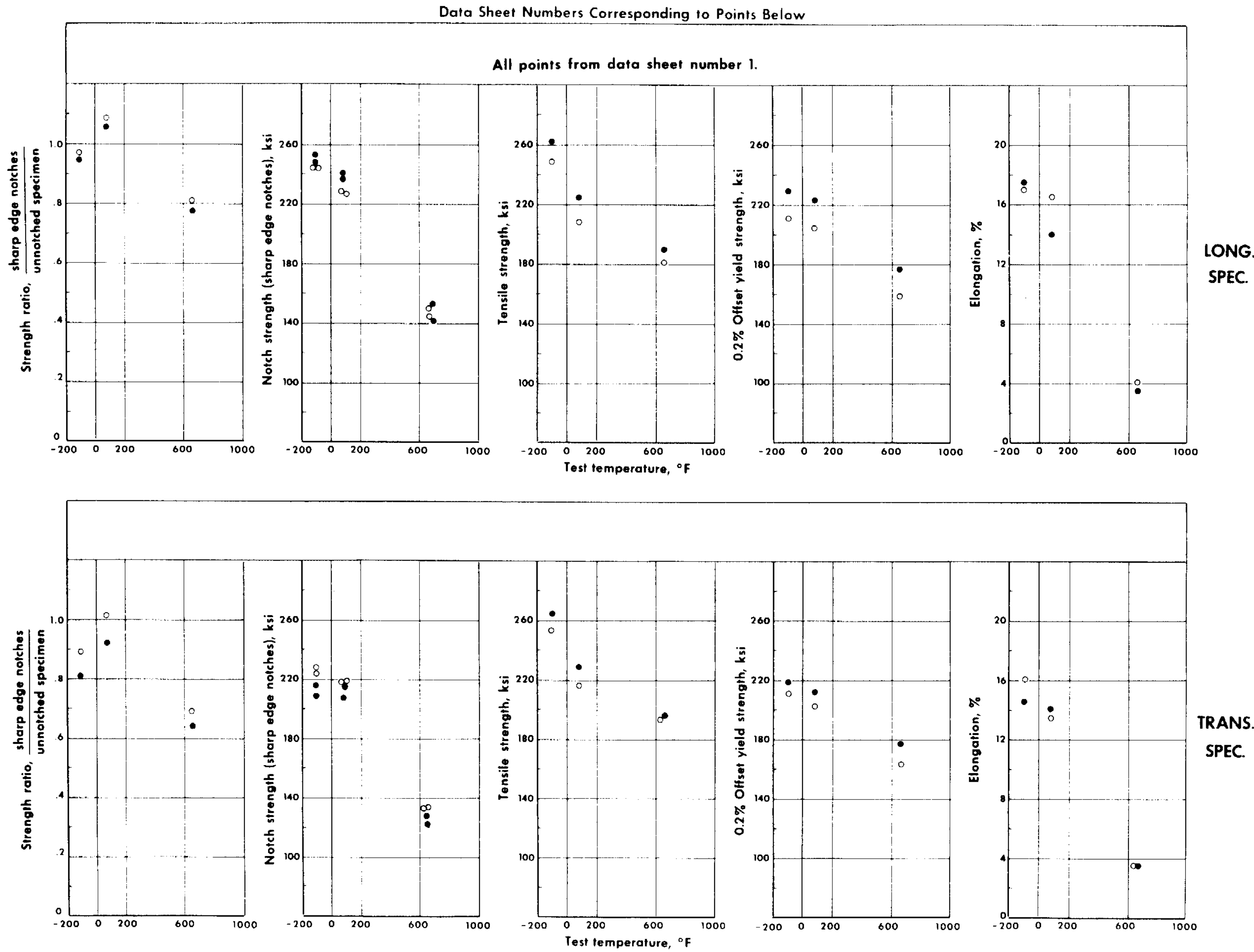


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

AM350 (C. R. 20% + 3 hrs. 825°)

Coated with sea salt during exposure
- 1000 hrs., 650°F, 40 ksi
- 1000 hrs., 650°F, 60 ksi

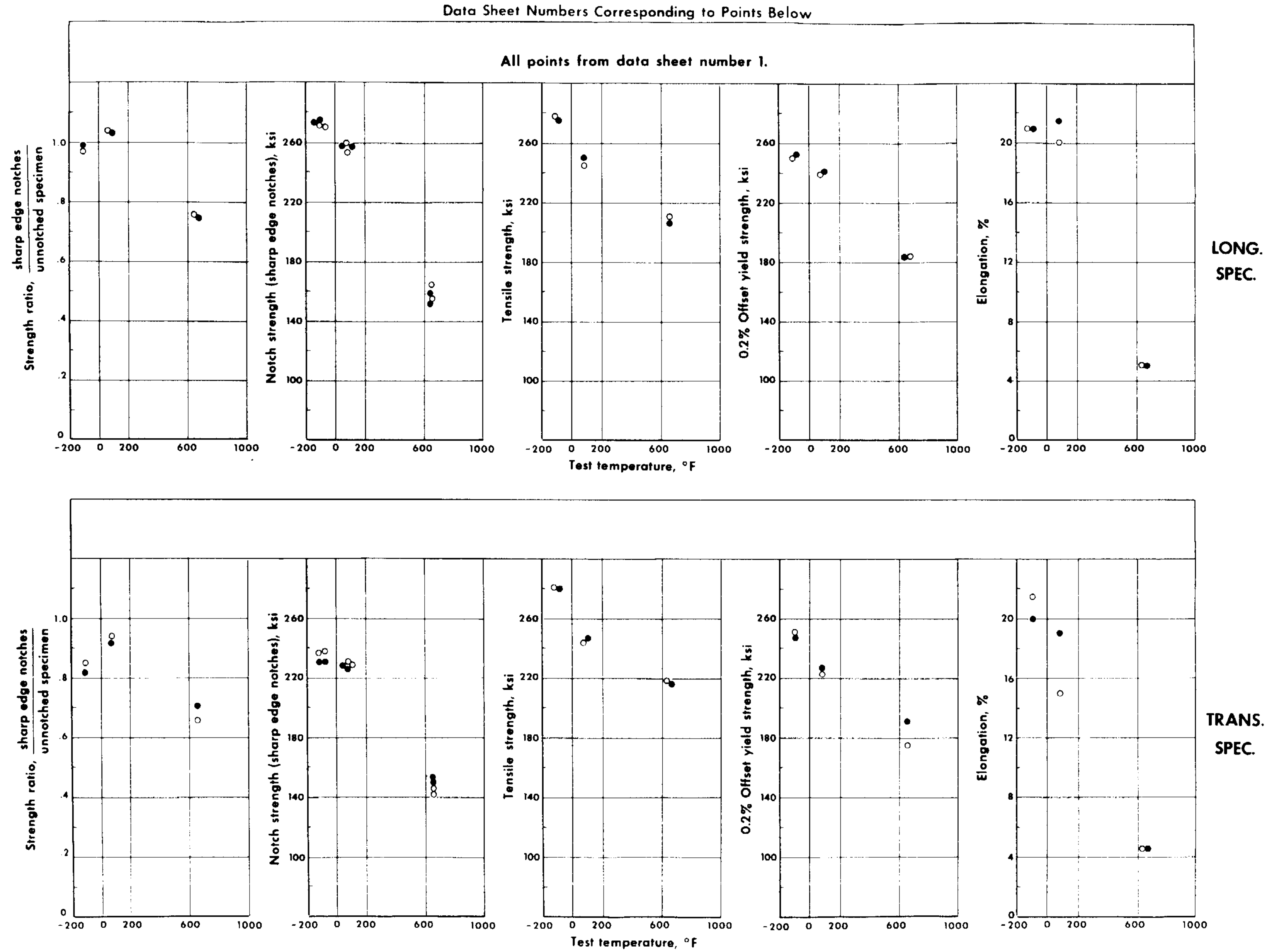
Conditions of prior exposure
- Unexposed
- 1000 hrs., 650°F, 40 ksi
- 5000 hrs., 550°F, 67 ksi



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

AM350 (C. R. 30% + 3 hrs. 950°)

Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

AM350 (C. R. 30% + 3 hrs. 825°)

Conditions of prior exposure

○ Unexposed

● 1000 hrs., 650°F, 40 ksi

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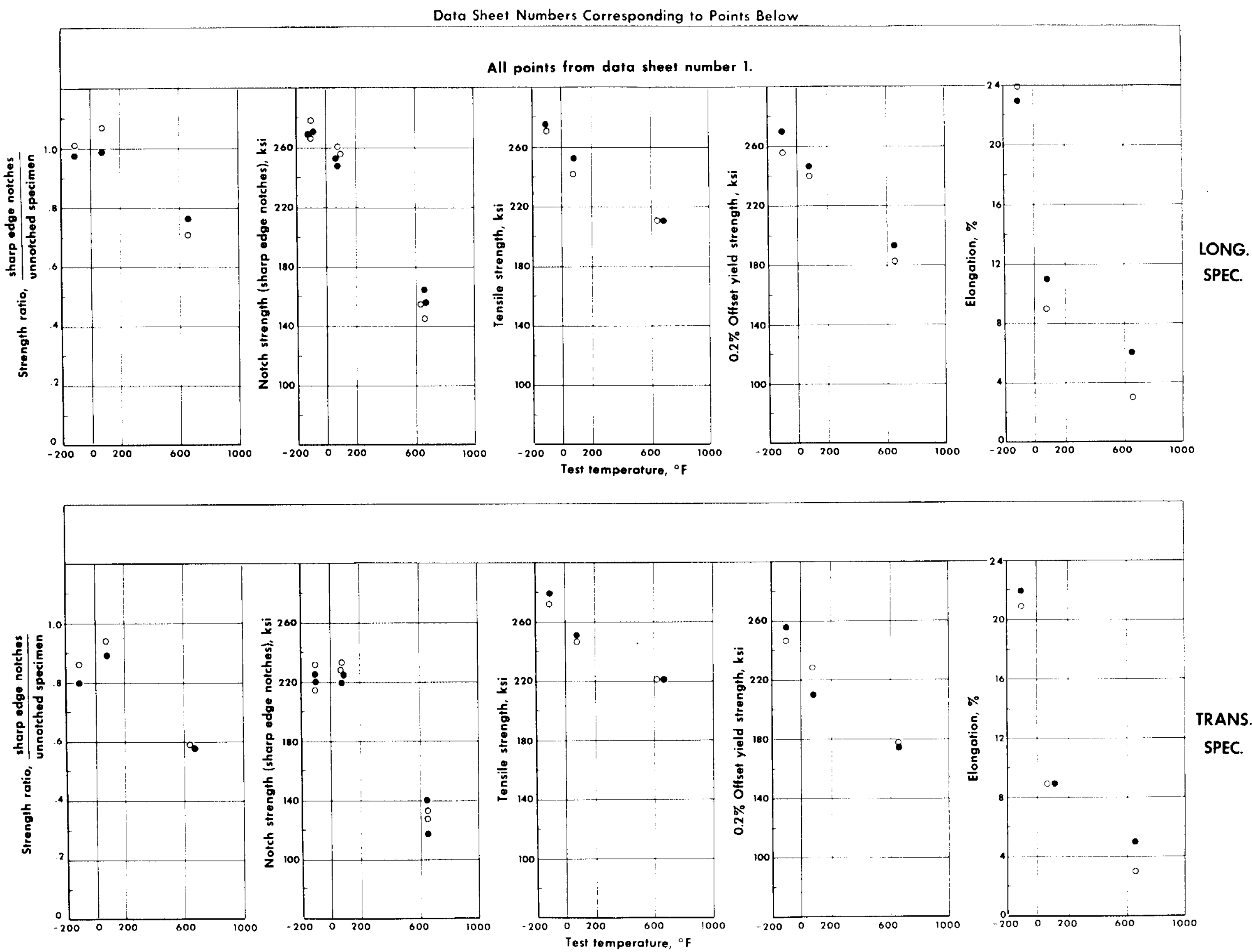
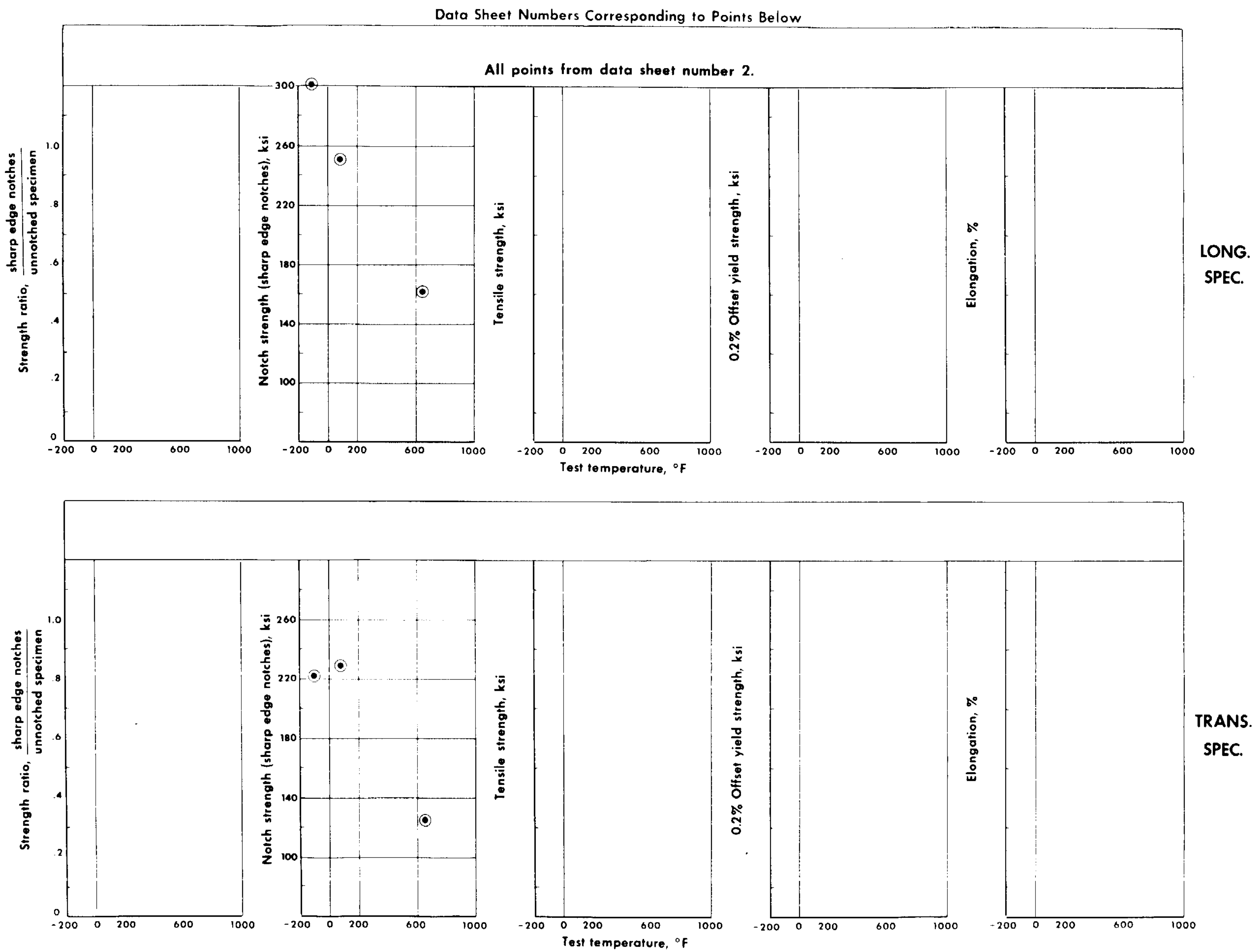


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

AM350 (C. R. 30%+ 3 hrs. 700°)

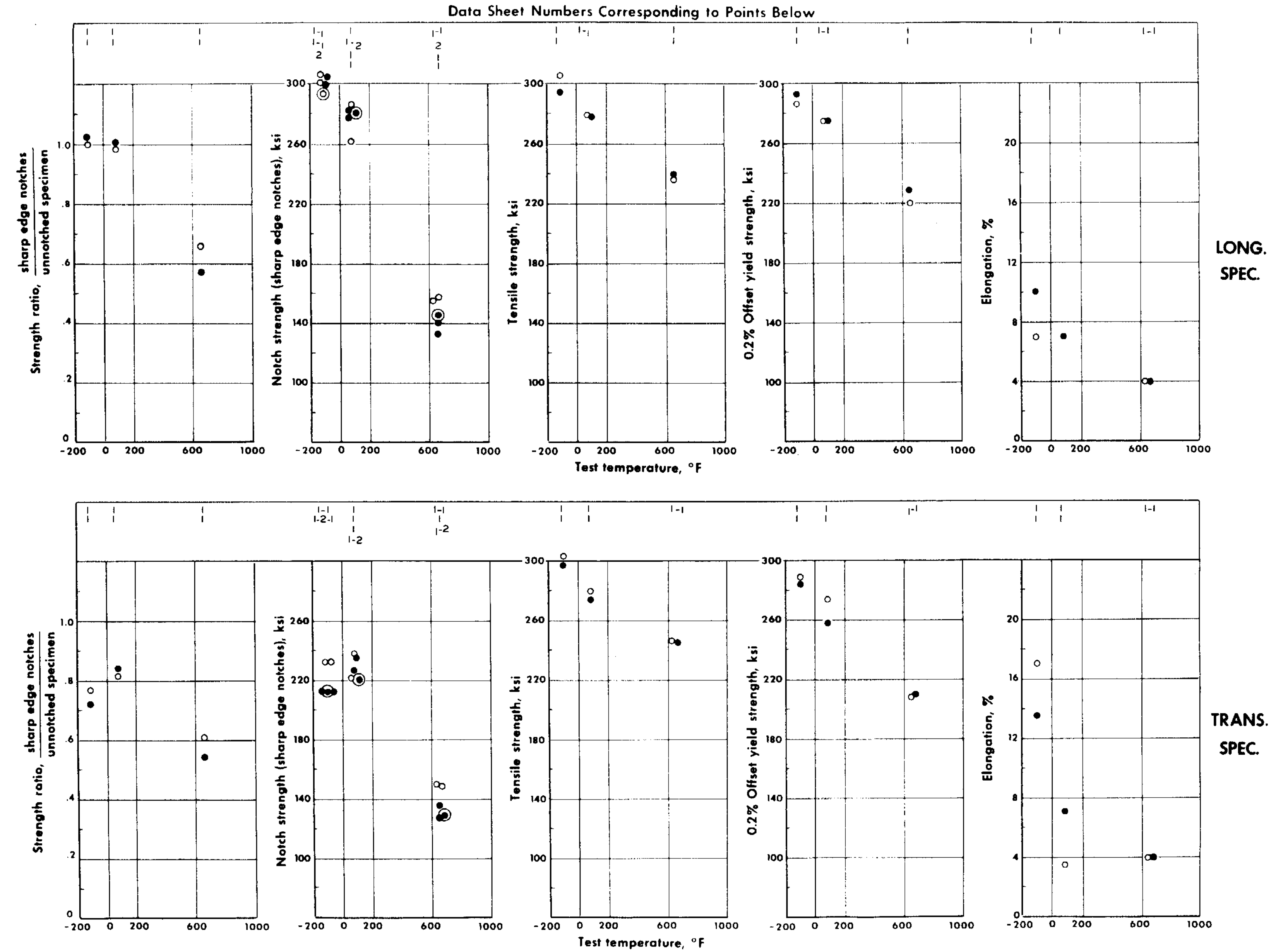
Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi



Tensile-test results in the longitudinal and transverse directions for sheet tested after exposure.

AM350 (C. R. 45% + 3 hrs. 950°)

Conditions of prior exposure
◉ 1000 hrs., 650°F, 40 ksi (Coated with sea salt)

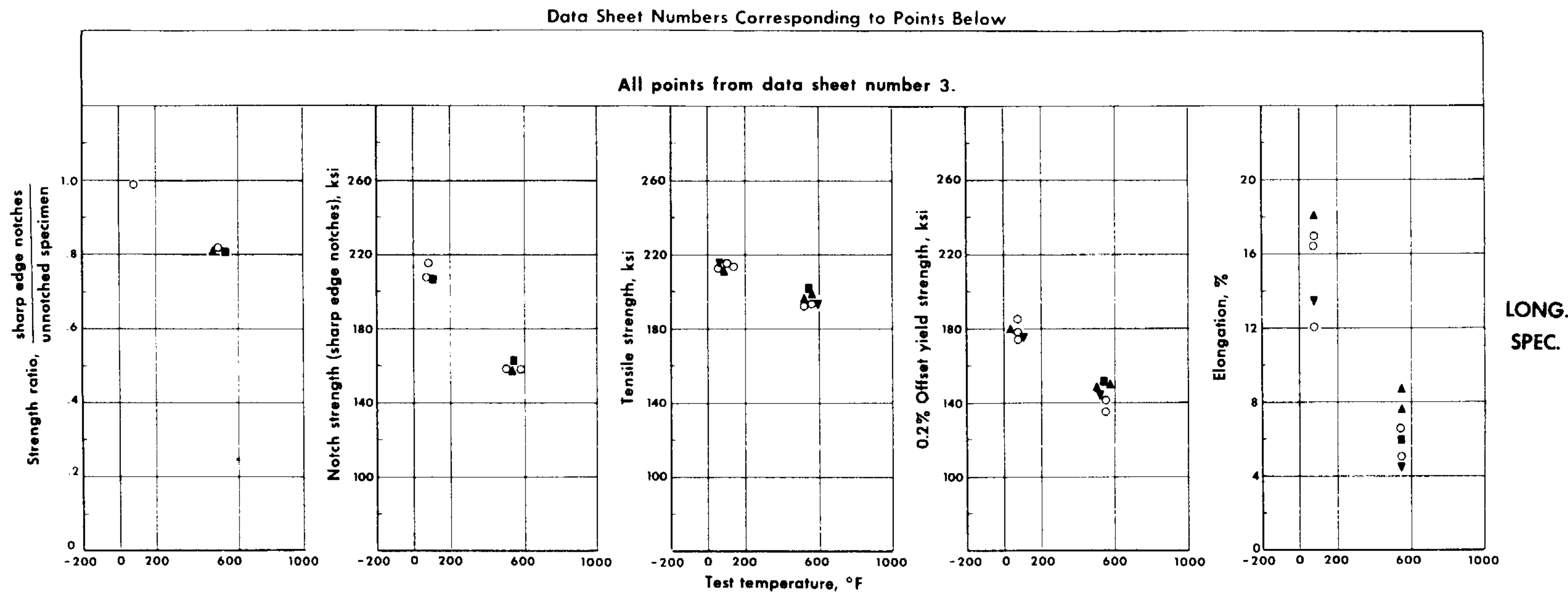


Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ◉ 1000 hrs., 650°F, 40 ksi (Coated with sea salt)

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

AM350 (C. R. 45% + 3 hrs. 825°)

LONG.
SPEC.



Tensile-test results in the longitudinal direction for sheet tested before and after exposure.

AM350 (SCT condition)

Conditions of prior exposure
- ○ Unexposed
- ▲ 2000 hrs., 550°F, 67 ksi
- ▼ 5000 hrs., 550°F, 67 ksi
- ■ 200 hrs., 700°F, 67 ksi

Alloy Designation: AM350 CEVM-CRT Contributor: NASA Lewis Research Center Data Sheet No.: 1

Heat Treatment: As noted Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
20% Cold Rolled + 950°F, 3 hrs.																			
None			-110	245.7	250.7	167.3	167.0	17.5		17.5		195.5	189.3	0.80	0.75				
None			-110	-----	-----	-----	-----	----		----		195.6	188.9						
650	40	1000	-110	257.7	258.5	173.7	178.4	12.5		18		195.5	187.2	0.76	0.72				
650	40	1000	-110	-----	-----	-----	-----	----		----		198.3	186.6						
None			Room	198.8	205.8	168.0	167.7	19		17		195.0	191.5	0.98	0.93				
None			Room	-----	-----	-----	-----	----		----		193.9	190.4						
650	40	1000	Room	203.3	210.0	172.9	175.0	17.5		18		195.0	189.3	0.96	0.90				
650	40	1000	Room	-----	-----	-----	-----	----		----		196.1	188.2						
None			650	150.5	158.8	130.9	139.2	5.5		2.5		141.7	144.6	0.97	0.87				
None			650	-----	-----	-----	-----	----		----		151.7	132.8						
650	40	1000	650	161.5	166.3	143.2	145.3	6.5		6		134.4	134.3	0.88	0.82				
650	40	1000	650	-----	-----	-----	-----	----		----		150.3	139.2						
20% Cold Rolled + 825°F, 3 hrs.																			
None			-110	277.1	276.7	205.2	202.1	22		22		229.4	216.4	0.83	0.77				
None			-110	-----	-----	-----	-----	----		----		230.2	210.3						
650	40	1000	-110	265.2	266.3	199.0	192.7	20.5		22		216.9	206.7	0.83	0.77				
650	40	1000	-110	-----	-----	-----	-----	----		----		224.0	203.9						
None			Room	223.7	218.6	179.4	171.1	24.5		24.5		218.0	203.4	0.97	0.93				
None			Room	-----	-----	-----	-----	----		----		214.4	203.9						
650	40	1000	Room	224.0	218.3	190.0	180.2	25		25		217.8	205.0	0.97	0.94				
650	40	1000	Room	-----	-----	-----	-----	----		----		217.2	205.0						
None			650	162.2	172.9	141.2	145.8	8		6.5		155.6	147.8	0.94	0.83				
None			650	-----	-----	-----	-----	----		----		149.7	137.8						
650	40	1000	650	168.8	172.9	143.2	148.4	8.5		7		155.4	148.0	0.93	0.84				
650	40	1000	650	-----	-----	-----	-----	----		----		157.8	142.7						
30% Cold Rolled + 950°F, 3 hrs.																			
None			-110	249.5	253.8	211.3	210.4	17		16		242.2	227.2	0.97	0.89				
None			-110	-----	-----	-----	-----	----		----		242.2	223.9						
650	40	1000	-110	262.3	264.6	229.2	218.8	17.5		14.5		253.1	216.6	0.95	0.81				
650	40	1000	-110	-----	-----	-----	-----	----		----		247.7	209.4						
None			Room	208.7	215.7	204.1	202.1	16.5		13.5		229.4	217.9	1.09	1.01				
None			Room	-----	-----	-----	-----	----		----		227.2	218.9						
650	40	1000	Room	225.6	229.2	222.7	212.5	14		14		241.1	215.5	1.06	0.92				
650	40	1000	Room	-----	-----	-----	-----	----		----		237.6	207.2						
None			650	181.4	193.8	158.8	162.9	4		3.5		144.2	133.7	0.81	0.69				
None			650	-----	-----	-----	-----	----		----		150.8	133.3						
650	40	1000	650	189.8	196.9	176.5	177.1	3.5		3.5		141.9	122.1	0.78	0.64				
650	40	1000	650	-----	-----	-----	-----	----		----		152.8	128.3						
30% Cold Rolled + 825°F, 3 hrs.																			
None			-110	279.0	280.4	250.5	250.1	21		21.5		272.2	237.2	0.97	0.85				
None			-110	-----	-----	-----	-----	----		----		270.8	238.1						
650	40	1000	-110	276.1	280.0	253.3	246.4	21		20		275.1	230.4	0.99	0.82				
650	40	1000	-110	-----	-----	-----	-----	----		----		273.9	230.4						
None			Room	245.0	243.8	239.0	221.9	20		15		252.8	230.7	1.04	0.94				
None			Room	-----	-----	-----	-----	----		----		260.2	228.6						
650	40	1000	Room	250.7	246.7	241.2	227.1	23		19		257.1	226.5	1.03	0.92				
650	40	1000	Room	-----	-----	-----	-----	----		----		258.1	228.7						
None			650	211.4	218.6	184.4	175.2	5		4.5		165.7	145.2	0.76	0.66				
None			650	-----	-----	-----	-----	----		----		154.7	141.7						
650	40	1000	650	207.1	216.7	183.7	190.1	5		4.5		158.2	153.0	0.75	0.70				
650	40	1000	650	-----	-----	-----	-----	----		----		152.5	149.7						
30% Cold Rolled + 700°F, 3 hrs.																			
None			-110	271.3	272.5	256.3	246.9	24		21		267.4	215.1	1.01	0.86				
None			-110	-----	-----	-----	-----	----		----		278.7	232.0						
650	40	1000	-110	276.3	278.8	270.1	256.3	23		22		269.6	220.6	0.98	0.80				
650	40	1000	-110	-----	-----	-----	-----	----		----		272.1	226.0						
None			Room	242.5	246.7	240.6	228.4	9		9		260.7	233.1	1.07	0.94				
None			Room	-----	-----	-----	-----	----		----		256.7	229.4						
650	40	1000	Room	252.4	251.3	247.4	210.4	11		9		248.6	226.5	0.99	0.89				
650	40	1000	Room	-----	-----	-----	-----	----		----		253.3	219.9						
None			650	211.4	220.8	183.3	178.1	3		3		155.3	128.0	0.71	0.59				
None			650	-----	-----	-----	-----	----		----		146.0	133.0						
650	40	1000	650	211.5	220.8	192.7	174.5	6		5		156.4	138.9	0.76	0.58				
650	40	1000	650	-----	-----	-----	-----	----		----		165.1	117.9						

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified. [c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure[a] Stress ksi	Prior exposure[a] Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
45% Cold Rolled + 825°F, 3 hrs.																			
None			-110	305.8	302.9	287.6	288.5	7		17		301.1	233.0	1.00	0.77				
None			-110	-----	-----	-----	-----	----		----		307.8	233.3						
650	40	1000	-110	294.4	297.7	292.8	284.5	10		13.5		298.9	213.3	1.03	0.72				
650	40	1000	-110	-----	-----	-----	-----	----		----		306.1	213.3						
None			Room	280.0	280.0	274.2	274.1	(e)		3.5		287.2	238.3	0.98	0.82				
None			Room	-----	-----	-----	-----	----		----		262.2	221.7						
650	40	1000	Room	279.2	274.3	274.2	258.2	7		7		278.8	226.0	1.01	0.84				
650	40	1000	Room	-----	-----	-----	-----	----		----		283.5	235.8						
None			650	237.5	246.3	219.7	208.3	4		4		154.4	150.0	0.66	0.61				
None			650	-----	-----	-----	-----	----		----		157.3	149.4						
650	40	1000	650	239.6	245.4	229.2	209.3	4		4		140.9	136.7	0.57	0.54				
650	40	1000	650	-----	-----	-----	-----	----		----		133.3	127.8						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Broke outside gauge marks

Alloy Designation: AM350 Contributor: Materials Research Laboratory, Inc. Data Sheet No.: 2
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES AFTER SALT EXPOSURES[e]

Prior exposure[a] Temp. °F	Prior exposure[a] Stress ksi	Prior exposure[a] Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
20% Cold Rolled + 950°F, 3 hrs.																			
650	40	1000	-110									219.0	187.2						
650	40	1000	-110									197.8	186.6						
650	60	1000	-110									195.2	181.2						
650	40	1000	Room									187.9	198.0						
650	40	1000	Room									188.0	181.0						
650	60	1000	Room									223.0	191.5						
650	40	1000	650									166.0	152.0						
650	40	1000	650									152.9	133.2						
650	60	1000	650									151.8	130.3						
20% Cold Rolled + 825°F, 3 hrs.																			
650	40	1000	-110									224.0	197.2						
650	40	1000	-110									219.5	206.0						
650	60	1000	-110									223.0	209.9						
650	40	1000	Room									212.9	204.4						
650	40	1000	Room									212.0	205.0						
650	60	1000	Room									215.0	201.0						
650	40	1000	650									160.0	152.0						
650	40	1000	650									172.9	148.8						
650	60	1000	650									166.1	143.3						
45% Cold Rolled + 950°F, 3 hrs.																			
650	40	1000	-110									302	222.0						
650	40	1000	Room									251.4	228.7						
650	40	1000	650									161.6	124.9						
45% Cold Rolled + 825°F, 3 hrs.																			
650	40	1000	-110									295	212						
650	40	1000	Room									281.6	221.0						
650	40	1000	650									146.3	129.2						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Exposed with a solid coating of natural sea salt.

Alloy Designation: AM-350 Contributor: The University of Michigan (ASD sponsored) Data Sheet No.: 3
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches[e]				Edge notches, K_t = 3			
				Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S		Tensile strength, ksi		Strength ratio, N/S	
Temp. °F	Stress ksi	Time, hr.		L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
1710°F, 5-10 min., AC + -100°F, 3 hrs, + 850°F, 3 hrs., AC (SCT Condition)																			
None			Room	214.9	-----	185.3	-----	17		----		216.0	----		----	241.5	-----		
None			Room	213.1	-----	178.0	-----	12		----		208.3	----	} 0.99	----	-----	-----	}1.13	----
None			Room	214.0	-----	176.0	-----	16.5		----		-----	----		----	-----	-----		
550	67	2000	Room	-----	-----	-----	-----	----		----		-----	-----	----	----	238.8	-----	}1.12	----
550	67	2236	Room	212.0	-----	179.0	-----	18		----		-----	-----	----	----	237.5	-----		
550	67	5000	Room	216.0	-----	176.0	-----	13.5		----		-----	-----	----	----	238.5	-----	1.10	----
700	67	200	Room	-----	-----	-----	-----	----		----		208.8	-----	----	----	-----	-----	----	----
None			550	193.6	-----	135.0	-----	5		----		159.3	-----	} 0.82	----	210.0	-----	}1.08	----
None			550	194.4	-----	141.0	-----	6.5		----		159.0	-----			-----	-----		
550	0	2236	550	199.5	-----	142.0	-----	7.5		----		-----	-----	----	----	-----	-----	----	----
550	67	2000	550	195.9	-----	150.0	-----	8.5		----		159.2	-----	} 0.81	----	-----	-----	}1.04	----
550	67	2236	550	199.0	-----	147.5	-----	7.5		----		-----	-----			206.1	-----		
550	67	5000	550	193.5	-----	145.0	-----	4.5		----		-----	-----	----	----	208.0	-----	1.07	----
600	67	2000	550	198.5	-----	145.5	-----	5.5		----		-----	-----	----	----	-----	-----	----	----
650	67	200	550	195.8	-----	140.0	-----	6		----		-----	-----	----	----	-----	-----	----	----
700	67	20	550	200.3	-----	146.0	-----	5.5		----		-----	-----	----	----	-----	-----	----	----
700	67	200	550	201.2	-----	151.5	-----	6		----		163.0	----	0.81	----	-----	-----	----	----
Cold rolled 20% + 850°F, 3 hrs.																			
None			Room	218.5	-----	185.5	-----	28		----		214.0	-----		----	225.5	-----		
None			Room	217.0	-----	191.0	-----	16.5		----		215.1	-----	} 0.98	----	-----	-----	1.03	----
None			Room	224.2	-----	182.0	-----	23.5		----		-----	-----		----	-----	-----		
550	40	2000	Room	212.5	-----	178.0	-----	21		----		-----	-----	----	----	-----	-----	----	----
550	67	2000	Room	-----	-----	-----	-----	----		----		212.0	-----	----	----	220.0	-----	----	----
550	67	5000	Room	222.2	-----	185.5	-----	19		----		-----	-----	----	----	223.8	-----	1.01	----
550	90	2000	Room	221.4	-----	186.0	-----	16.5		----		-----	-----	----	----	-----	-----	----	----
550	150	2000	Room	221.1	-----	(208.0)	-----	19.5		----		-----	-----	----	----	-----	-----	----	----
700	67	200	Room	-----	-----	-----	-----	----		----		209.8	-----	----	----	-----	-----	----	----
None			550	169.0	-----	153.0	-----	4		----		172.1	-----	} 1.00	----	185.0	-----	}1.10	----
None			550	168.8	-----	153.5	-----	4.5		----		166.8	-----			-----	-----		
550	67	2000	550	163.5	-----	141.0	-----	2		----		160.0	-----	0.98	----	178.2	-----	1.09	----
550	67	5000	550	168.6	-----	151.0	-----	2		----		170.5	-----	1.01	----	181.8	-----	1.08	----
600	67	2000	550	172.0	-----	153.0	-----	5		----		-----	-----	----	----	-----	-----	----	----
650	67	200	550	170.8	-----	154.0	-----	4		----		-----	-----	----	----	-----	-----	----	----
700	67	20	550	170.7	-----	145.0	-----	4		----		-----	-----	----	----	-----	-----	----	----
700	67	200	550	188.0	-----	152.5	-----	4.5		----		>151.0[f]	-----	----	----	-----	-----	----	----

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Sharp edge notches added after exposures. f - Specimen shoulder tore; no fracture at the notch.

Alloy Designation: AM350 Contributor: The University of Michigan (NASA sponsored) Data Sheet No.: 4
Heat Treatment: 23% Cold rolled + 850°F, 3 hrs. Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
				Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
Temp. °F	Stress ksi	Time, hr.		L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			-110	252	250	214	194	26		21	1.75	236	215	0.94	0.86				
None			Room	199	205	164	174	23		20	1.75	217	204	1.09	1.00				
650	40	1000	Room	199	207	188	176	22		17	1.75	216	201	1.08	0.97				
None			650	174	176	148	141	6		4.3	1.75	162	156	0.93	0.89				
650	40	1000	650	171	178	151	144	6		3.5	1.75	166	152	0.97	0.85				
None			800	160	169	130	126	8.0		6.0	1.75	154	141	0.96	0.84				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation

Alloy Designation: AM350 Contributor: Joliet Metallurgical Laboratories, Inc. Data Sheet No.: 5

Heat Treatment: 1950°F mill anneal + 15 min. at 1710°F, AC + 3 hrs. at -100°F + 3 hrs. at 850°F (SCT Condition) Sheet Thickness, inches 0.064

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			Room	210.2		181.8		9.8											
650	180	1220	Room	245.5		245		2.5											
650	184	669	Room	243		242		1.5											
650	184	816	Room	242		240		2.5											
650	185	1488	Room	246.5		246		1.5											
650	186	1320	Room	249		248.5		2.5											
800	130	550	Room	232		228.5		4.0											
800	140	694	Room	234.5		233.5		4.0											
800	150	296	Room	234.5		234		2.5											
800	160	222.6	Room	240		238.5		2.0											
None			800	185.1		115.7		7.5											
None			800	185.2		119.2		8.5											
None			800	181.7		121.9		7.0											

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation

Alloy Designation: AM350 M Alloy Contributor: North American Aviation, Inc. Data Sheet No.: 6

Heat Treatment: Brazed at 1900°F and cooled to room temperature + heat to 1700°F and cool to -100°F + age at 850°F for 3 hours and air cool. Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES[d]

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens					Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi	Yield strength,[b] ksi	Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S				
									L	T	L	T	L	T	L	T
None			Room	203	165.0	13.1										
None			Room	201	170.0	13.0										
None			Room	207	167.0	12.5										

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]Test direction not stated

STRESS-CORROSION TESTS

Cantilever beam tests at 650°F in circulating air furnace.

Salt coated by dipping in hot concentrated 6 parts NaCl + 1 part $MgCl_2$ and drying.

Smooth and Notched Specimens Tested - 60°V-notches, 0.010-inch deep with 0.005-inch root radius, machined across flat surface at point of maximum stress and at a point of very low stress.

Test Condition	Maximum Stresses: Smooth (ksi)	Maximum Stresses: Notched (ksi)	Fracture Time (hours)	Surface Condition at 4700 Hours
Bare Surface - continuously exposed	58.3, 59.0, 59.1	160.3, 159.4	a	Slight bluing
Salt Coated - continuously exposed(b)	55.9, 55.0, 58.1	152.8, 148.4	a	Gold to brown color - rust spots on 20 to 50% of surface
Braze Coated - continuously exposed	49.9, 51.1, 51.0	136.7, 129.3	a	Slight darkening
Braze + Salt Coated - continuously exposed	51.6, 50.8, 52.1	129.5, 136.0	a	No comment
Salt Coated - 2 weeks at 650°F + 2 weeks in humidity cabinet at 100°F intermittently	57.1	------------	3360	Surface heavily rusted and two specimens had cracks other than failure
	57.2	------------	3290	
	57.0	------------	3290	
	56.3	------------	2880	

(a) Unbroken at 4700 hours
(b) Salt coating appeared spotty at 4700 hours

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Alloy Designation: AM350 | Contributor: Douglas Aircraft Company, Inc., Aircraft Division | Data Sheet No.: 7

Heat Treatment: SCT 850°F | Sheet Thickness, inches:

TEAR-TEST DATA (All in the transverse direction)

Width of Panel (inches)	Thickness of Panel (inches)	Gross Area (sq. in.)	Initial Length of Notch Plus Crack (inches)	Net Area (sq. in.)	Failure Load (pounds)	Gross Failure Stress (psi)	Average Gross Failure Stress (psi)	Ratio: Average Gross Failure Stress - Ultimate Tensile Strength	Ratio: Initial Crack Length - Panel Width
8.00	0.0655	0.524	2.450	0.3635	41,000	78,200			
8.00	0.0650	0.520	2.450	0.3608	42,000	80,800	81,000	0.37	0.31
8.00	0.0655	0.524	2.450	0.3635	44,000	84,000			
8.00	0.0655	0.524	2.450	0.3635	41,500	79,200			
8.00	0.0650	0.520	2.450	0.3608	43,000	82,700	80,400	0.37	0.31
8.00	0.0655	0.524	2.450	0.3635	41,500	79,200			

TENSILE PROPERTIES

F_{tu} = 216,300 psi ; F_{ty} = 183,100 psi ; E = 10.1 %

Alloy Designation: AM350 SCT | Contributor: The Boeing Company, Transport Division | Data Sheet No.: 8

Heat Treatment: | Sheet Thickness, inches: 0.020

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength, ksi T	Elong.[c] % L	Red. Area % L	Elong. % T	Red. Area % T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
None			-65	234.0	232.0	207.0	206.0	10.0	23	9.5	--								
				234.0	230.0	205.0	205.0	9.5	23	9.5	18								
				235.0	230.0	207.0	205.0	10.0	22	8.0	19								
None			Room	217.5	204.4	189.2	173.2	12	19.7	15	25.9								
				219.1	203.6	190.3	170.2	10	21.7	14	24.1								
				217.5	203.9	188.3	171.1	12	22.4	14	23.2								
None			300	197.0	196.0	161.0	158.0	8	19	8.5	17								
				198.0	197.0	162.0	158.0	8	18	8	19								
				199.0	197.0	163.0	161.0	8.5	17	8.5	18								
None			400	195.0	195.0	153.0	154.0	8	10	7.5	10								
				198.0	195.0	155.0	152.0	8	12	8	11								
				195.0	195.0	153.0	156.0	7.5	10	8.5	10								
None			500	182.0	185.0	134.0	142.0	8.5	14	8	12								
				182.0	186.0	139.0	142.0	8.5	13	8.5	13								
				183.0	184.0	141.0	140.0	9	15	9	15								

Notes: The test specimens were cut from the broken halves of the tear-test specimens, tested at the same temperature as the tensile test.

Reduction of area values are very approximate.

TEAR TEST DATA ON SPECIMENS WITH MACHINED CENTER NOTCHES

				Specimen Dimensions length (in.)	width (in.)	thickness (in.)	Critical Crack Length (in.)	Failure Load (lbs.)	Gross Section Strength (ksi)	Net Section Strength (ksi)	k x 10^{-3} ($\sigma_G\sqrt{a}$ a)	$\Delta\sigma_G/\Delta t$ x 10^{-3}	G_c	σ_{ns}/σ_u	
None			-65	14 L	24.0	0.0205	8.00	14,980	30.5	45.75	65.3	1070	445		
None			-65	14 L	24.0	0.0209	8.00	17,550	35.0	52.5	75.0	750	589		
None			Room	39 L	24.15	0.0208	8.00	31,200(5)	62.2	92.8	133.0	808	1850		
None			Room	39 L	24.15	0.0206	8.00	33,450	67.4	100.8	144.0	966	2170		
None			300	14 L	24.0	0.0205	8.00	30,980	63.0	94.5	135.0	955	1905		
None			300	14 L	24.0	0.0208	8.00	35,000	70.0	105.0	150.0	1000	2350		
None			400	14 L	24.0	0.0205	8.00	32,950	67.0	100.5	143.3	880	2150		
None			400	14 L	24.0	0.0205	8.00	35,300	71.7	107.5	153.5	960	2470		
None			500	14 L	24.0	0.0205	8.00	30,410	61.7	92.5	132.0	1062	1820		
None			500	14 L	24.0	0.0201	8.00	34,700	72.0	108.0	154.0	985	2480		

Notes:

1) Notches were at the center and were 8.00 inches long transverse to testing direction. Complete notch for room temperature tests was 0.005-inch wide. For all other tests, the notch was 0.030-inch wide except for the last 0.250 inch at each end which was 0.005-inch wide.
2) All G_c values based on E = 30 x 10^6 psi.
3) The a in k = $\sigma_G\sqrt{a}$ a is Irwin's correction factor for axial rigidity of panel.
4) $\Delta\sigma_G/\Delta t$ was calculated from slope of load versus time curve.
5) Accuracy of load measurement ±10 percent.
6) Specimen length is the distance between grips.

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified. [c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation

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Alloy Designation: AM350 CRT   Contributor: The Boeing Company, Transport Division   Data Sheet No.: 9
Heat Treatment: Sheet Thickness, inches 0.020

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	Red. Area % L	Elong. % T	Red. Area % T	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T
None			Room	213.8	218.5	209.4	195.2	26	23	20	23				
None			Room	214.4	218.6	209.9	198.0	23	25	20	22				
None			Room	211.4	220.8	207.8	193.8	27	25	24	22				
None			Room	212.9	218.5	200.4	189.5	20		20.5					
None			Room	212.5	217.7	197.1	188.9	21		20					
None			Room	212.5	216.1	198.5	186.6	21		19.5					
None			500	181.3	181.9	169.8	156.6	2.5		2.5					
None			500	182.3	183.3	169.2	157.1	3		2.5					
None			500	182.9	179.8	168.7	157.5	3		3					

Notes: The test specimens were cut from the broken halves of the tear test specimens tested at the same temperature as the tensile tests.
Reduction of area values are very approximate.

TEAR TEST DATA ON SPECIMENS WITH MACHINED CENTER NOTCHES

				Specimen Dimensions length (in.)	width (in.)	thickness (in.)	Critical Crack Length (in.)	Failure Load (lbs.)	Gross Section Strength (ksi)	Net Section Strength (ksi)	$k \times 10^{-3}$ $(\sigma_G \sqrt{a\,\alpha})$	$\Delta\sigma_G/\Delta t \times 10^{-3}$	G_c
None			-65	14L	24.0	0.0205	8.60	39,970	81.3	126.5	182.5	900	3480
None			-65	14L	24.0	0.0206	8.80	43,000	86.0	137.0	196.5	250	4040
None			Room	39L	23.98	0.0208	8.50	31,200(5)	62.6	97.0	139.5	895	2010
None			Room	39L	24.00	0.0208	8.56	37,500	75.2	116.9	168.0	915	2960
None			300	14L	24.0	0.0205	8.00	28,450	57.8	86.6	123.7	1020	1600
None			300	14L	24.0	0.0208	8.00	30,300	60.6	90.9	130.0	910	1765
None			400	14L	24.0	0.0205	8.00	26,270	53.5	80.2	114.3	955	1365
None			400	14L	24.0	0.0205	8.00	27,700	56.2	84.3	120.0	965	1510
None			500	14L	24.0	0.0205	8.00	23,040	46.8	70.1	100.0	1000	1040
None			500	14L	24.0	0.0208	8.00	22,600	45.1	67.6	96.5	910	975
None			Room	14T	24.0	0.021	8.00	28,900	57.4	86.0	123.0	885	1585
None			Room	14T	24.0	0.021	8.00	29,300	58.1	87.1	124.3	950	1620
None			500	14T	24.0	0.0205	8.00	21,300	43.3	65.0	92.5	890	895
None			500	14T	24.0	0.0205	8.00	21,100	42.9	66.4	91.8	823	880
None			500	14L	24.0	0.0205	8.00	25,400	51.7	77.5	110.5	890	1275
None			500	14L	24.0	0.0205	8.00	26,000	53.0	79.5	113.0	890	1335

Notes:
1) Notches were at the center and were 8.00 inches long transverse to testing direction. Complete notch for room temperature tests was 0.005-inch wide. For all other tests, the notch was 0.030-inch wide except for the last 0.250 inch at each end which was 0.005-inch wide.
2) All G_c values based on $E = 30 \times 10^6$ psi.
3) The α in $k = \sigma_G \sqrt{a\,\alpha}$ is Irwin's correction factor for axial rigidity of panel.
4) $\Delta\sigma_G/\Delta t$ was calculated from slope of load versus time curve.
5) Accuracy of load measurement ±10 percent.
6) Specimen length is the distance between grips.

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation

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Alloy Designation: AM 350 Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 10
Heat Treatment: As noted below Sheet Thickness, inches

TEAR-TEST DATA

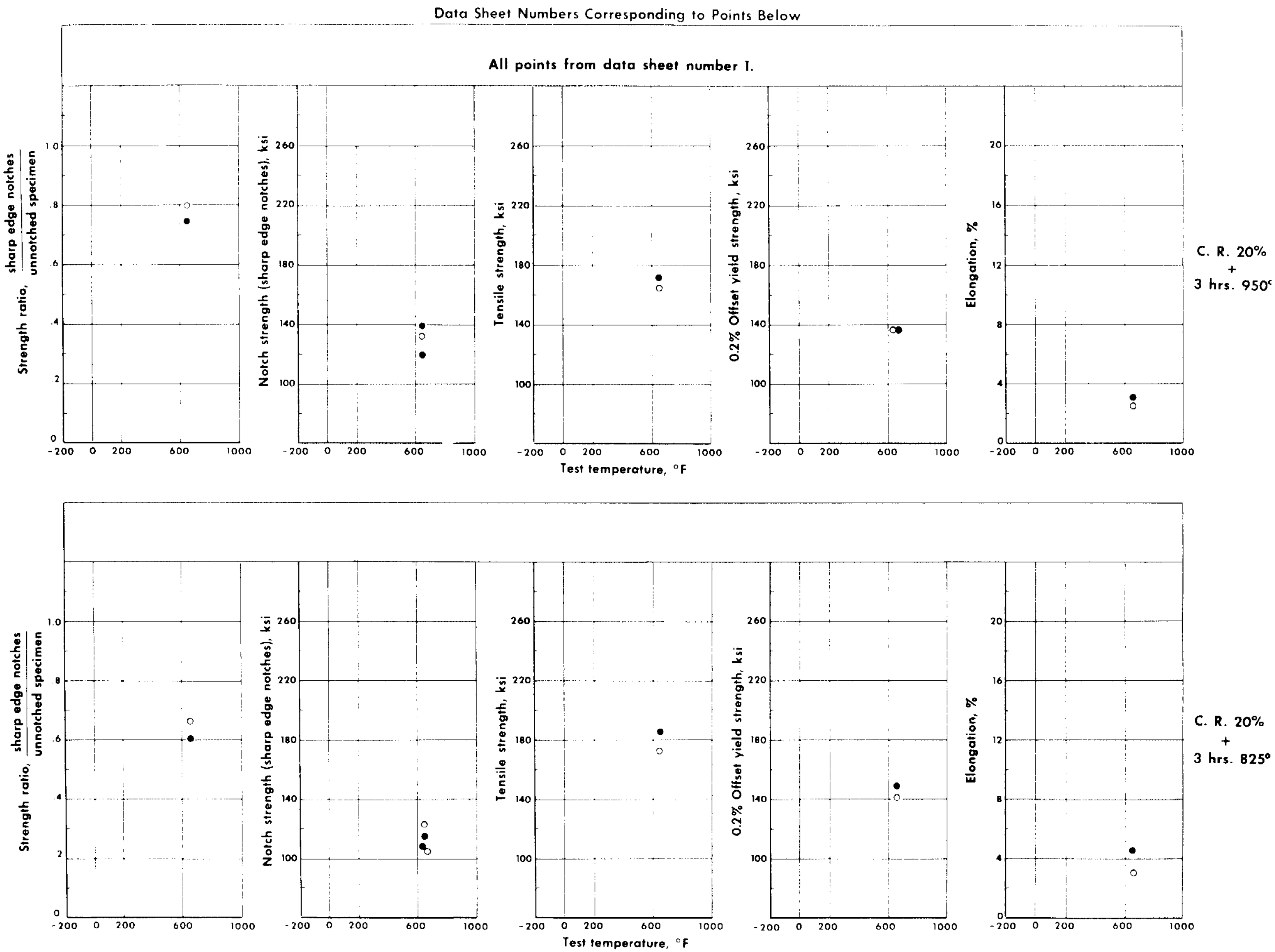
Test Temp. (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data				Control Coupon Data		
				Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
AM350 CRT (3 hrs. at 650°F)										
-65	T	0.0204	8.99	19200	104.9	1.89	1142			
-65	T	0.0204	8.98	12700	69.4	2.92	834			
Room	T	0.0201	9.00	19800	109.7	1.67	1086	184.9	217.5	17
Room	T	0.0201	8.99	13700	75.8	2.66	884			
600	T	0.0201	8.98	9700	53.7	1.42	262	154.2	179.4	4.1
600	T	0.0202	9.00	7470	41.1	2.57	298			
AM350 CRT (3 hrs. at 850°F)										
Room	L	0.0190	9.01	22500	131.4	1.83	1790	207	219	19
Room	L	0.0190	8.99	16000	93.6	2.91	1560			
Room	T	0.0190	9.01	17100	99.9	1.82	1028	189	223	16
Room	T	0.0190	9.00	11700	68.4	2.90	834			
600	L	0.0190	9.00	11500	67.2	2.03	525	147.9	200.7	3.6
600	L	0.0190	8.99	7910	46.3	2.69	345			
600	T	0.0190	9.01	8240	47.9	1.92	250	151.3	201.2	3.2
600	T	0.0190	8.99	6060	35.5	2.75	204			
AM350 CRT (3 hrs. at 1050°F)										
Room	T	0.0206	8.99	15400	83.2	1.86	707	125.1	209.6	9.5
Room	T	0.0207	8.99	15800	84.9	1.67	645			
Room	T	0.0206	8.99	15200	82.1	1.76	648			
Room	T	0.0164	9.02	10300	69.6	2.78	787			
Room	T	0.0169	8.99	9800	64.5	2.70	653			
Room	T	0.0164	8.99	9900	67.2	2.80	741			

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Lewis Research Center, NASA	Allegheny Ludlum	W23299-5
3	Boeing Company, Transport Div.	Allegheny Ludlum	--------
4	Lockheed Aircraft Corp., Calif.	Allegheny Ludlum	84137
		" "	35781

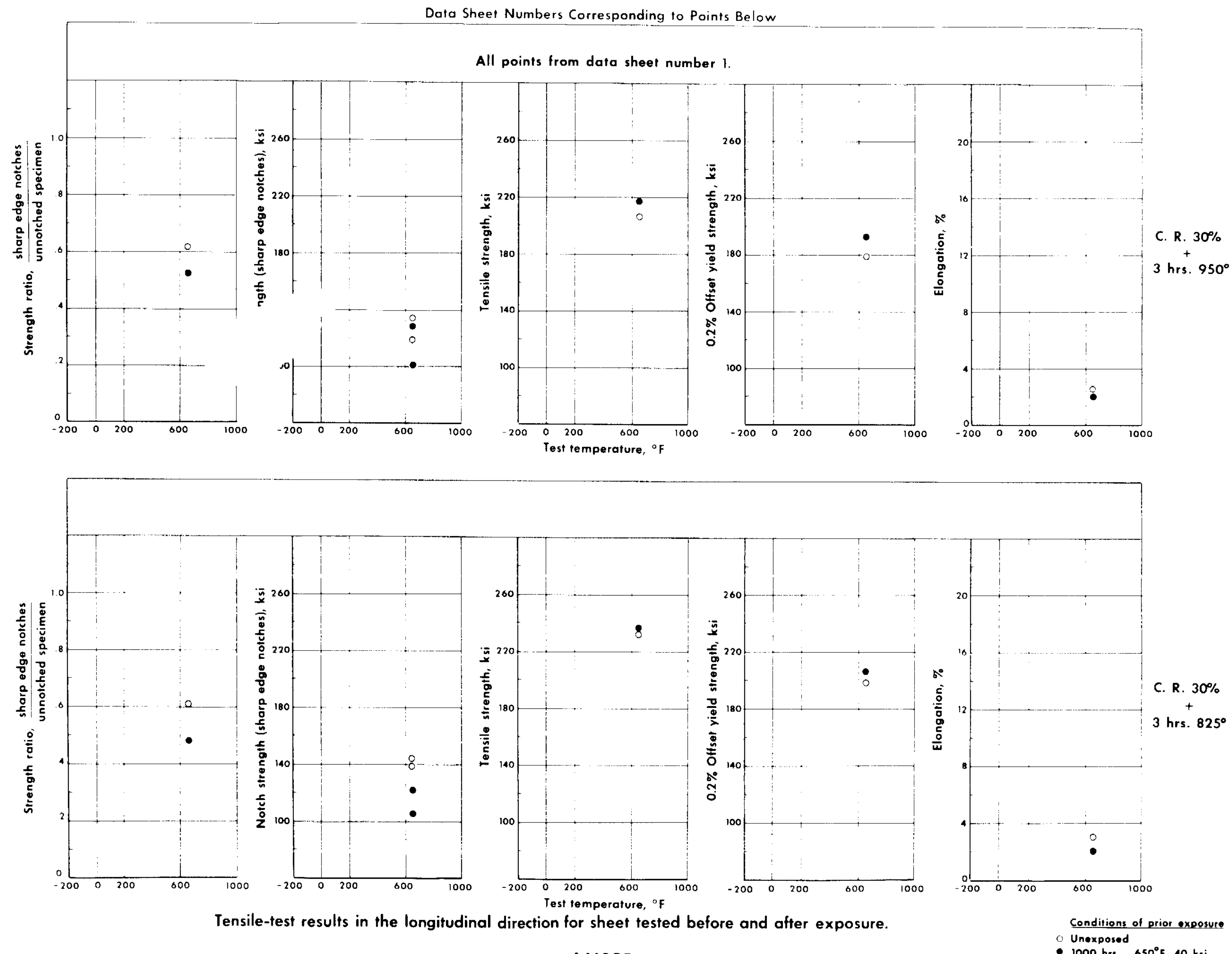
Composition, percent

Data Sheet	Cr	Mn	Mo	Ni	Si	Fe	C	P	S	N
1	15.22	0.99	2.70	4.29	0.34	Bal	0.128	0.025	0.003	0.082
(84137) 4	15.96	0.74	2.76	4.20	0.33	Bal	0.13	0.021	0.014	
(35781) 4	15.41	0.85	2.73	4.24	0.49	Bal	0.13	0.024	0.011	
3	15.18	0.79	2.88	4.11	0.23	Bal	0.14	0.022	0.015	0.11



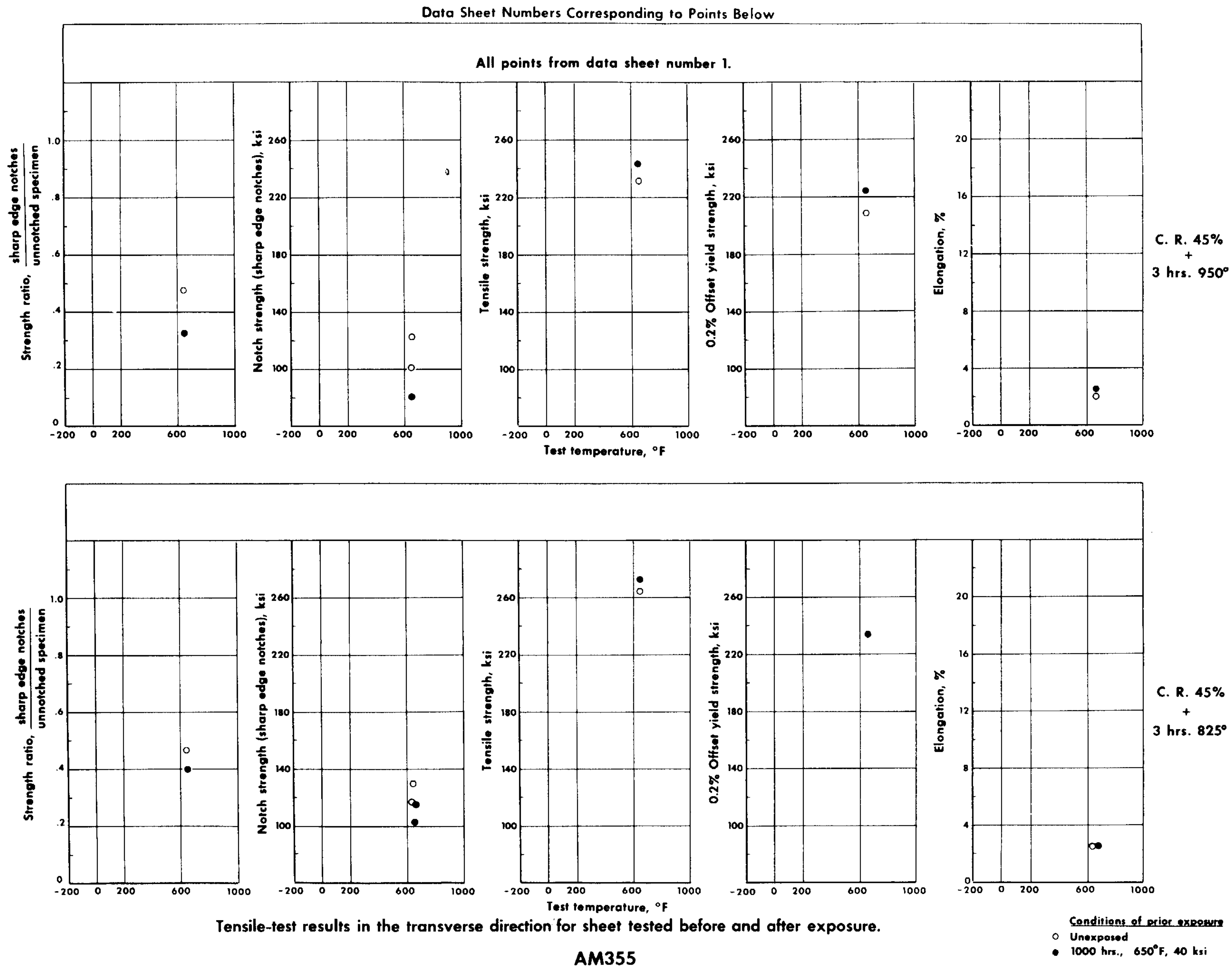
Tensile-test results in the longitudinal direction for sheet tested before and after exposure.

AM355



Tensile-test results in the longitudinal direction for sheet tested before and after exposure.

AM355



Tensile-test results in the transverse direction for sheet tested before and after exposure.

AM355

Alloy Designation: AM355 CEVM-CRT Contributor: NASA Lewis Research Center Data Sheet No.: 1

Heat Treatment: As noted Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure[a] Stress ksi	Prior exposure[a] Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % (L)	G.L., in. (L)	Elong. % (T)	G.L., in. (T)	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
				Cold rolled 20% + 950°F, 3 hrs.															
None			650	-----	165.0	-----	137.0	----		2.5		-----	132.0	----	0.80				
650	40	1000	650	-----	172.0	-----	137.0	----		3		-----	139.0	} ----	0.75				
650	40	1000	650	-----	-----	-----	-----	----		----		-----	120.0						
				Cold rolled 20% + 825°F, 3 hrs.															
None			650	-----	173.0	-----	141.0	----		3		-----	105.0	} ----	0.66				
None			650	-----	-----	-----	-----	----		----		-----	122.6						
650	40	1000	650	-----	186.0	-----	149.0	----		4.5		-----	107.6	} ----	0.60				
650	40	1000	650	-----	-----	-----	-----	----		----		-----	114.2						
				Cold rolled 30% + 950°F, 3 hrs.															
None			650		207.0		179.0			2.5			135.0	} ----	0.62				
None			650		-----		-----			----			119.7						
650	40	1000	650		218.0		192.5			2			129.0	} ----	0.53				
650	40	1000	650		-----		-----			----			101.0						
				Cold rolled 30% + 825°F, 3 hrs.															
None			650		232.0		198.0			3			144.3	} ----	0.61				
None			650		-----		-----			----			139.0						
650	40	1000	650		237.0		207			2			105.3	} ----	0.48				
650	40	1000	650		-----		-----			----			122.7						
				Cold rolled 45% + 950°F, 3 hrs.															
None			650		232.0		209.0			2			101.8	} ----	0.48				
None			650		-----		-----			----			122.7						
650	40	1000	650		244.0		224.0			2.5			81.4	----	0.33				
				Cold rolled 45% + 825°F, 3 hrs.															
None			650		265.0		(e)			2.5			117.2	} ----	0.47				
None			650		-----		-----			----			129.8						
650	40	1000	650		273.0		234.0			2.5			102.8	} ----	0.40				
650	40	1000	650		-----		-----			----			116.0						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Extensometer did not function

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Alloy Designation: AM355 CRT　　Contributor: The Boeing Company, Transport Division　　Data Sheet No.: 3
Heat Treatment: 　　Sheet Thickness, inches 0.020

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	Red. Area %	Elong. %	Red. Area %	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L	L	T	T	L	T	L	T	L	T	L	T
None			Room	240.8	250.0	227.7	198.5	15	20	20	20								
None			Room	237.9	245.6	220.9	196.6	21	21	13	13								
None			Room	240.2	246.2	223.0	196.6	21	21	16	13								
None			Room	235.5	241.0	217.0	191.0	17.5		12.5									
None			Room	230.0	240.0	217.0	190.5	17		12.5									
None			Room	231.5	238.0	215.0	192.5	17		12.5									
None			500	198.6	204.8	181.0	160.5	2.5		3									
None			500	198.0	199.0	184.0	175.0	2.5		3									
None			500	199.0	204.3	186.5	173.8	3		2.5									
None			-65	248.0	255.0	-----	200.0	18	17	17	19								
None			-65	253.0	253.0	214.0	200.0	19	16	17.5	20								
None			-65	259.0	260.0	240.0	197.0	20	18	----									
None			300	190.0	193.0	185.0	172.0	5.5	10	3	6								
None			300	190.0	195.0	-----	173.0	5.5	11	3.5	5								
None			300	190.0	194.0	181.0	171.0	8.0	10	4	6								
None			400	182.0	188.0	173.0	166.0	4	7	3.5	6								
None			400	182.0	188.0	174.0	167.0	4	8	4	7								
None			400	182.0	188.0	174.0	167.0	4.5	8	3.5	7								
None			500	178.0	185.0	166.0	160.0	3.5	6	3	6								
None			500	178.0	184.0	167.0	157.0	3.5	6	3.5	6								
None			500	178.0	184.0	165.0	159.0	4	6	3.5	6								

Notes: The test specimens were cut from the broken halves of the tear test specimens tested at the same temperature as the tensile tests
Reduction of area values are very approximate

TEAR TEST DATA ON SPECIMENS WITH MACHINED CENTER NOTCHES

Prior exposure[a]			Test Temp. °F	Specimen Dimensions			Critical Crack Length (in.)	Failure Load (lbs.)	Gross Section Strength (ksi)	Net Section Strength (ksi)	$k \times 10^3$ ($\sigma_G \sqrt{a\alpha}$)	$\Delta\sigma_G/\Delta t \times 10^3$	G_c
Temp °F	Stress ksi	Time, hr.		length (in.)	width (in.)	thickness (in.)							
None			Room	39L	24.00	0.020	8.40	32,600	68.0	104.5	150.5	750	2360
None			Room	39L	24.00	0.020	8.40	32,600	68.0	104.5	150.5	800	2360
None			Room	14T	24.0	0.020	8.00	32,400	67.5	101.0	144.5	915	2190
None			Room	14T	24.0	0.020	8.00	33,900	70.6	106.0	151.0	900	2390
None			500	14T	24.0	0.020	8.00	17,600	36.6	54.9	78.3	780	642
None			500	14T	24.0	0.020	8.00	17,700	36.8	55.2	78.8	660	650
None			500	14L	24.0	0.020	8.00	21,600	45.0	67.5	96.2	760	967
None			500	14L	24.0	0.020	8.00	20,700	43.1	64.6	92.3	880	891

Series of Tests at Room Temperature to Show Effect of Strain Rate on Tear Resistance
(24-inch wide x 39-inch between grips x 0.020-inch thick specimens tested in longitudinal direction)

Approx. Time To Failure (seconds)	Yield Zone width (in.)	α Factor	Critical Crack Length (in.)	Failure Load (lbs.)	Gross Section Strength (ksi)	Net Section Strength (ksi)	$k \times 10^3$ ($\sigma_G \sqrt{a\alpha}$)	$\Delta\sigma_G/\Delta t$ $\times 10^3$	G_c
0.20	0.09	1.074	8.2	35,000	73.0	110.0	158.5	365	2630
0.41	0.10	1.080	8.5	37,200	77.5	120.0	173.0	189	3120
1.5	0.13	1.092	9.0	39,200	81.6	130.0	190.0	54.5	3770
1.60	0.14	1.088	8.8	40,700	84.7	133.0	193.0	53.0	3900
3.55	0.15	1.092	9.0	42,200	88.0	140.0	204.0	24.8	4365
12.4	0.20	1.103	9.4	42,900	89.4	147.0	214.0	9.2	4790
24.0	0.21	1.103	9.4	41,200	85.7	139.0	205.0	3.57	4400
200	0.36	1.110	9.6	39,350	84.0	137.0	204.0	0.42	4365*

* Test conducted in static tensile machine

Comments: [a]Conditions of exposure, if any, between heat treatment and testing.
[b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]L = longitudinal orientation T = transverse orientation

Alloy Designation AM355 Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No. 4
Heat Treatment: As noted below Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	Control Coupon Data F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
AM355 SCT (3 hrs. at 850°F)										
-65	T	0.0202	9.06	6400	35.0	1.27	86	206.6	235.8	3.7
-65	T	0.0193	9.06	4880	27.9	2.34	106			
Room	T	0.0186	9.07	13340	79.1	1.65	578	186.1	223.6	7
Room	T	0.0203	9.05	10080	54.9	2.61	469			
600	T	0.0187	9.07	12440	73.3	2.01	640	149.3	207.7	3.7
600	T	0.0194	9.00	9600	55.0	3.28	655			
AM355 SCT (3 hrs. at 1075°F)										
-65	T	0.0192	9.04	16450	94.8	1.69	855	140.4	195.9	9.1
-65	T	0.0200	9.05	12850	71.0	2.78	844			
Room	T	0.0199	9.02	16500	91.9	1.81	865	137.8	181.7	8.5
Room	T	0.0213	9.02	12420	64.6	3.23	855			
600	T	0.0199	9.03	13480	75.0	1.61	524	126.1	154.6	3.8
600	T	0.0198	9.03	8640	48.3	2.98	443			
AM355 SCCRT (3 hrs. at 1075°F)										
-65	T	0.0222	9.07	5500	27.3	1.13	46	299.7	310.9	2.5
Room	T	0.0210	9.00	10440	55.2	1.35	228	277.5	290.1	1.9
Room	T	0.0218	9.02	5800	29.5	2.26	115			
600	T	0.0213	9.02	13560	70.6	1.54	444	232.9	268.7	2.0
600	T	0.0218	9.03	9240	47.0	2.80	387			
AM355 CRT (3 min. at 850°F)										
Room	T	0.0102	9.00	8900	96.9	1.77	972	173.8	250.7	14
AM355 CRT (3 hrs. at 850°F)										
Room	T	0.0102	9.00	8400	91.5	1.81	886	181.5	255.0	14
AM355 CRT (3 hrs. at 1050°F)										
Room	T	0.0101	9.02	6680	73.4	1.79	546	140.3	224.6	6
Room	T	0.0102	9.00	4420	48.1	2.91	426			

AM-367

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Allegheny Ludlum Steel Corp.	Allegheny Ludlum	23932
2	Allegheny Ludlum Steel Corp.	Allegheny Ludlum	"
3	Allegheny Ludlum Steel Corp.	Allegheny Ludlum	"

Composition, percent

Data Sheet	C	Mn	P	S	Si	Cr
1,2,3	0.021	0.024	0.002	0.009	0.08	14.25

Ni	Co	Mo	Ti	Al	Fe
3.40	15.44	1.99	0.35	0.03	Bal

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Alloy Designation: AM-367 Contributor: Allegheny Ludlum Steel Corporation Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	Maraging Conditions: Temperature, °F	Time, hours
Annealed 7 min. at 1400°F + Refrigerated 16 hrs. at -100°F + Maraged as indicated																	
None			-100	261.9	-----	261.5	-----	3.0		---	---	242.6	-----	0.93	----	800	24
None			-100	261.9	-----	261.0	-----	3.0		---	---	249.0	-----	0.95	----	850	8
None			-100	269.7	-----	266.3	-----	4.0		---	---	237.0	-----	0.88	----	850	16
None			-100	276.4	-----	273.5	-----	3.0		---	---	249.2	-----	0.90	----	850	24
None			-100	263.3	284.7	260.0	273.3	3.6		1.8		241.0	223.4	0.92	0.78	950	8
None			Room	163.7	172.8	116.6	123.0	5.8		5.8		-----	-----	-----	----	---	--
None			Room	245.2	-----	242.3	-----	3.5		---	---	226.2	-----	0.92	----	800	24
None			Room	245.7	-----	242.3	-----	3.0		---	---	221.5	-----	0.89	----	850	8
None			Room	256.4[f]	-----	254.9	-----	4.5		---	---	225.0	-----		----	850	8
650	40	500	Room	262.9[f]	-----	262.9	-----	3.0		---	---	218.2	-----	0.83	----	850	8
None			Room	248.1	-----	244.3	-----	3.0		---	---	218.1	-----	0.83	----	850	16
None			Room	255.5	-----	245.4	-----	2.5		---	---	217.0	-----	0.86	----	850	24
None			Room	241.0	262.4	241.0	256.7	1.0		1.5		230.8	201.1	0.96	0.77	950	8
Annealed 7 min. at 1500°F + Refrigerated 16 hrs. at -100°F + Maraged as indicated																	
None			-100	250.5	-----	236.0	-----	8.5		---	---	201.9	-----	0.81	----	800	24
None			-100	248.0	-----	237.7	-----	6.9		---	---	230.0	-----	0.93	----	850	8
None			-100	251.4	-----	241.9	-----	9.6		---	---	223.6	-----	0.89	----	850	16
None			-100	261.4	-----	253.2	-----	8.7		---	---	209.0	-----	0.80	----	850	24
None			-100	259.0	265.4	251.9	261.1	8.9		3.4		247.8	239.6	0.91	0.90	950	8
None			Room	152.8	152.6	98.2	100.4	5.8		5.8		-----	-----	----	----	---	--
None			Room	222.9	-----	218.0	-----	6.5		---	---	218.0	-----	0.98	----	800	24
None			Room	223.2	-----	218.4	-----	5.0		---	---	218.0	-----	0.95	----	850	8
None			Room	237.9[f]	-----	232.3	-----	6.0		---	---	220.5	-----		----	850	8
650	40	500	Room	248.0[f, g]	-----	241.5	-----	5.5		---	---	210.2	-----	0.85	----	850	8
None			Room	228.9	-----	225.0	-----	6.5		---	---	227.9	-----	1.00	----	850	16
None			Room	235.8	-----	230.0	-----	6.5		---	---	235.0	-----	1.00	----	850	24
None			Room	235.5	241.0	233.2	236.8	7.5		2.7		231.5	231.3	0.98	0.96	950	8
Annealed 7 min. at 1350°F + Refrigerated 16 hrs. at -100°F + Maraged as indicated																	
None			-100	264.1	282.5	257.8	269.1	3.1		2.2		245.0	236.8	0.93	0.84	950	8
None			Room	168.0	179.8	122.0	127.3	6.2		6.2		-----	-----	----	----	---	--
None			Room	241.2	258.0	243.5	249.0	3.0		1.0		222.6	183.0	0.92	0.71	950	8
Annealed 7 min. at 1600°F + Refrigerated 16 hrs. at -100°F + Maraged as indicated																	
None			-100	252.4	256.9	242.9	249.8	9.3		4.2		197.1	226.3	0.78	0.88	950	8
None			Room	147.2	146.8	94.6	93.6	6.8		6.0		-----	-----	----	----	---	--
None			Room	233.0	238.2	226.8	232.0	9.0		3.1		233.5	227.7	1.00	0.96	950	8
Annealed 7 min. at 1800°F + Refrigerated 16 hrs. at -100°F + Maraged as indicated																	
None			-100	245.7	244.8	225.9	233.9	10.2		8.4		161.6	92.9	0.66	0.38	950	8
None			Room	142.5	139.0	84.8	88.3	6.2		5.5		-----	-----	----	----	---	--
None			Room	220.3	226.4	209.4	221.4	9.0		5.0		230.3	209.5	1.05	0.93	950	8
Annealed 7 min. at 2000°F + Refrigerated 16 hrs. at -100°F + Maraged as indicated																	
None			-100	230.4	234.3	217.6	223.0	8.5		5.3		61.9	55.3	0.27	0.24	950	8
None			Room	126.5	127.9	92.6	94.0	3.8		4.5		-----	-----	----	----	---	--
None			Room	208.3	218.0	202.2	207.4	8.0		5.0		112.3	88.0	0.55	0.40	950	8

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] ASTM notch radius 0.0007 inch, average of two tests [f] = average of two tests
[g] One notch specimen overheated to 720°F for 12 hours during exposure

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Alloy Designation: AM367 Contributor: Allegheny Ludlum Steel Corporation Data Sheet No. 2
Heat Treatment: As noted below Sheet Thickness, inches As noted below

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp °F	Stress ksi	Time, hr.	Test Temp °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	L	T	L	T
			Annealed 1500°F (0.050-inch thick sheet)																
			Room	147.4	149.1	89.5	93.6	8.8	2.0	9.0	2.0	-----	-----	----	----				
			Annealed 1400°F + 16 hrs. at -100°F + 4 to 8 hrs. at 950°F (0.050-incl thick sheet)																
			-100	268.6	289.2	267.8	284.3	7.1	2.0	2.9	2.0	268.2	259.2	1.00	0.90				
			Room	251.8	268.8	248.4	262.3	4.0	2.0	3.5	2.0	251.2	228.4	1.00	0.85				
			Annealed 1500°F (0.025-inch thick sheet)																
			Room	152.8	152.6	98.2	100.4	5.8	2.0	5.8	2.0	------	-----	----	----				
			Annealed 1600°F (0.050-inch thick sheet)																
			Room	147.4	149.1	89.5	93.6	8.8	2.0	9.0	2.0	-----	-----	----	----				
			Annealed at 1600°F, AC + 16 hrs. at -100°F + 8 hrs. at 950°F, AC (0.062-inch thick sheet)[e]																
			Room	227.6		220.8		6.0	2.0			243.3		1.07					
			Annealed 15 min. at 1625°F, FC to 1100°F in 45 min., then AC + 16 hrs. at -100°F + 8 hrs. at 950°F, AC (0.062-inch thick sheet)[e]																
			Room	220.3		212.0		7.5	2.0			229.0		1.04					

Comments: [a]Conditions of exposure, if any, between heat treatment and testing.
[b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]L = longitudinal orientation T = transverse orientation
[e]Specimen orientation not stated

Alloy Designation: AM367 Contributor: Allegheny Ludlum Steel Corporation Data Sheet No. 3
Heat Treatment: Strips butt welded by automatic tungsten process with no filler metal, then treated as noted below Sheet Thickness, inches 0.052

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	Location of fracture	L	T
			Annealed 1600°F															
			Room	167.6[e]		122.2		7.6										
			As Welded															
			Room	162.8	154.7	116.2	123.8	7.0		4.5						Weld		
			As Welded + 8 hrs. at 950°F															
			Room	251.4	241.9	243.9	239.0	4.8		2.8						Weld		
			As Welded + 16 hrs. at -100°F + 8 hrs. at 950°F															
			Room	260.3[e]		255.9		3.9										
			Room	253.2	244.5	243.8	241.8	4.5		2.5						Weld		
			As Welded + 15 min. at 1600°F + 8 hrs. at 950°F															
			Room	232.4	227.1	223.7	219.5	5.5		7.8						Base metal		
			As Welded + 15 min. at 1600°F + 16 hrs. at -100°F + 8 hrs. at 950°F															
			Room	235.2	229.6	226.2	223.9	6.5		7.5						Base metal		

Comments: [a]Conditions of exposure, if any, between heat treatment and testing.
[b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]L = longitudinal weld T = transverse weld
[e]Unwelded specimen

PH 15 - 7 MO

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Syracuse University Research Institute	Republic Steel Corporation	3330522
2	Langley Research Center, NASA	Armco Steel Corporation	890610
3	Syracuse University Research Institute	Armco Steel Corporation	880656
4	North American Aviation, Inc.	------	----
5	Lockheed Aircraft Corp., Calif. Co.	Armco Steel Corporation	46623
		" " "	880656

Composition, percent

Data Sheet	C	Mn	P	S	Si	Ni	Cr	Mo	Al	N	Fe
1	0.07	0.52	0.015	0.016	0.30	7.20	15.34	2.24	1.15	0.01	Bal
3 & 5	0.08	0.54	0.014	0.008	0.26	7.12	15.05	2.16	1.16		
(46623) 5	0.07	0.81	0.018	0.014	0.20	7.29	14.80	2.33	1.33		

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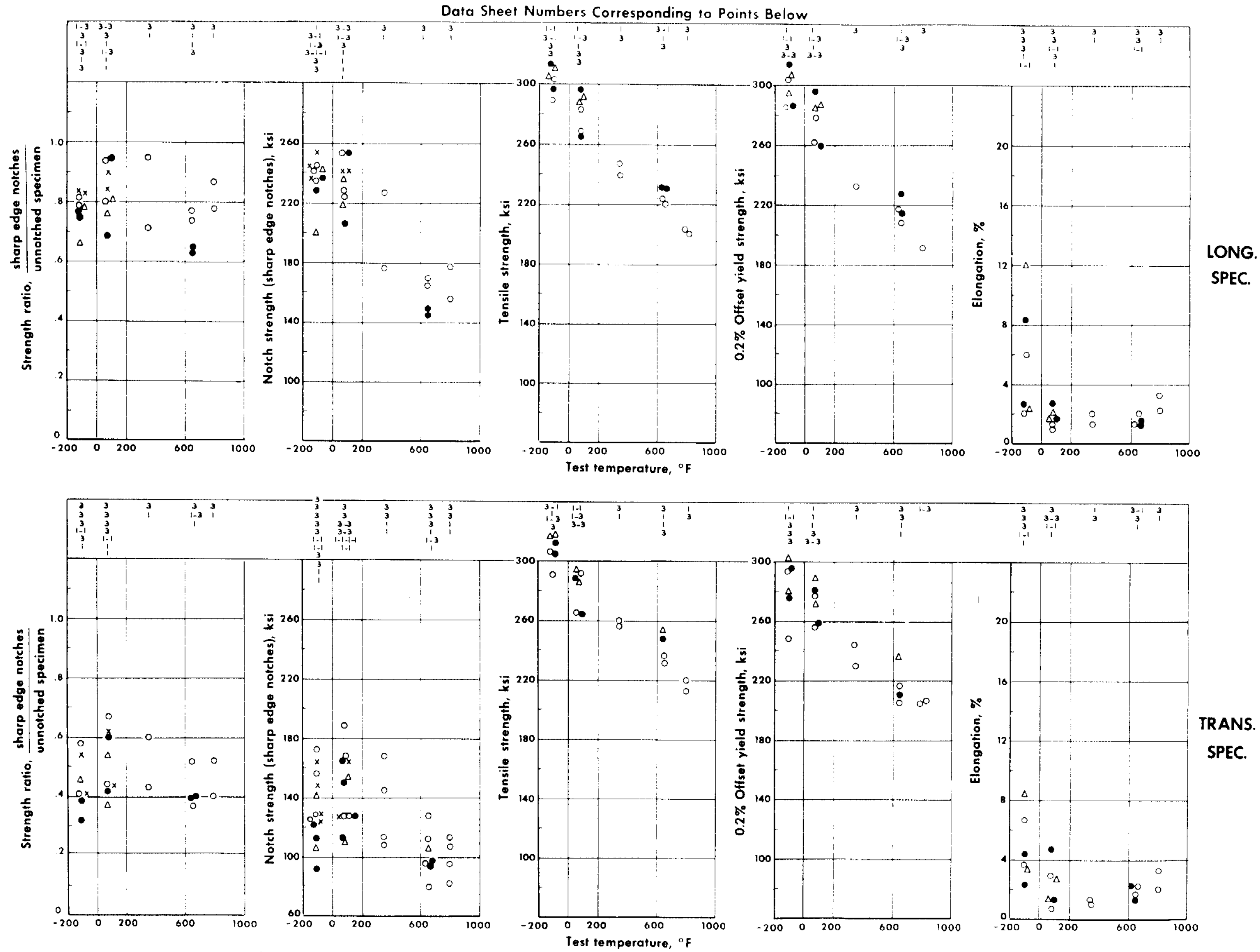
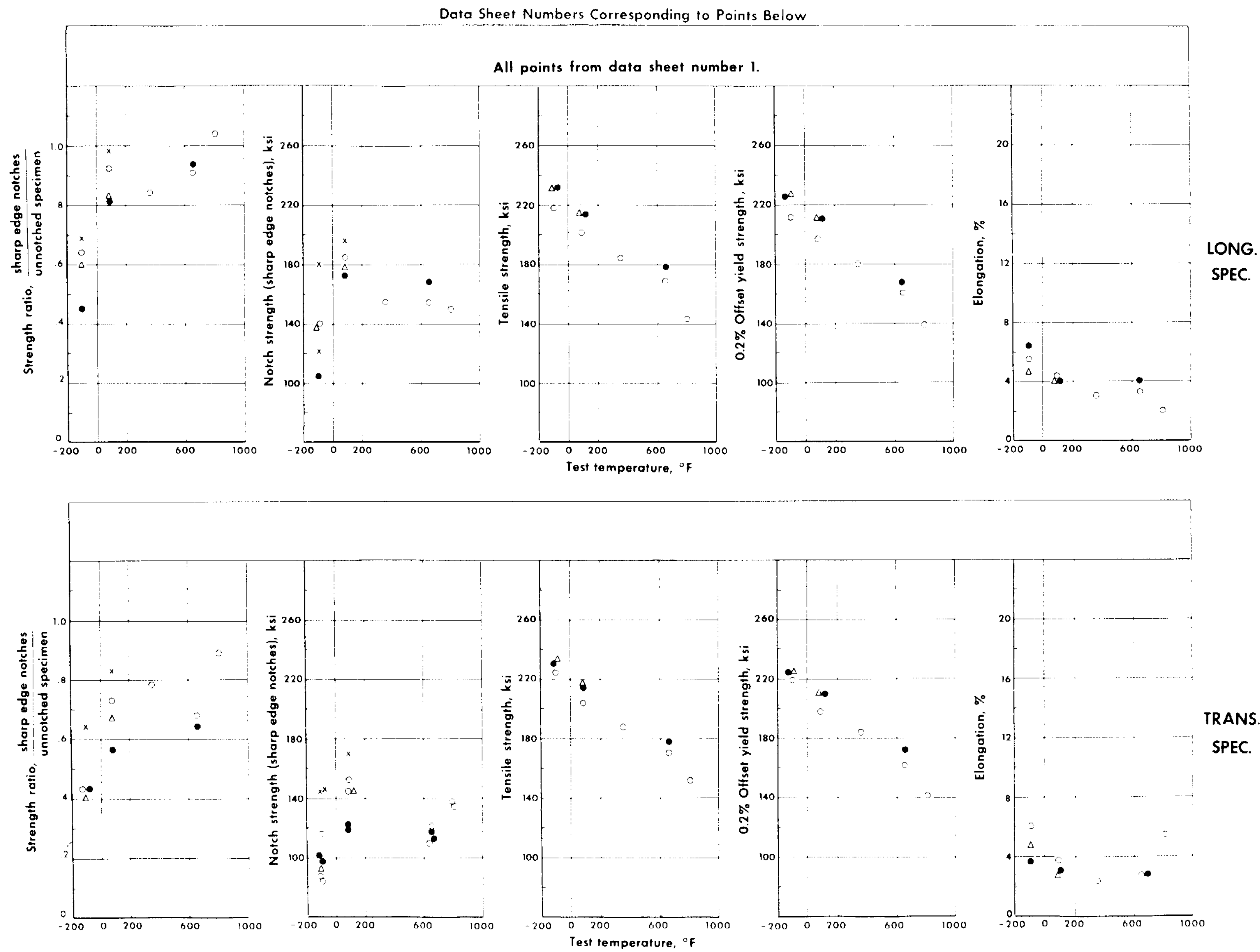


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Conditions of prior exposure
○ Unexposed (× fatigue-cracked edge notches)
● 1000 hrs., 650°F, 40 ksi (△ unstressed)

PH 15-7 Mo (CH 900)



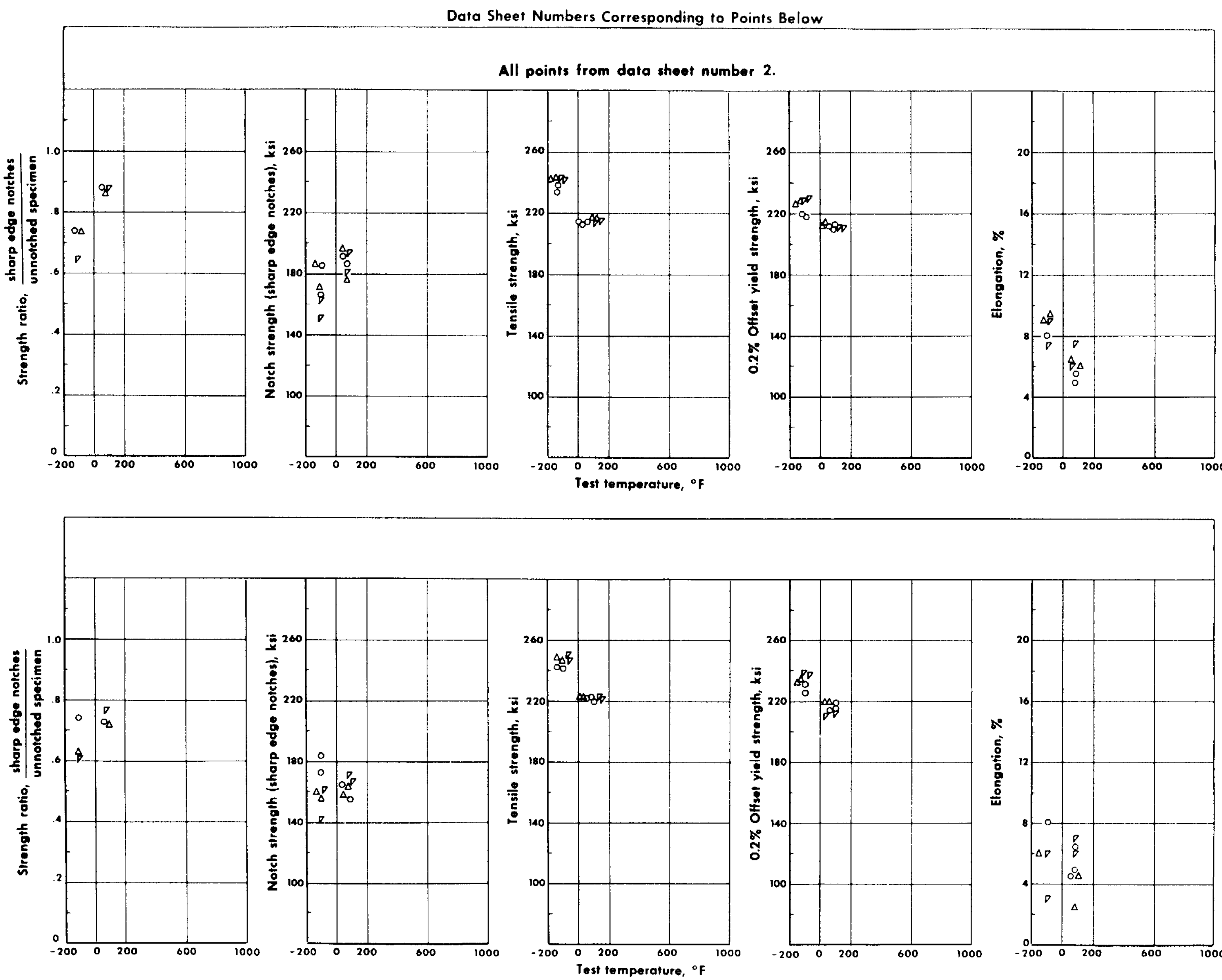
Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Conditions of prior exposure

○ Unexposed (× fatigue-cracked edge notches)

● 1000 hrs., 650°F, 40 ksi (△ unstressed)

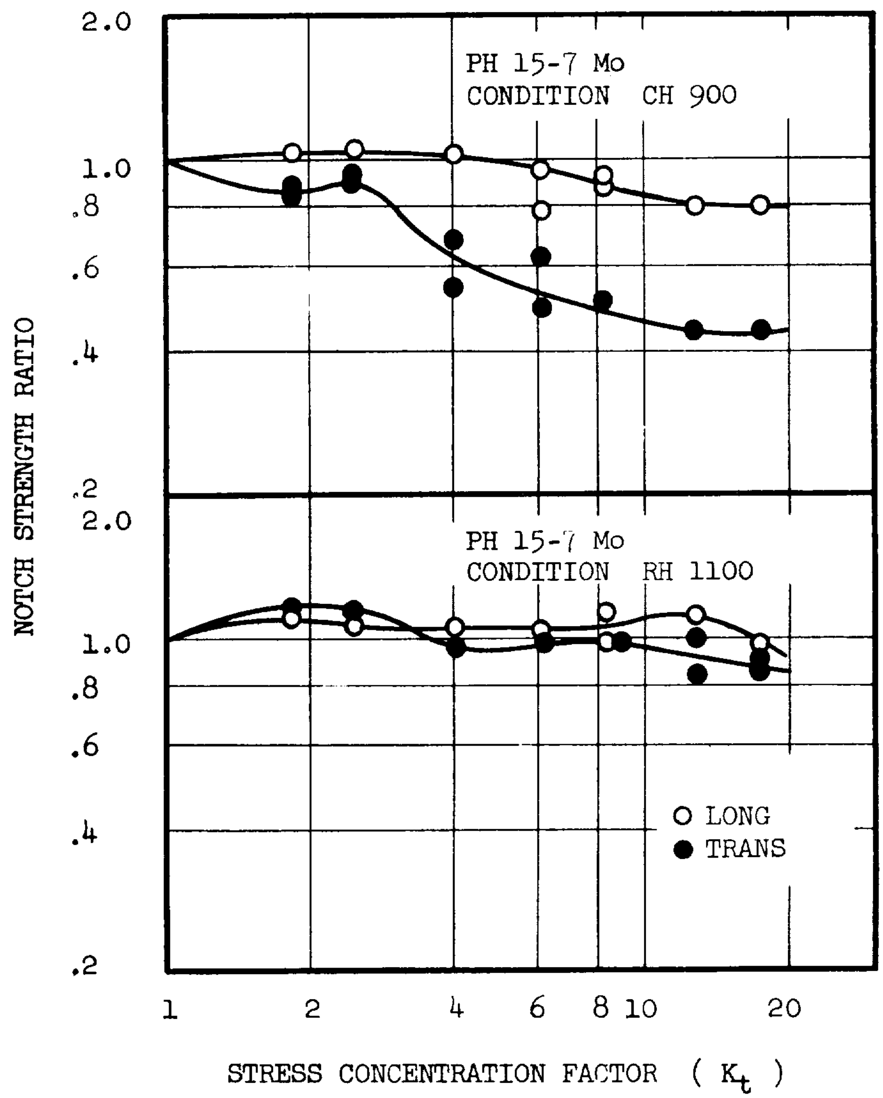
PH 15-7 Mo (RH 1050)



Conditions of prior exposure
- ○ Unexposed
- △ 2000 hrs., 550°F, unstressed
- ▽ 4000 hrs., 550°F, unstressed

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

PH 15-7 Mo (TH 1050 condition)



Notch strength ratio at room temperature versus stress concentration factor (K_t) for PH 15-7 Mo. A single point designates the average of two test points having close values. (Data Sheet No. 1)

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Alloy Designation: PH15-7 Mo   Contributor: Syracuse University Research Institute   Data Sheet No.: 1
Heat Treatment: As noted below   Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress, ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	[e]Edge Cracked Specimens: Tensile Str. (C), ksi L	T	Strength Ratio, C/S L	T
CH 900 Condition																			
None			-110	304	307	304	294	2.0	1.5	3.7	1.5	236	126.3	0.79	0.41	254	129	0.84	0.41
None			-110	---	---	---	---	---	---	---	---	245	127.5			---	124		
650	0	1000	-110	311	318	307	302.5	2.3	1.5	3.3	1.5	243	---	0.78					
650	40	1000	-110	314	313	313.5	296	2.7	1.5	2.3	1.5	237	105.8	0.75	0.32				
650	40	1000	-110	---	---	---	---	---	---	---	---	---	92						
None			Room	283.9	292	279	278	1.0	1.5	0.7	1.5	229	128	0.80	0.44	242	127	0.85	0.44
None			Room	---	---	---	---	---	---	---	---	225	128			---	---		
650	0	1000	Room	288	294	284	289	1.7	1.5	1.3	1.5	219	110	0.76	0.37				
650	40	1000	Room	296.5	290	296.5	281	1.7	1.5	1.3	1.5	206	113.7	0.69	0.42				
650	40	1000	Room	---	---	---	---	---	---	---	---	---	128.5						
None			350	248	257	---	230	1.3	1.5	1.3	1.5	177	114	0.71	0.43				
None			350	---	---	---	---	---	---	---	---	---	108.5						
None			650	224	236	217.5	206	1.3	1.5	2.3	1.5	166	96	0.74	0.37				
None			650	---	---	---	---	---	---	---	---	---	79.5						
650	40	1000	650	231	248.5	228	210	1.3	1.5	1.3	1.5	149	97	0.65	0.39				
None			800	201	220	---	205.5	2.3	1.5	2.0	1.5	156	95.5	0.78	0.40				
None			800	---	---	---	---	---	---	---	---	---	82.4						
RH 1050 Condition																			
None			-110	218	224.5	212	219	5.5	1.5	6.0	1.5	139	116	0.64	0.43	180	144.5	0.69	0.64
None			-110	---	---	---	---	---	---	---	---	---	87			121.5	145		
None			-110	---	---	---	---	---	---	---	---	---	84			---	---		
650	0	1000	-110	232	234	227	225	4.7	1.5	4.7	1.5	138.5	92.5	0.60	0.40				
650	40	1000	-110	232	230	226.5	224.5	6.4	1.5	3.7	1.5	105.2	98	0.45	0.43				
650	40	1000	-110	---	---	---	---	---	---	---	---	---	100						
None			Room	201	204	196.5	197.5	4.3	1.5	3.7	1.5	185.2	152	0.92	0.73	196.5	169.5	0.98	0.8
None			Room	---	---	---	---	---	---	---	---	---	144			---	---		
650	0	1000	Room	215	217	211	210	4.0	1.5	2.7	1.5	178	144.4	0.83	0.67				
650	40	1000	Room	214	214	211	209	4.0	1.5	3.0	1.5	173	122	0.82	0.56				
650	40	1000	Room	---	---	---	---	---	---	---	---	---	118						
None			350	184	186.5	180	182.5	3.0	1.5	2.3	1.5	155	143	0.84	0.78				
None			350	---	---	---	---	---	---	---	---	---	149						
None			650	169	170	159.5	161	3.3	1.5	2.7	1.5	154	110	0.91	0.68				
None			650	---	---	---	---	---	---	---	---	---	120						
650	40	1000	650	178	176.8	167	172	4.0	1.5	2.7	1.5	167.5	116.5	0.94	0.64				
650	40	1000	650	---	---	---	---	---	---	---	---	---	111.3						
None			800	143.5	152	139	141	2.0	1.5	5.4	1.5	150	137	1.04	0.89				
None			800	---	---	---	---	---	---	---	---	---	134						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Specimen 1.00 in. wide notched 0.05 in. deep, then fatigued to 0.70 in. between the roots of the edge cracks.

Alloy Designation: PH15-7 Mo Contributor: NASA, Langley Research Center Data Sheet No.: 2
Heat Treatment: TH 1050 Condition Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			-110	239.0	243.0	220.0	231.0	(e)	---	(e)		165.0	174.0	0.74	0.74				
None			-110	236.0	242.0	219.0	226.0	8.0	2.5	8.0		186.0	184.0						
550	0	2000	-110	242.0	249.0	227.0	235.0	9.5	2.5	(e)		171.5	155.0	0.74	0.63				
550	0	2000	-110	243.0	247.0	229.0	232.0	9.0	2.5	6.0		187.5	160.0						
550	0	4000	-110	243.0	248.0	229.0	238.0	7.5	2.5	3.0		163.0	162.0	0.65	0.61				
550	0	4000	-110	242.0	250.0	230.0	239.5	9.0	2.5	6.0		151.0	142.0						
None			Room	215.8	222.4	212.0	218.9	5.5	2.5	4.5		-----	-----						
None			Room	214.3	220.0	210.8	214.2	---	---	5.0		187.5	166.1	0.88	0.73				
None			Room	215.4	221.7	212.8	215.0	5.0	2.5	6.5		192.0	155.7						
550	0	2000	Room	217.0	223.0	215.0	219.0	6.5	2.5	4.5		176.0	164.0	0.86	0.72				
550	0	2000	Room	216.0	223.0	213.0	220.0	6.0	2.5	2.5		196.5	158.0						
550	0	4000	Room	215.0	221.0	211.0	212.0	6.0	2.5	7.0		182.0	172.0	0.88	0.77				
550	0	4000	Room	214.5	222.0	211.0	210.0	7.5	2.5	6.0		195.0	167.0						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Irregular fracture

Alloy Designation: PH15-7Mo Contributor: Syracuse University Research Institute Data Sheet No.: 3
Heat Treatment: CH900 Condition Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches				[e] Edge-Cracked Specimens			
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S		Tensile Str. (C), ksi		Strength Ratio, C/S	
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
None			-110	290	292	285.5	248.5	6.0	1.5	6.7	1.5	242	156.5	0.83	0.58	244	165	0.83	0.54
None			-110	---	---	---	---	---	---	---	---	---	173			236	149		
650	0	1000	-110	305	318	294	281	12.0	1.5	8.4	1.5	200	141	0.66	0.46	---	---	---	---
650	40	1000	-110	297	305	286	276.5	8.4	1.5	4.4	1.5	229	122	0.77	0.39				
650	40	1000	-110	---	---	---	---	---	---	---	---	---	113						
None			Room	269	266	262	256	1.3	1.5	3.0	1.5	254	189	0.94	0.67	242	164	0.90	0.62
None			Room	---	---	---	---	---	---	---	---	---	168			---	---		
650	0	1000	Room	292	286	287.5	272	2.0	1.5	2.7	1.5	236	153	0.81	0.54	---	---	---	---
650	40	1000	Room	266	265	260	258	2.7	1.5	4.7	1.5	254	165	0.95	0.60				
650	40	1000	Room	---	---	---	---	---	---	---	---	---	150.5						
None			350	240	260	233	244	2.0	1.5	1.0	1.5	228	146	0.95	0.60				
None			350	---	---	---	---	---	---	---	---	---	168						
None			650	221	232	208.5	216.5	2.0	1.5	1.7	1.5	170	112	0.77	0.52				
None			650	---	---	---	---	---	---	---	---	---	128						
650	40	1000	650	232	254	214	236.5	1.3	1.5	2.3	1.5	146	106	0.63	0.40				
650	40	1000	650	---	---	---	---	---	---	---	---	---	94.6						
None			800	203	214	191.5	186	3.3	1.5	3.3	1.5	177.5	114	0.87	0.52				
None			800	---	---	---	---	---	---	---	---	---	107						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Specimen 1.00 in. wide notched 0.05 in. deep, then fatigued to 0.70 in. between the roots of the edge cracks.

Alloy Designation: PH15-7Mo Contributor: North American Aviation, Inc. Data Sheet No.: 4

Heat Treatment: Brazed at 1900°F and cooled to room temperature + heat to 1730°F and cool to -100°F for 4 hours + age at 1075°F for 1 hour and air cool Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES[d]

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens						Sharp edge notches			
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi	Yield strength,[b] ksi	Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi	Strength ratio, N/S		
									T	L T	L T	L T	L T
None			Room	204	197	6							
None			Room	203	192.5	5.4							
None			Room	204	-----	6							

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]Test direction not stated

STRESS-CORROSION TESTS

Cantilever beam tests at 650°F in circulating air furnace.

Salt coated by dipping in hot concentrated 6 parts NaCl + 1 part $MgCl_2$ and drying.

Smooth and Notched Specimens Tested - 60°V-notches, 0.010-inch deep with 0.005-inch root radius, machined across flat surface at point of maximum stress and at a point of very low stress.

Test Condition	Maximum Stresses Smooth (ksi)	Maximum Stresses Notched (ksi)	Status at 4700 Hours[(a)]
Bare Surface - continuously exposed	61.3, 60.4, 59.8	168.4, 168.4	Slightly blued
Salt Coated - continuously exposed[(b)]	57.3, 57.1, 59.8	155.0, 157.3	Gold to dark brown color - rust spots over 20 to 50% of surface
Braze Coated - continuously exposed	55.5, 54.3, 57.0	145.3, 140.6	Slight darkening
Braze + Salt Coated - continuously exposed	53.7, 54.1, 55.0	146.6, 147.1	50% of surface covered with rust-like spots
Salt Coated - 2 weeks at 650°F + 2 weeks in humidity cabinet at 100°F intermittently	59.5, 58.7 58.6, 58.6	-----------	Rough surface with considerable rusting

(a) Unbroken at 4700 hours
(b) At 4700 hours, salt coating appeared spotty

Alloy Designation: PH15-7Mo Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 5
Heat Treatment: As noted below Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	Control Coupon Data F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
CRT										
-65	T	0.0195	9.01	9600	54.6	1.47	252	--	259.7	--
-65	T	0.0194	9.00	6910	39.6	2.67	260			
Room	T	0.0195	9.00	9060	51.6	1.48	227	172.8	219.3	5
Room	T	0.0194	9.03	6400	36.5	2.60	214			
600	T	0.0193	9.01	6770	38.9	1.60	157	181.3	201.8	10
600	T	0.0193	9.00	5020	28.9	2.50	144			
CRT (1 hr. at 900°F)										
-65	T	0.0194	8.98	9410	54.0	1.54	260	305.8	311.0	5.2
-65	T	0.0194	8.98	7250	41.6	2.49	263			
Room	T	0.0187	8.99	9380	55.8	1.38	247	299.7	303.1	1.6
Room	T	0.0190	8.99	6260	36.7	2.59	216			
600	T	0.0189	8.99	8500	50.0	1.39	214	248.5	262.7	1.3
600	T	0.0188	9.00	5140	30.4	2.91	183			
RH 1075										
-65	T	0.0167	9.02	11100	73.7	1.53	473	143.5	195.4	10.9
-65	T	0.0167	9.03	8250	54.7	2.52	462			
Room	T	0.0166	9.02	11780	78.7	1.65	593	141.6	176.6	10.9
Room	T	0.0162	9.00	8960	61.5	2.77	657			
600	T	0.0162	9.02	8800	60.2	1.66	391	127.2	147.6	3.5
600	T	0.0161	9.04	5680	38.9	2.74	289			

PH14-8Mo

INDEX OF MATERIALS

Data Sheet	Organization Contributing Data	Alloy Producer	Heat Number
1	Armco Steel Corporation	Armco Steel Corporation	31562

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Alloy Designation: PH14-8 Mo Contributor: Armco Steel Corp. Data Sheet No.: 1
Heat Treatment: As noted below in right hand columns Sheet Thickness, inches: Mostly 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	Elong.[c] % T	Allison bend parameter L	Allison bend parameter T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	Center notch, fatigue cracked: Tensile strength, ksi L	Tensile strength, ksi T	Heat Treatment Condition
None			-110[f]	265.0	266.6	249.1	255.0	12	11			231.7	205.2	0.87	0.77			SRH 950
None			-110	-----	266.0	-----	255.0	----	11			-----	-----	----	----		170.0	SRH 950
None			Room[e]	-----	125.0	-----	55.0	25				-----	-----	----	----			Condition A
None			Room[e]	-----	235.0	-----	215.0	5				-----	-----	----	----			SRH 950
None			Room[f]	231.9	235.2	214.1	216.8	8	5			214.1	193.2	0.92	0.82			SRH 950
None			Room[f]	231.9	235.2	212.2	216.8	8	5			203.3[g]	161.2[g]	0.88	0.69			SRH 950
None			Room	-----	235.0	-----	217.0	----	6			-----	-----	----	----		170.0	SRH 950
None			Room	238.0	245.0	223.0	226.0	4.5	4.5	1.61	0.46	-----	-----	----	----			SRH 950
400	0	931	Room	238.0	243.0	225.0	230.0	7	5.5	1.41	0.45	-----	-----	----	----			SRH 950
550	0	100	Room	242.0	246.0	227.0	233.0	5	4	1.15	0.35	-----	-----	----	----			SRH 950
700	0	931	Room	262.0	266.0	248.0	246.0	5.5	4.5	0.62	0.20	-----	-----	----	----			SRH 950
650	0	1000	Room	-----	230.0	-----	212.7	----	10			-----	-----	----	----		219.0	SRH 950
650	0	1000	Room	-----	227.0	-----	218.0	----	10			-----	-----	----	----		214.0	SRH 950
650	0	1000	Room	-----	-----	-----	-----	----	----			-----	-----	----	----		216.0	SRH 950
650	0	1000	Room	-----	-----	-----	-----	----	----			-----	-----	----	----		212.0	SRH 950
650	0	1000	Room	-----	-----	-----	-----	----	----			-----	-----	----	----		216.0	SRH 950
650	67.0	1000	Room	-----	247.0	-----	227.5	----	4.5			-----	-----	----	----		216.0	SRH 950
650	67.0	1000	Room	-----	-----	-----	-----	----	----			-----	-----	----	----		218.0	SRH 950
650	67.0	1000	Room	-----	-----	-----	-----	----	----			-----	-----	----	----		215.0	SRH 950
None			650[f]	197.8	198.5	181.8	173.5	4.5	3			156.3	144.3	0.79	0.73			SRH 950
None			650	-----	197.0	-----	170.0	----	4			-----	-----	----	----	-----	125.0	SRH 950
None			Room	275.0	283.0	272.0	277.0	2	(i)	1.15	0.10							CH900
400	0	931	Room	271.0	274.0	269.0	271.0	2	(i)	1.17	0.07							CH900
550	0	100	Room	277.0	285.0	276.0	282.0	2.5	1.5	1.08	0.07							CH900
700	0	931	Room	314.0	302.0	310.0	293.0	2	(i)	0.45	0.04							CH900
None			Room	249.0	265.0	244.0	259.0	2	(i)	high	0.27							CH1050
400	0	931	Room	255.0	260.0	253.0	254.0	2	2	high	0.21							CH1050
550	0	100	Room	256.0	268.0	255.0	267.0	2.5	1.5	high	0.23							CH1050
700	0	931	Room	273.0	289.0	266.0	282.0	2	(i)	1.42	0.10							CH1050
None			Room	-----	215.0	-----	205.0	----	5	----	0.45							BCHT1050
None			Room	218.0	222.0	212.0	213.0	5	4	high	0.41							BCHT1050
400	0	931	Room	221.0	223.0	215.0	217.0	5	4	1.60	0.36							BCHT1050
550	0	100	Room	224.0	224.0	221.0	220.0	4	3.5	1.12	0.29							BCHT1050
700	0	931	Room	242.0	250.0	237.0	241.0	3.5	3	0.60	0.19							BCHT1050
None			Room[e]	-----	215.0	-----	205.0	----	5	----	0.60							SRH1050
None			Room	208.0	218.0	200.0	207.0	5.5	4.5	high	0.61							SRH1050
400	0	931	Room	212.0	217.0	206.0	211.0	6	4.5	high	0.71							SRH1050
550	0	100	Room	214.0	217.0	208.0	212.0	6	5	high	0.56							SRH1050
700	0	931	Room	235.0	242.0	228.0	234.0	6.5	4	1.41	0.43							SRH1050
Cold Rolled																		Cold Reduction
			Room	131.0	-----	61.0	-----	23	----									6.3 %
			Room	141.0	-----	65.0	-----	16.5	----									11.3 %
			Room	163.0	-----	78.0	-----	11.0	----									22.2 %
			Room	168.0	-----	109.0	-----	10.0	----									29.2 %
			Room	178.0	-----	150.0	-----	8.0	----									39.2 %
			Room	193.0	-----	177.0	-----	2.0	----									49.9 %
			Room	209.0	-----	207.0	-----	1.0	----									59.7 %
			Room	225.0	-----	222.0	-----	1.0	----									72.5 %
Cold Rolled + 1 Hour at 900°F																		
			Room	129.0		71.0		28.5										6.3 %
			Room	130.0		94.0		23.5										11.3 %
			Room	158.0		135.0		15.5										22.2 %
			Room	208.0		206.0		5										29.2 %
			Room	252.0		250.0		2										39.2 %
			Room	277.0		276.0		1										49.9 %
			Room	290.0		290.0		1										59.7 %
			Room	310.0		305.0		(i)										72.5 %
[j] Welded Joints (Tungsten Inert-gas Arc Welds with Parent Metal Filler)																		
None			-100[h]	245.6		-----		5.0	----									
None			Room[h]	224.2		189.1		12.0	----	0.04	weld metal							
None			650[h]	198.0		175.5		11.0	----									

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Typical values f - All values average of three tests g - 2-inch wide specimen
[h] Fractured in the weld metal [i] Failed outside gage section. [j] gage length 1/2 inch.

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Steel AFC-77

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Crucible Steel Company of America	Crucible Steel Company of America	46073 72238

Composition, percent

Heat No.	C	Mn	Si	P	S	Ni	Cr	V	Mo	Co	N
46073	0.15	0.10	0.07	0.010	0.008	0.08	14.22	0.30	4.62	12.93	0.03
72238	0.17	0.01	0.20	0.006	0.011	0.05	14.34	0.52	4.93	13.61	0.02

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Alloy Designation: Steel AFC 77 Contributor: Crucible Steel Company of America Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Fatigue-cracked center notch				Subsequent Treatment	
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S			
				L[d]	T	L	T	L	not given	T	not given	L	T	L	T	L	T
Heat 46073 - 1900°F, ½ hr., O.Q.: -100°F, ½ hr., 700°F, 2 + 2 hrs.																	
			-110	260		208		11									
			76	237		182		11									
			650	234		146		12									
650	40	1000	-110	269		225		7									
650	40	1000	76	215		202		10									
650	40	1000	650	241		162		10									
Heat 46073 - 1900°F, ½ hr., O.Q.: -100°F, ½ hr., 750°F, 2 + 2 hrs.																	
			-110	264		219		10									
			76	237		187		11									
			650	235		152		11									
650	40	1000	-110	269		225		14									
650	40	1000	76	252		204		10									
650	40	1000	650	234		164		6									
Heat 46073 - 1900°F, ½ hr., O.Q.: CR 10%; 700°F, 2 + 2 hrs.																	
			-110	294		284		6									
			76	264		255		5									
			650	252		218		9									
650	40	930	76	276		268		6									
Heat 72238 - 2000°F, O.Q. plus subsequent treatment indicated																	
			Room	258		170						193		0.69		-100°F, ½ hr.; 600°F, 2+2 hr.	
			Room	245		185						194		0.79		-100°F, ½ hr.; 700°F, 2+2 hr.	
			Room									209[e]				CR 5%; 700°F, 2 + 2 hr.	
			Room									229[e]				CR 10%; 700°F, 2 + 2 hr.	
			Room	259		204						187[e]		0.92		-100°F, ½ hr.; 800°F, 2+2 hr.	
			Room	281		272						221[e]		0.79		CR 5%; 800°F, 2 + 2 hr.	
			Room	297		287						191[e]		0.64		CR 10%; 800°F, 2 + 2 hr.	

ROOM TEMPERATURE PROPERTIES OF WELDED AND UNWELDED SHEET SPECIMENS - HEAT 72238[e,f]

Welding and Heat-Treatment Sequence after Hot Rolling	Sheet Thickness (in)	Yield Strength,[b] (ksi)	Tensile Strength (ksi)	Elong. (%)
2000°F, A.C.; Welded; -100°F, ½ hr; 1100°F, 2 + 2 hr.	1/8	218	285	3
2000°F, A.C.; -100°F, ½ hr; 1100°F, 2 + 2 hr.	1/8	219	290	8
2000°F, A.C.; Welded; 1100°F, 1 + 1 + 2 hr.	1/8	220	283	5
Welded; -100°F, ½ hr; 1100°F, 2 + 2 hr.	1/8	206	271	6
-100°F, ½ hr; 1100°F, 2 + 2 hr.	1/8	221	294	7
2000°F, A.C.; Welded; -100°F, ½ hr; 1100°F, 2 hr, -100°F, ½ hr; 1100°F, 2 hr.	1/8	221	286	4
2000°F, A.C.; -100°F, ½ hr; 1100°F, 2 hr, -100°F, ½ hr; 1100°F, 2 hr.	1/8	224	295	7
2000°F, A.C.; Welded; -100°F, ½ hr; 1100°F, 2 + 2 hr.	1/16	221	285	4
Welded; -100°F, ½ hr; 1100°F, 2 + 2 hr.	1/16	208	275	5

ROOM TEMPERATURE TENSILE PROPERTIES OF COLD ROLLED AND AGED CONDITION - HEAT 72238

Condition	Cold Reduction (%)	Yield Strength,[b] (ksi)	Tensile Strength (ksi)	Elong. (%)
2000°F, ½ hr, O.Q.; C.R.; 800°F, 2 + 2 hr.	5	272	281	7
2000°F, ½ hr, O.Q.; C.R.; 800°F, 2 + 2 hr.	10	287	297	6
2000°F, ½ hr, O.Q.; C.R.; 800°F, 2 + 2 hr.	15	297	308	5
2000°F, ½ hr, O.Q.; C.R.; 800°F, 2 + 2 hr.	20	301	313	4
2000°F, ½ hr, O.Q.; C.R.; 800°F, 2 + 2 hr.	30	326	331	3
C.R.; 1000°F, 2 + 2 hr.	55	327[e]	347[e]	2[e]
C.R.; 1100°F, 2 + 2 hr.	55	260[e]	326[e]	4[e]
C.R.; 1200°F, 2 + 2 hr.	55	222	294	5

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.
[b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.
[d] L = longitudinal orientation T = transverse orientation
[e] Average of two or more tests
[f] Inert gas-shielded tungsten electrode welding process; no filler metal.

A286

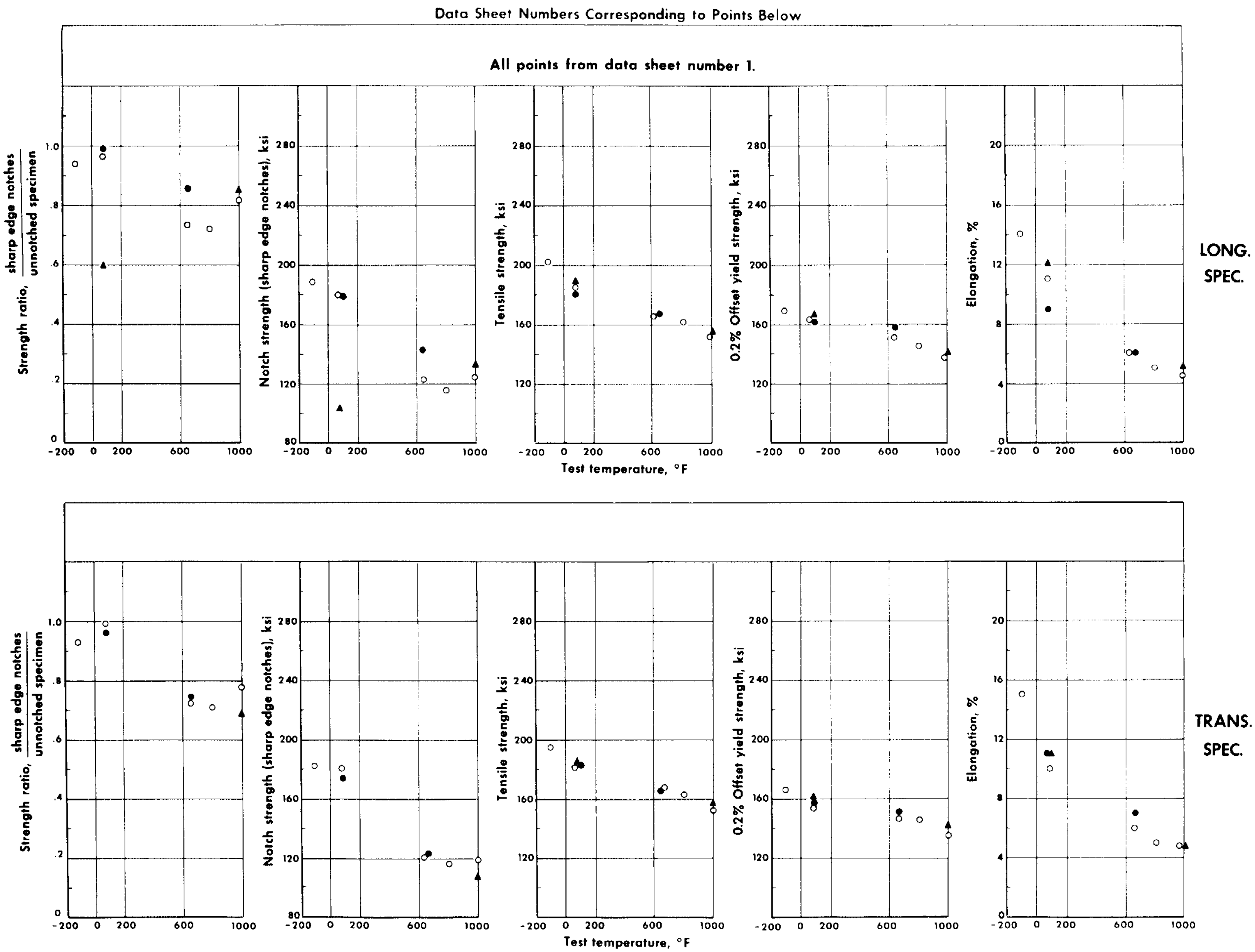
INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1, 2	The University of Michigan	Allegheny Ludlum	21467

Composition, percent

Data Sheet	C	Si	Mn	Cr	Ni	Mo	Ti
1	0.057	0.60	1.10	15.22	24.86	1.24	2.12

Al	V	Fe	P	S	B
0.23	0.33	Bal	0.028	0.007	0.0015



Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ▲ 1000 hrs., 1000°F, 40 ksi

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

A-286 (C. R. 30%+ 16 hrs. 1300°)

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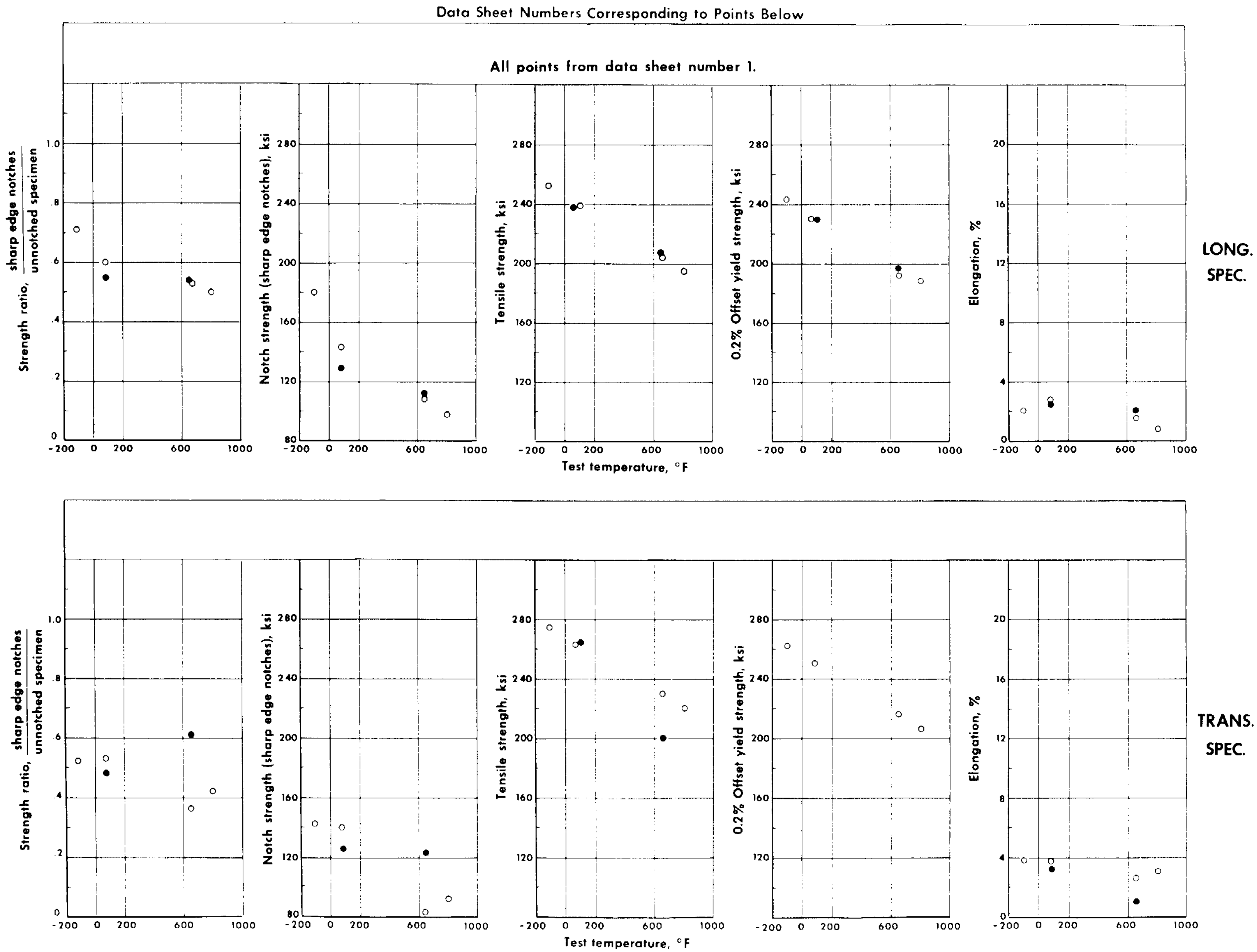

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

A-286 (C. R. 80% + 16 hrs. 1100°)

Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi

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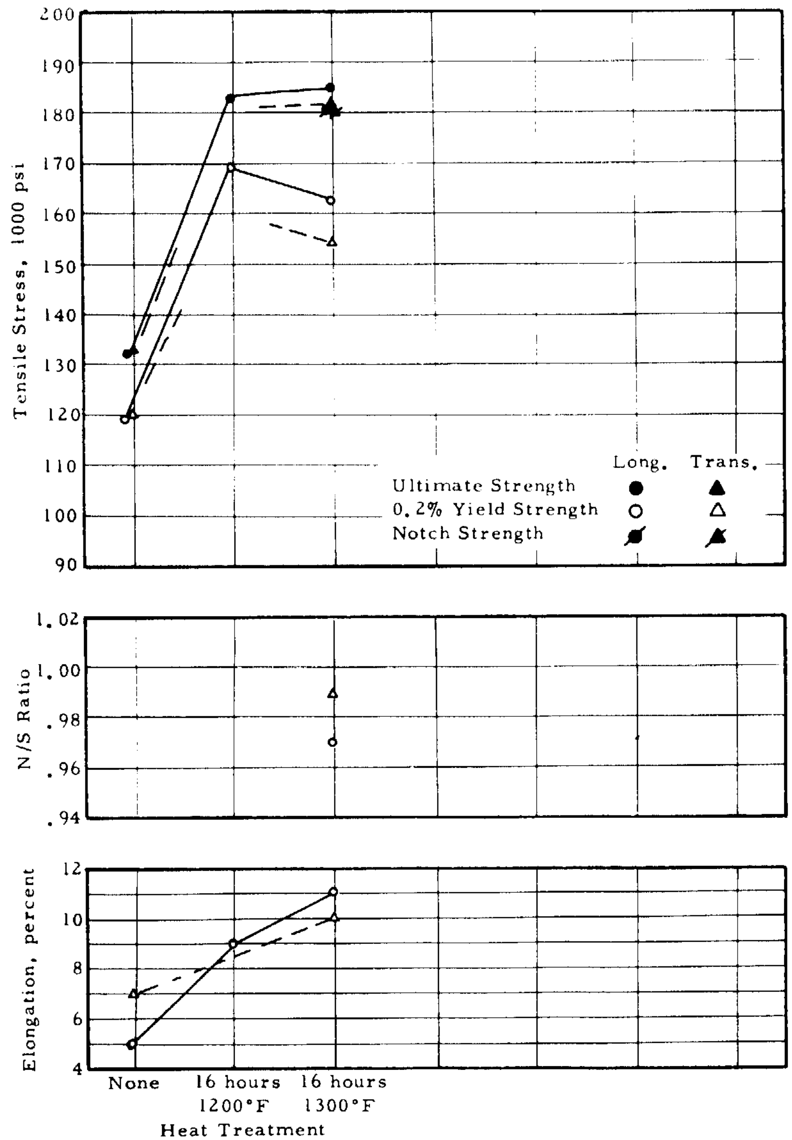
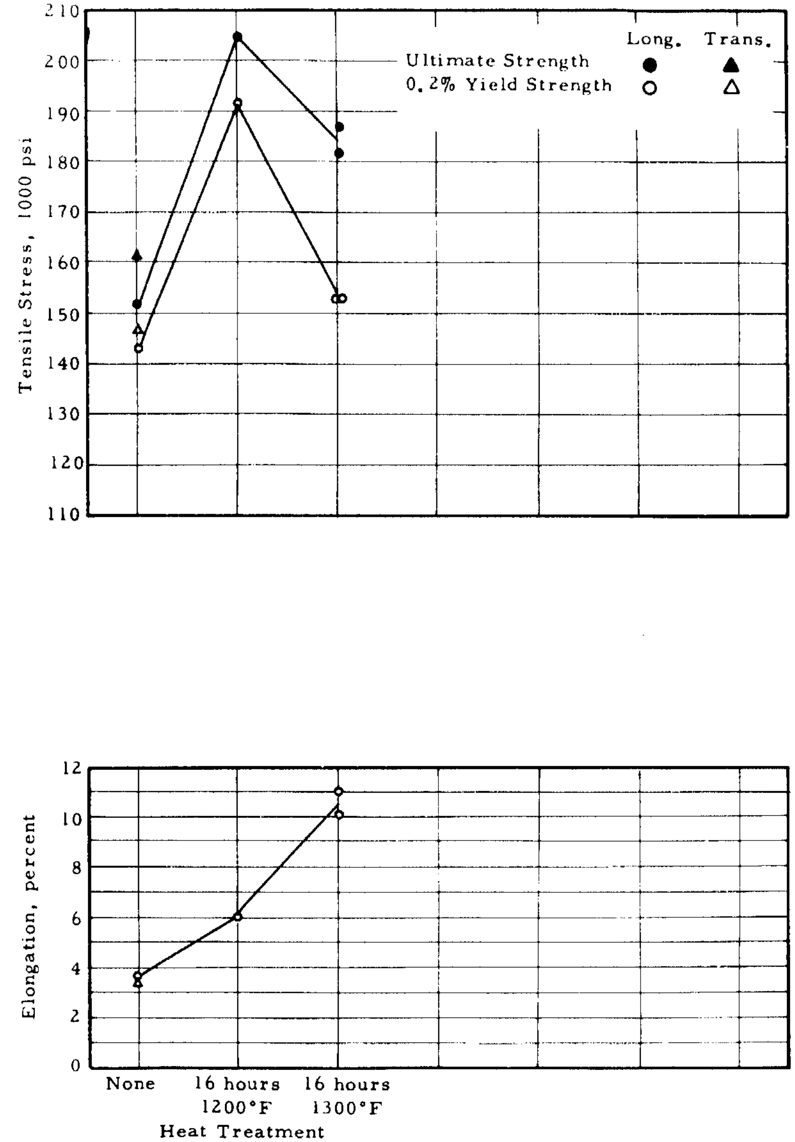
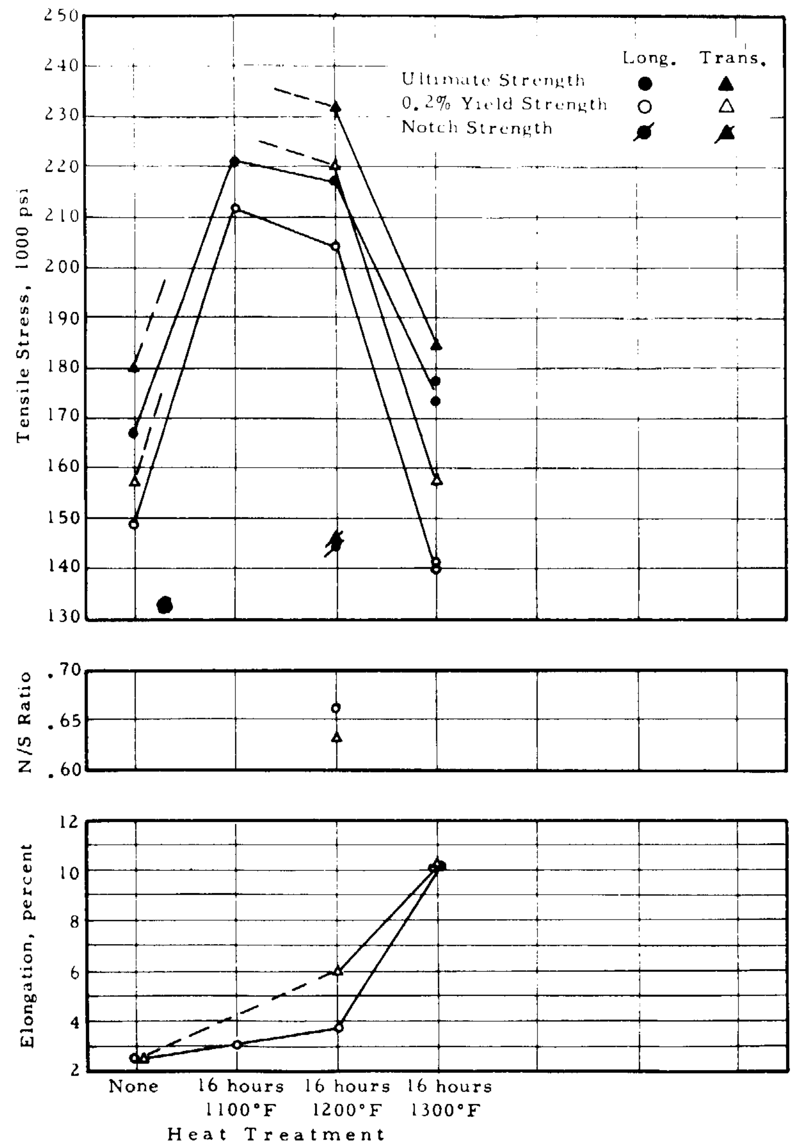


Results for 30-percent cold worked strip.

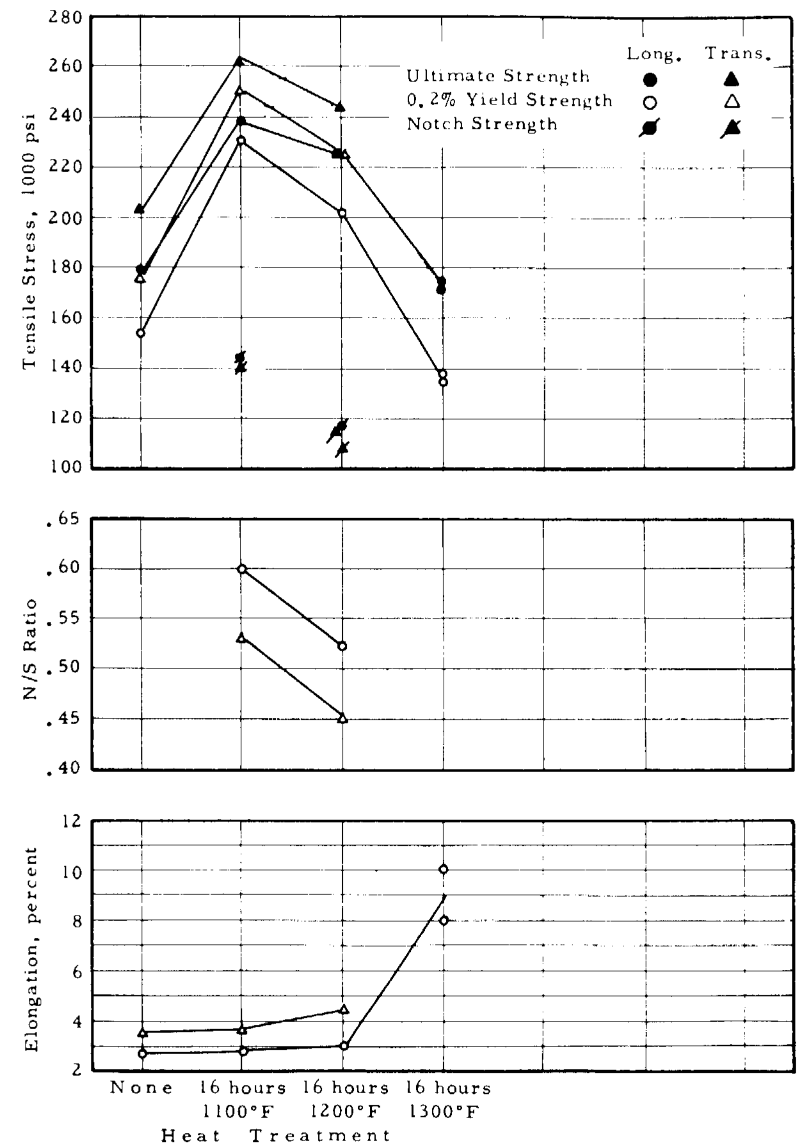


Results for 50-percent cold worked strip.

Effect of heat treatment on the room-temperature tensile properties of A-286 alloy.



Results for 65-percent cold worked strip.



Results for 80-percent cold worked strip.

Effect of heat treatment on the room-temperature tensile properties of A-286 alloy. (Concluded).

Alloy Designation: A286 Contributor: The University of Michigan Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
							30% Cold rolled + 1300°F, 16 hours												
None			-110	202	195	169	166	14		15		189	182	0.94	0.93				
None			Room	185	181	163	154	11		10		180	180	0.97	0.99				
650	40	1000	Room	181	182	162	157	9		11		179	174	0.99	0.96				
1000	40	1000	Room	190	185	168	162	12		11		114	(e)	0.60	----				
None			650	166	167	151	147	6		6		123	121	0.74	0.72				
650	40	1000	650	167	166	158	151	6		7		143	123	0.86	0.74				
None			800	162	163	145	146	5		5		116	115	0.72	0.71				
None			1000	153	152	138	136	4.5		4.8		125	119	0.82	0.78				
1000	40	1000	1000	156	157	141	142	5.0		4.8		134	108	0.86	0.69				
							80% Cold rolled + 1100°F, 16 hours												
None			-110	253	275	243	262	2.0		3.8		180	142	0.71	0.52				
None			Room	239	263	230	250	2.8		3.8		143	140	0.60	0.53				
650	40	1000	Room	238	264	229	---	2.5		3.3		130	126	0.55	0.48				
None			650	204	230	192	216	1.5		2.5		108	83	0.53	0.36				
650	40	1000	650	207	200	197	---	2.0		1.0		112	123	0.54	0.61				
None			800	195	220	188	206	0.8		3.0		98	92	0.50	0.42				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Failed during exposure

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Alloy Designation: A-286 **Contributor:** The University of Michigan (NASA Sponsored) **Data Sheet No.:** 2

Heat Treatment: As noted below **Sheet Thickness, inches** 0.025

EVALUATION OF HEAT TREATMENT
A-286 ALLOY

(all tests at room temperature)

		CONDITION OF MATERIAL PRIOR TO AGING																			
		COLD WORKED 30%					COLD WORKED 50%					COLD WORKED 65%					COLD WORKED 80%				
Heat Treatment	Direction (a)	UTS(b) (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S
None	L	132	120	5	---	---	152	143	3.5	---	---	167	149	2.5	---	---	178	153	2.7	---	---
	T	133	121	7	---	---	162	147	3.3	---	---	180	157	2.5	---	---	204	177	3.5	---	---
16 hrs at 1100°F	L	---	---	-	---	---	---	---	---	---	---	221	212	3	---	---	239	230	2.8	143	.60
	T	---	---	-	---	---	---	---	---	---	---	---	---	---	---	---	263	250	3.8	140	.53
16 hrs at 1200°F	L	183	169	9	---	---	205	192	6	---	---	217	204	3.8	143	.66	224	202	3	116	.52
	T	---	---	-	---	---	---	---	--	---	---	232	220	6	146	.63	243	226	4.5	109	.45
16 hrs at 1300°F	L	185	163	11	180	.97	182	153	11	---	---	173	139	10	---	---	170	136	8	---	---
	L	---	---	-	---	---	187	153	10	---	---	177	140	10	---	---	174	135	10	---	---
	T	181	154	10	180	.99	---	---	---	---	---	184	157	10	---	---	---	---	---	---	---

(a) L = Longitudinal
T = Transverse

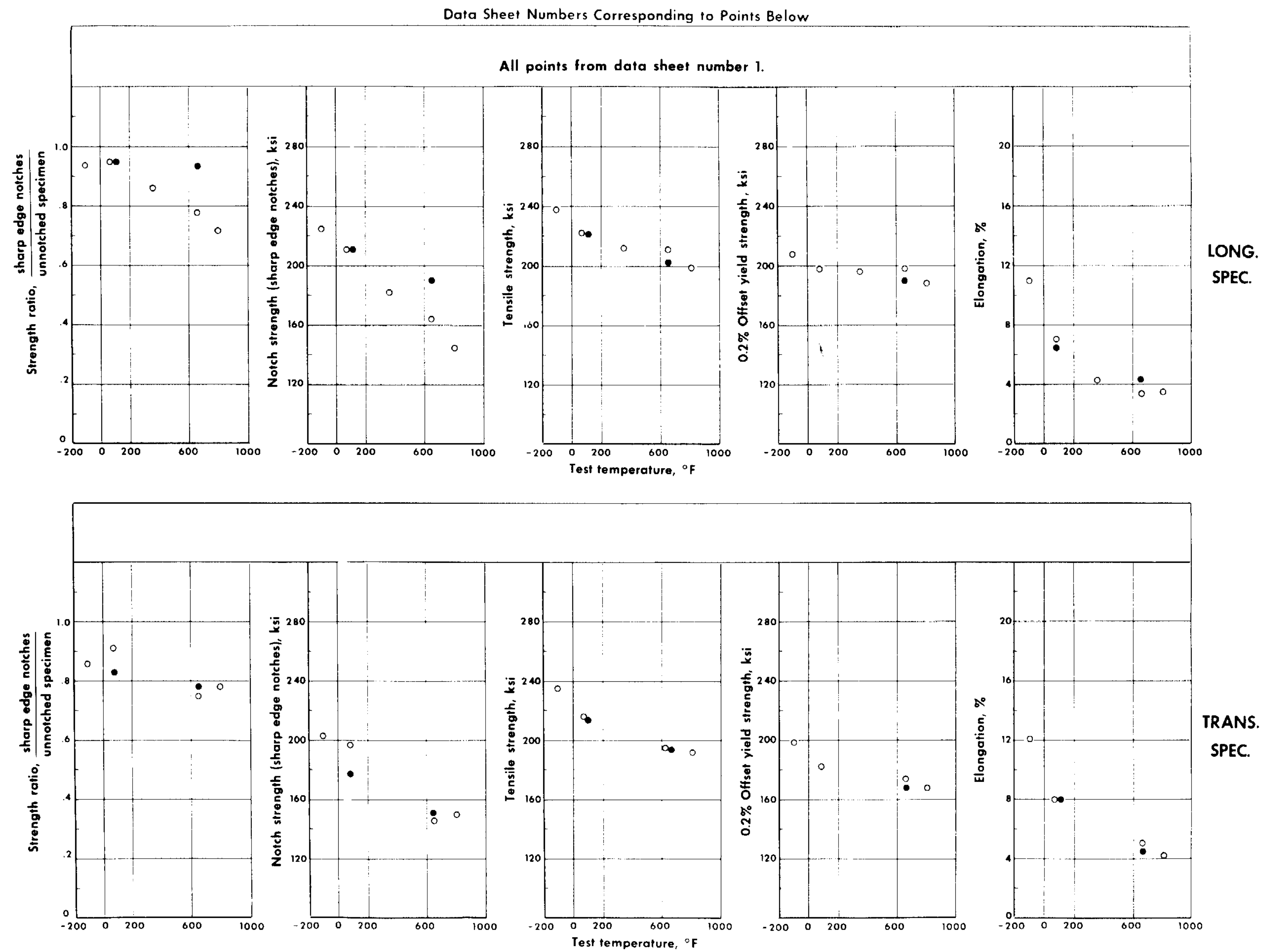
(b) UTS - ultimate tensile strength; YS - 0.2-percent offset yield strength; Elong. - elongation in 2 inches; NS - tensile strength of sharp edge notch sample; N/S - ratio of notch strength to unnotched tensile strength.

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1, 3	The University of Michigan	Allegheny Ludlum	W23211
2	Lockheed Aircraft Corp., California Co.	" "	21630

Composition, percent

Data Sheet	C	Si	Mn	Cr	Ni	Mo	Ti	Al	W	Fe	P	S	B
1	0.078	0.15	0.18	15.02	43.97	4.06	3.04	1.02	3.57	Bal	0.007	0.006	0.12
2	0.06	0.14	0.16	14.5	43.6	4.2	3.2	0.9	3.8	Bal			0.015



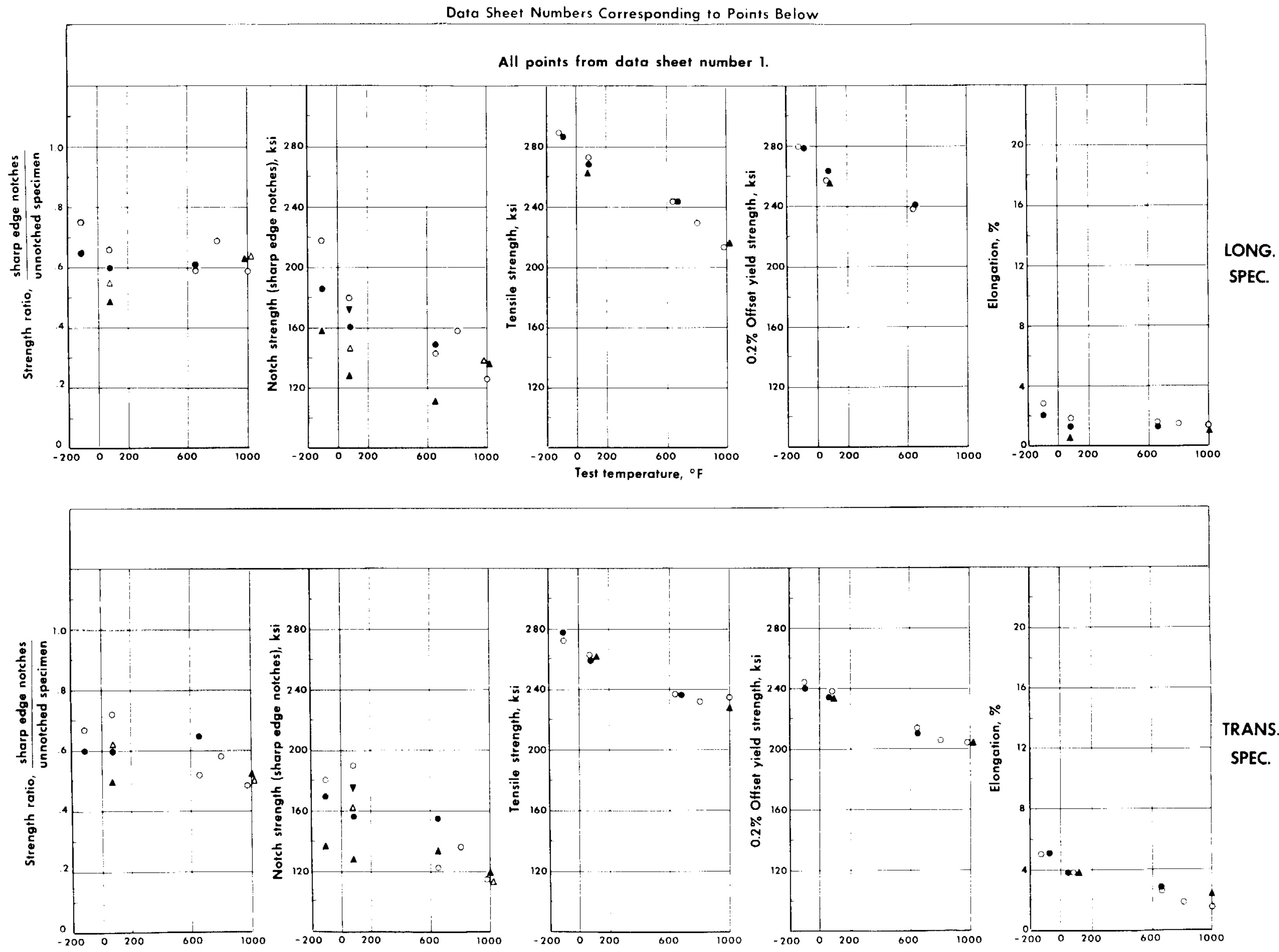
Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

D 979 (C. R. 30% + 16 hrs. 1200°)

Conditions of prior exposure

○ Unexposed

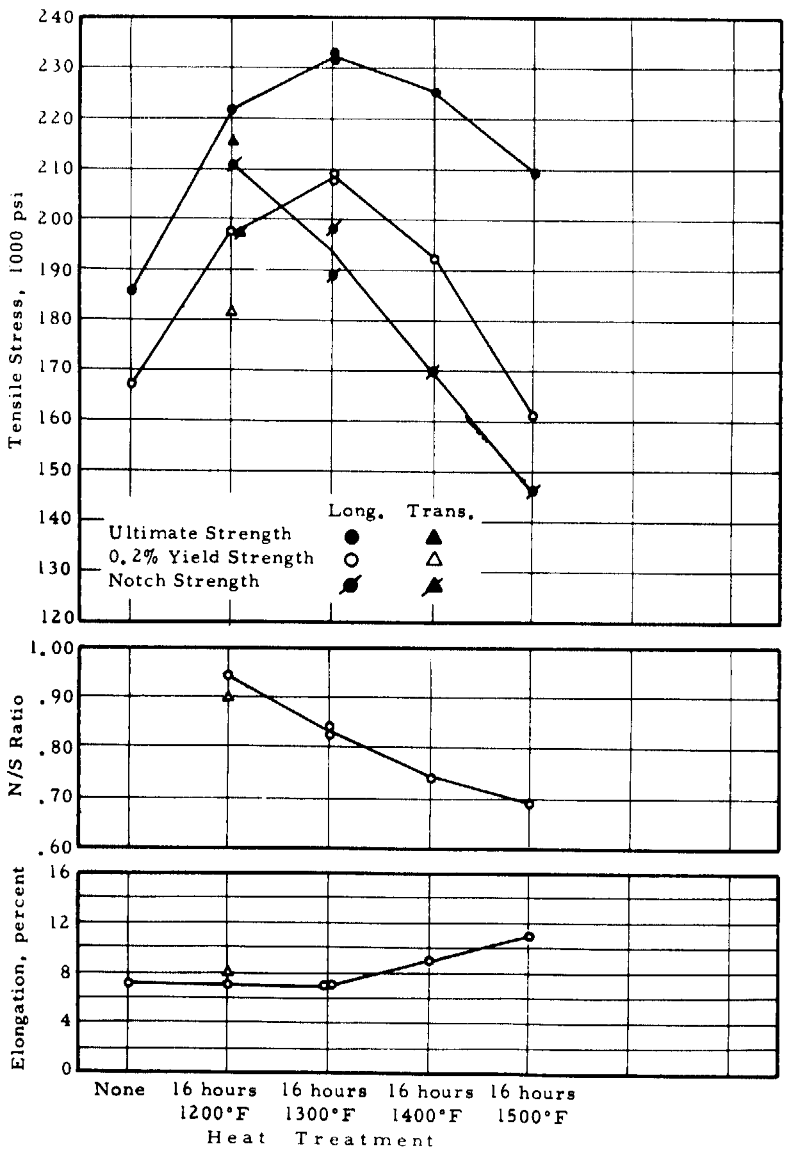
● 1000 hrs., 650°F, 40 ksi



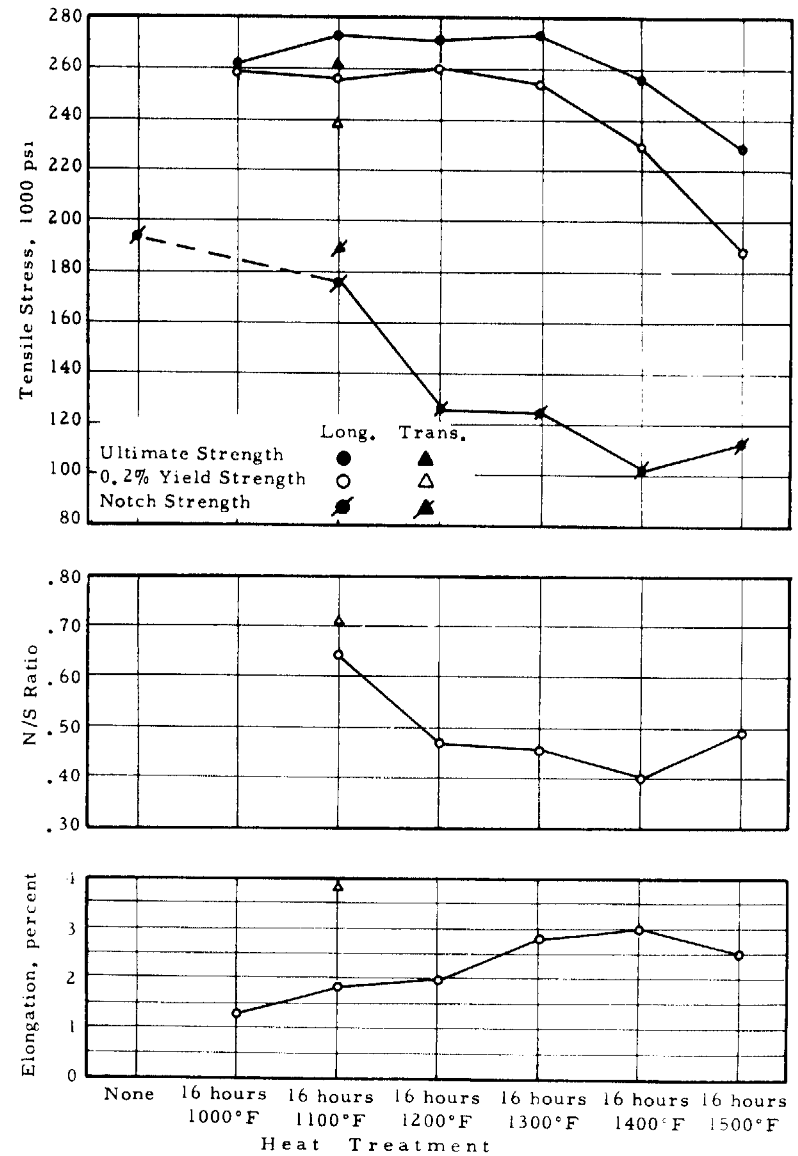
Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ▼ 1000 hrs., 800°F, 40 ksi
- ▲ 1000 hrs., 1000°F, 40 ksi
- △ 1000 hrs., 1000°F, 40 ksi (Notched after exposure)

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

D 979 (C. R. 50% + 16 hrs. 1100°)

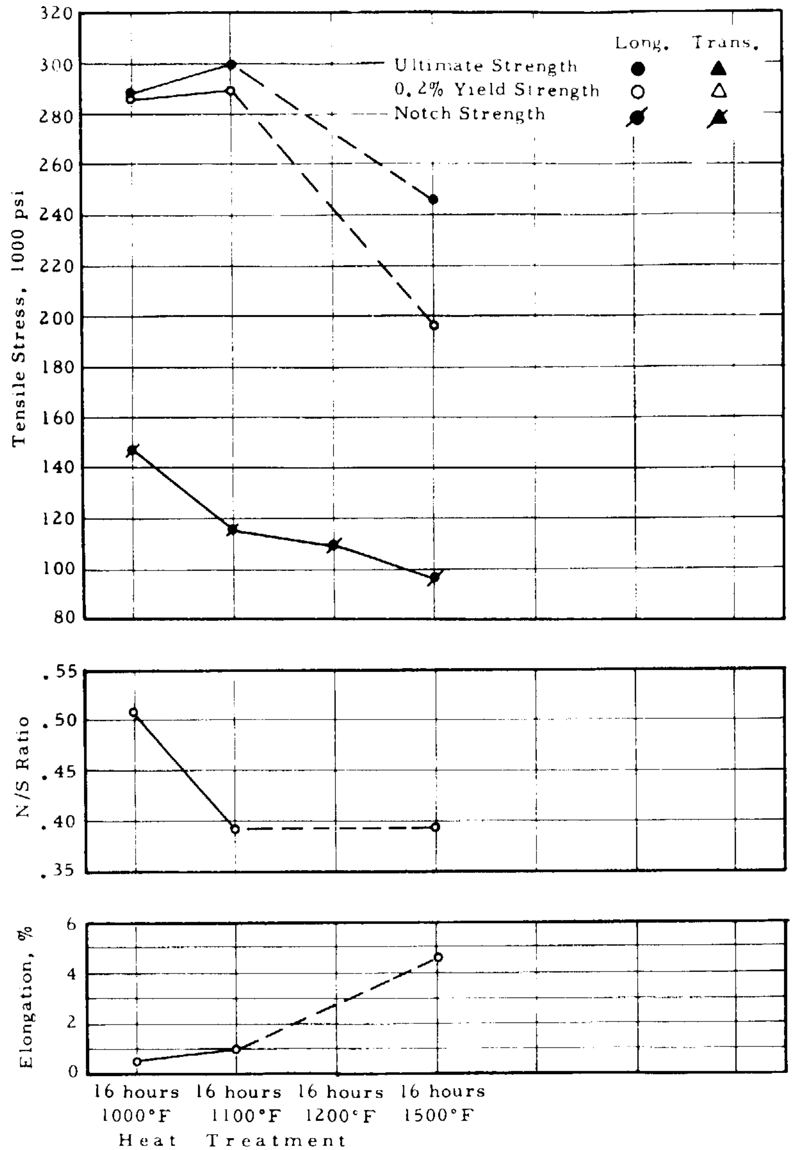


Results for 30-percent cold worked strip.

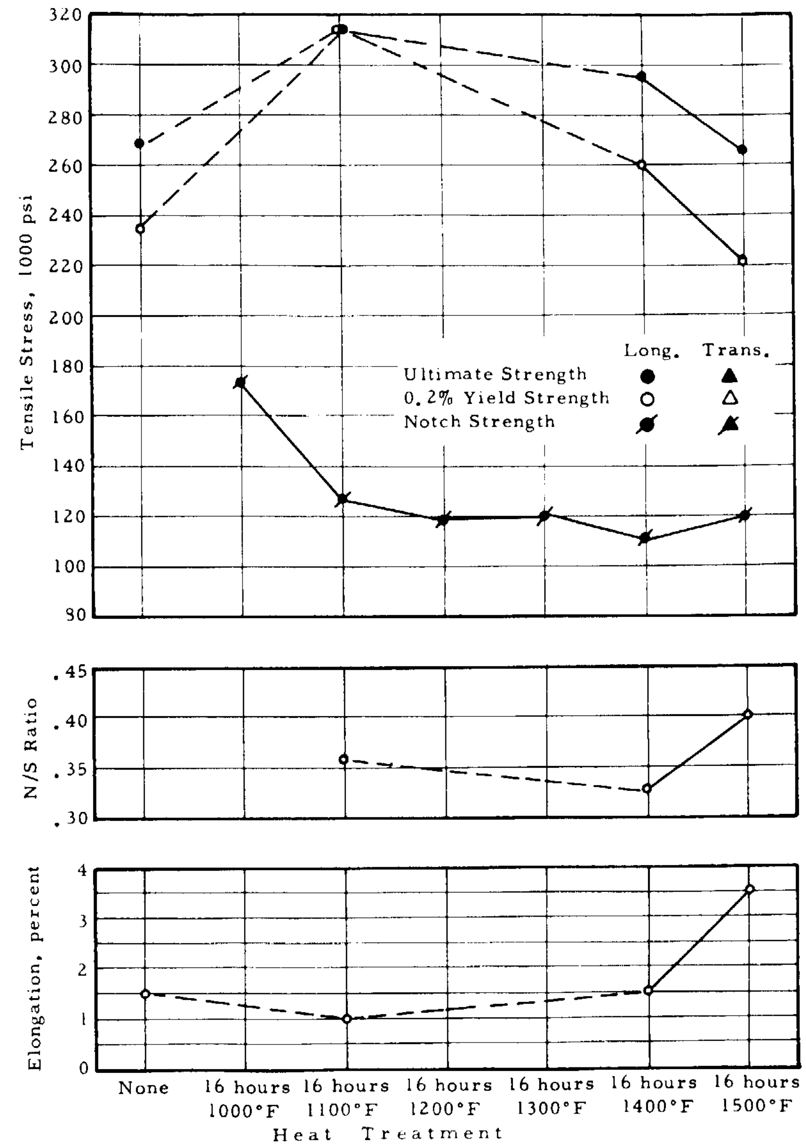


Results for 50-percent cold worked strip.

Effect of heat treatment on the room-temperature tensile properties of D-979 alloy.



Results for 65-percent cold worked strip.



Results for 80-percent cold worked strip.

Effect of heat treatment on the room-temperature tensile properties of D-979 alloy. (Concluded).

Alloy Designation: D979 Contributor: The University of Michigan Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	L	T	L	T
30% Cold rolled + 16 hours, 1200°F																			
None			-110	238	235	208	198	11.0		12.0		225	203	0.94	0.86				
None			Room	222	216	198	182	7.0		8.0		211	197	0.95	0.91				
650	40	1000	Room	221	214	---	---	6.5		8.0		211	177	0.95	0.83				
None			350	212	---	196	---	4.3		---		182	---	0.86	---				
None			650	211	195	198	174	3.3		5.0		164	146	0.78	0.75				
650	40	1000	650	202	194	190	168	4.3		4.5		190	151	0.94	0.78				
None			800	199	192	188	168	3.5		4.3		144	150	0.72	0.78				
50% Cold rolled + 16 hours, 1100°F																			
None			-110	289	272	280	244	2.8		5.0		218	181	0.75	0.67				
650	40	1000	-110	286	278	279	241	2.0		5.0		186	170	0.65	0.61				
1000	40	1000	-110	---	---	---	---	---		---		158	136	---	---				
None			Room	273	262	257	238	1.8		3.8		180	190	0.66	0.72				
650	40	1000	Room	269	260	263	235	1.3		3.8		161	157	0.60	0.60				
800	40	1000	Room	---	---	---	---	---		---		172	176	---	---				
1000	40	1000	Room	263	261	255	234	<1		3.8		128	128	0.49	0.49				
1000	40	1000	Room	---	---	---	---	---		---		146[e]	161[e]	0.55	0.62				
None			650	244	237	239	213	1.5		2.5		143	123	0.59	0.52				
650	40	1000	650	244	237	240	210	1.3		2.8		149	155	0.61	0.65				
1000	40	1000	650	---	---	---	---	---		---		111	133	---	---				
None			800	230	233	(f)	206	1.5		1.8		158	136	0.69	0.58				
None			1000	214	234	(f)	204	1.3		1.5		126	115	0.59	0.49				
1000	40	1000	1000	215	228	(f)	204	1.0		2.3		136	119	0.63	0.52				
1000	40	1000	1000	---	---	---	---	---		---		137[e]	113[e]	0.64	0.50				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.
[b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.
[d] L = longitudinal orientation T = transverse orientation
[e] Notch machined after exposure
[f] Specimens failed near the yield strength

Alloy Designation: D979 Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 2
Heat Treatment: Solution treated 15 min. at 1850°F, air cool, and aged 6 hrs. 1550°F, air cool, and 16 hrs. 1300°F, air cool Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data: Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	Control Coupon Data: F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
Room	L	0.054	8.98	42900	88.5	1.62	689	150	199	7.0
Room	L	0.054	8.97	30000	62.0	2.59	568			

138

Alloy Designation: D 979 **Contributor:** The University of Michigan (NASA Sponsored) **Data Sheet No.:** 3

Heat Treatment: As noted below **Sheet Thickness, inches** 0.025

EVALUATION OF HEAT TREATMENT
D-979 ALLOY

(all tests at room temperature)

		CONDITION OF MATERIAL PRIOR TO AGING																			
		COLD WORKED 30%					COLD WORKED 50%					COLD WORKED 65%					COLD WORKED 80%				
Heat Treatment	Direction (a)	UTS (b) (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S
None	L	186	167	7	---	---	---	---	---	187	---	---	---	--	---	---	249	214	1.5	---	..
	T	---	---	--	---	---	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
16 hrs at 1000°F	L	---	---	--	---	---	261	259	1.3	---	---	289	287	<1	148	.51	---	---	---	153	---
	T	---	---	--	---	---	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
16 hrs at 1100°F	L	---	---	--	---	---	273	257	1.8	176	.64	300	290	1	116	.39	294	294	1	107	.36
	T	---	---	--	---	---	262	238	3.8	190	.72	---	---	--	---	---	---	---	---	---	---
16 hrs at 1200°F	L	222	198	7	211	.95	271	260	2	126	.47	---	---	--	110	---	---	---	---	99	---
	T	216	182	8	197	.91	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
16 hrs at 1300°F	L	232	208	7	189	.82	273	254	2.8	125	.46	---	---	--	---	---	---	---	---	100	---
	L	233	209	7	198	.85	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
	T	---	---	--	---	---	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
16 hrs at 1400°F	L	226	193	9	170	.75	256	229	3	102	.40	---	---	--	---	---	275	240	1.5	90	.33
	T	---	---	--	---	---	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
16 hrs at 1500°F	L	210	162	11	147	.70	228	187	2.5	112	.49	246	196	4.5	97	.39	246	201	3.5	99	.40
	T	---	---	--	---	---	---	---	---	---	---	---	---	--	---	---	---	---	---	---	..

(a) L - Longitudinal
T - Transverse

(b) UTS - ultimate tensile strength; YS - 0.2-percent offset yield strength; Elong. - elongation in 2 inches; NS - tensile strength of sharp edge notch sample; N/S - ratio of notch strength to unnotched tensile strength.

L-605

INDEX OF MATERIALS

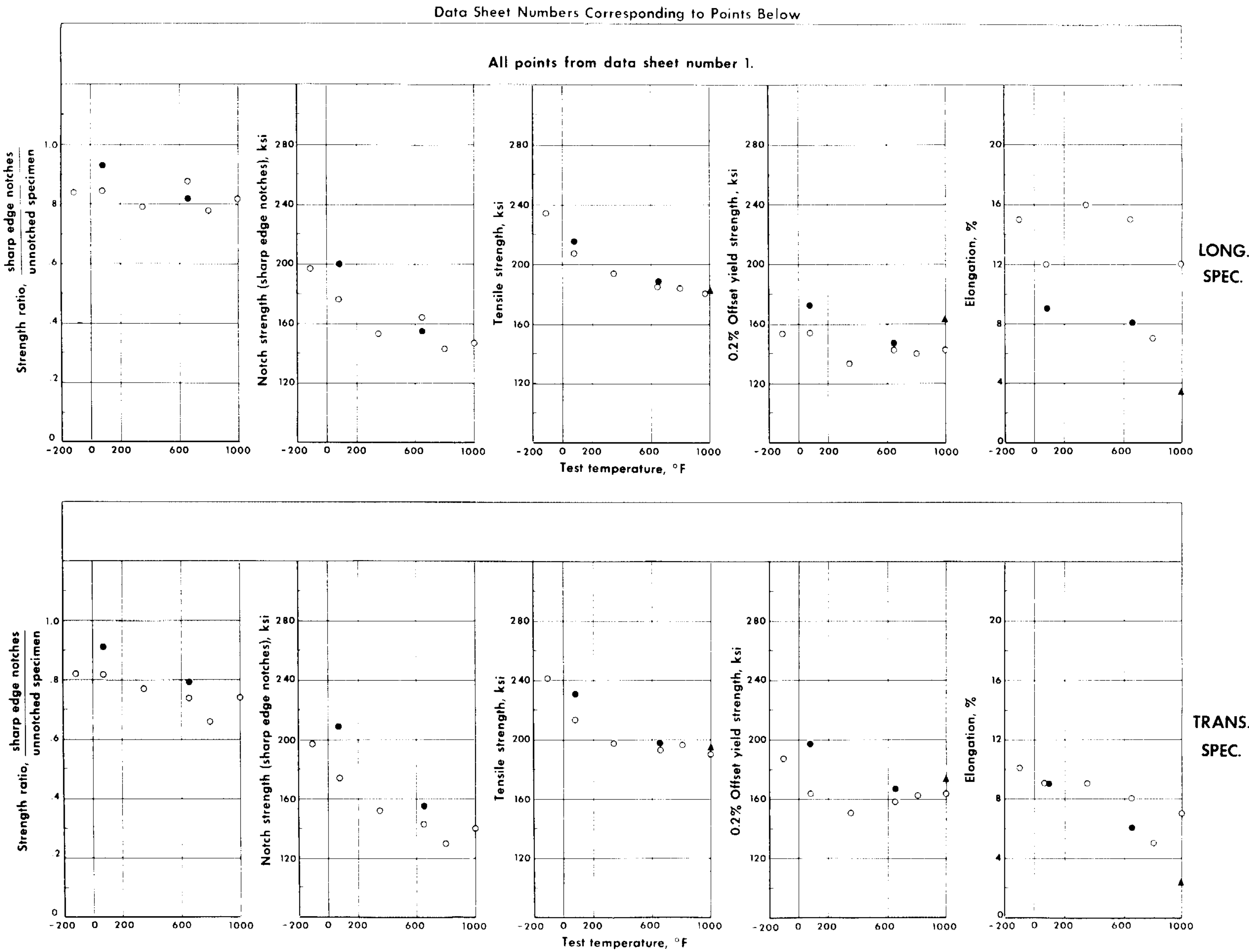
Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	The University of Michigan	Allegheny Ludlum	L1842

Composition, percent

Data Sheet	C	Si	Mn	Cr	Ni	W
1	0.09	0.65	1.34	20.37	9.60	14.49

Fe	P	S	Co
1.98	0.009	0.010	Bal

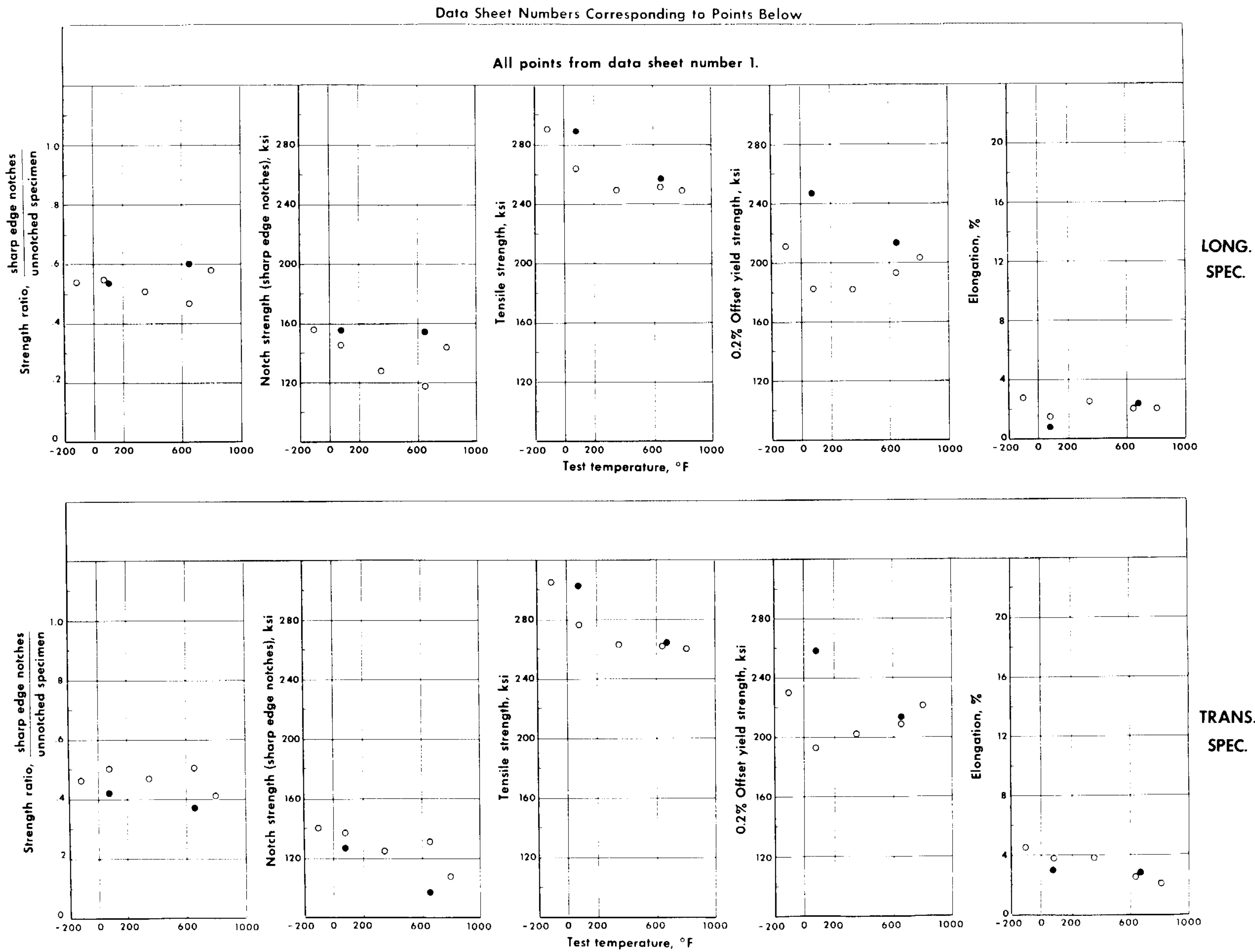
140



Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ▲ 1000 hrs., 1000°F, 40 ksi

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

L 605 (C. R. 25%)



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

L 605 (C. R. 45%)

Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi

Alloy Designation: L-605 Contributor: The University of Michigan Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
Cold reduced 25%																			
None			-110	234	241	154	187	15		10		197	197	0.84	0.82				
None			Room	208	213	154	163	12		9		176	174	0.85	0.82				
650	40	1000	Room	215	230	172	197	9		9		200	209	0.93	0.91				
None			350	194	197	133	150	16		9		153	152	0.79	0.77				
None			650	186	193	143	158	15		8		164	142	0.88	0.74				
650	40	1000	650	188	197	147	167	8		6		155	155	0.82	0.79				
None			800	184	196	140	162	7		5		143	130	0.78	0.66				
None			1000	181	190	143	164	12		7		148	140	0.82	0.74				
1000	40	1000	1000	183	195	164	174	3.5		2.5		(e)	(f)	---	---				
Cold reduced 35%																			
None			Room	232		191		8				172		0.74					
None			650	212		168		7				156		0.74					
Cold reduced 45%																			
None			-110	291	305	211	230	2.8		4.5		157	140	0.54	0.46				
None			Room	264	276	182	192	2.5		3.8		146	137	0.55	0.50				
650	40	1000	Room	>290[g]	302	247	258	>0.8		3.0		156	127	<0.54	0.42				
None			350	250	263	182	202	2.5		3.8		128	124	0.51	0.47				
None			650	251	262	193	208	2.0		2.5		118	130	0.47	0.50				
650	40	1000	650	257	264	214	213	2.3		2.8		154	97	0.60	0.37				
None			800	249	260	203	221	2.0		2.0		144	107	0.58	0.41				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.
[b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.
[d] L = longitudinal orientation T = transverse orientation
[e] Notched specimen fractured after 26.4 hours exposure
[f] Notched specimen fractured after 33.4 hours exposure
[g] Specimen broke at pin hole, not in gage section

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N 155

INDEX OF MATERIALS

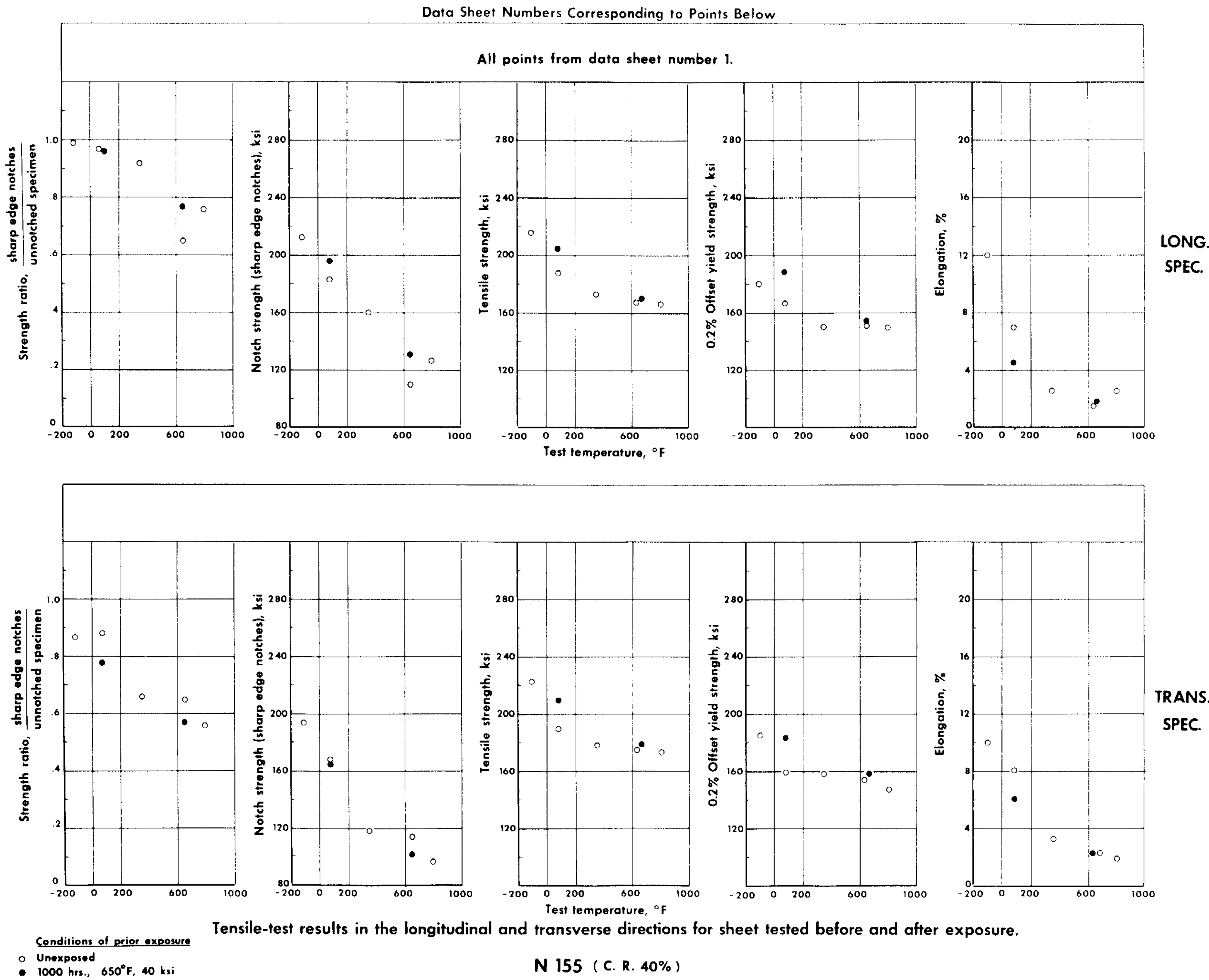
Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	The University of Michigan	Allegheny Ludlum	M-5623

Composition, percent

Data Sheet	C	Si	Mn	Cr	Ni	Co	Mo
1	0.11	0.72	1.62	22.14	19.91	19.50	3.22

Cb + Ta	W	P	S	Fe
1.21	2.40	0.017	0.011	Bal

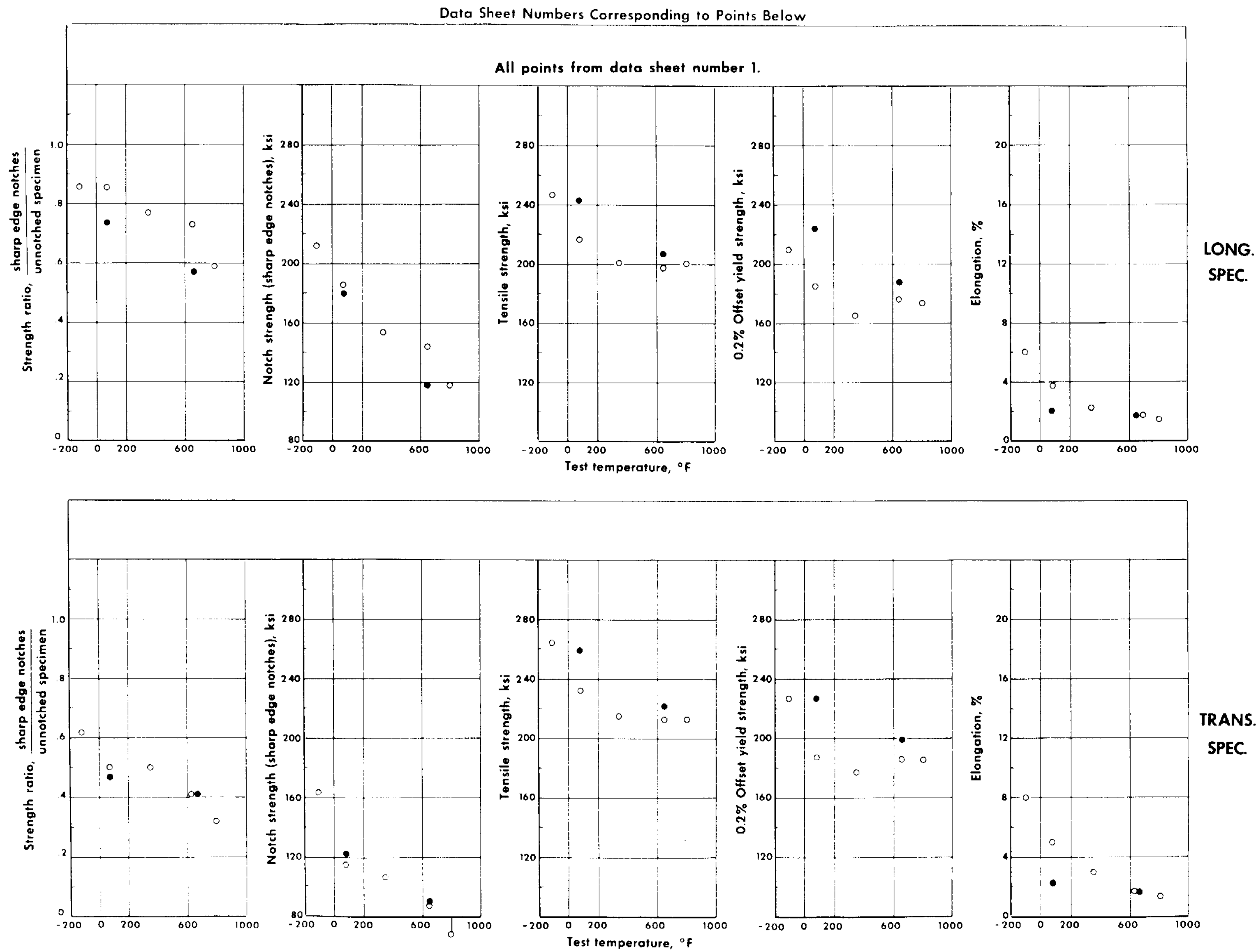
144



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

N 155 (C. R. 40%)

145



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi

N 155 (C. R. 65%)

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Alloy Designation: N155 Contributor: The University of Michigan Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
Cold reduced 40%																			
None			-110	216	222	180	185	12		10		213	194	0.99	0.87				
None			Room	188	190	167	159	7.0		8		183	168	0.97	0.88				
650	40	1000	Room	205	211	189	183	4.5		6		197	164	0.96	0.78				
None			350	173	178	150	158	2.5		3.3		160	118	0.92	0.66				
None			650	168	175	151	154	1.5		2.3		110	114	0.65	0.65				
650	40	1000	650	170	179	155	158	1.8		2.3		131	102	0.77	0.57				
None			800	166	173	150	147	2.5		1.8		127	97	0.76	0.56				
Cold reduced 55%																			
None			Room	209		183		4.5				179		0.86					
None			650	190		170		1.5				132		0.69					
Cold reduced 65%																			
None			-110	247	264	210	227	6.0		8		212	164	0.86	0.62				
None			Room	217	232	185	187	3.8		5.0		186	115	0.86	0.50				
650	40	1000	Room	244	259	224	227	2.0		2.3		180	122	0.74	0.47				
None			350	201	215	165	177	2.3		3.0		154	107	0.77	0.50				
None			650	198	213	176	186	1.8		1.8		144	88	0.73	0.41				
650	40	1000	650	207	221	188	199	1.8		1.8		118	91	0.57	0.41				
None			800	201	213	174	185	1.5		1.3		118	69	0.59	0.32				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation

INCONEL W

INDEX OF MATERIALS

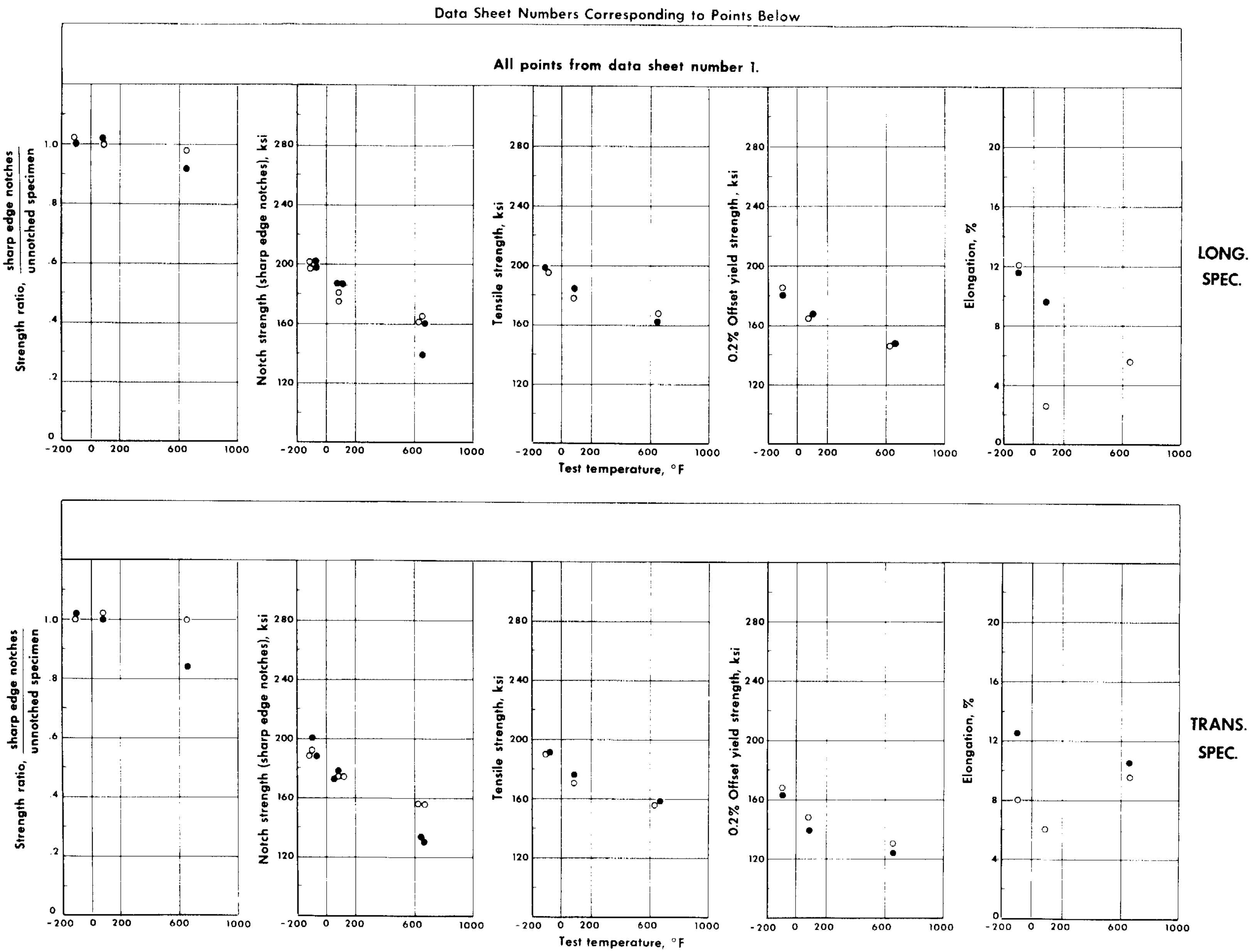
Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Lewis Research Center, NASA Materials Research Laboratories, Inc.[a]	Allegheny Ludlum	3565-WL

Composition, percent

Data Sheet	C	Mn	Si	S	Cr	Ni	Al	Fe	Ti
1	0.04	0.50	0.59	0.007	15.19	74.19	0.68	6.23	2.52

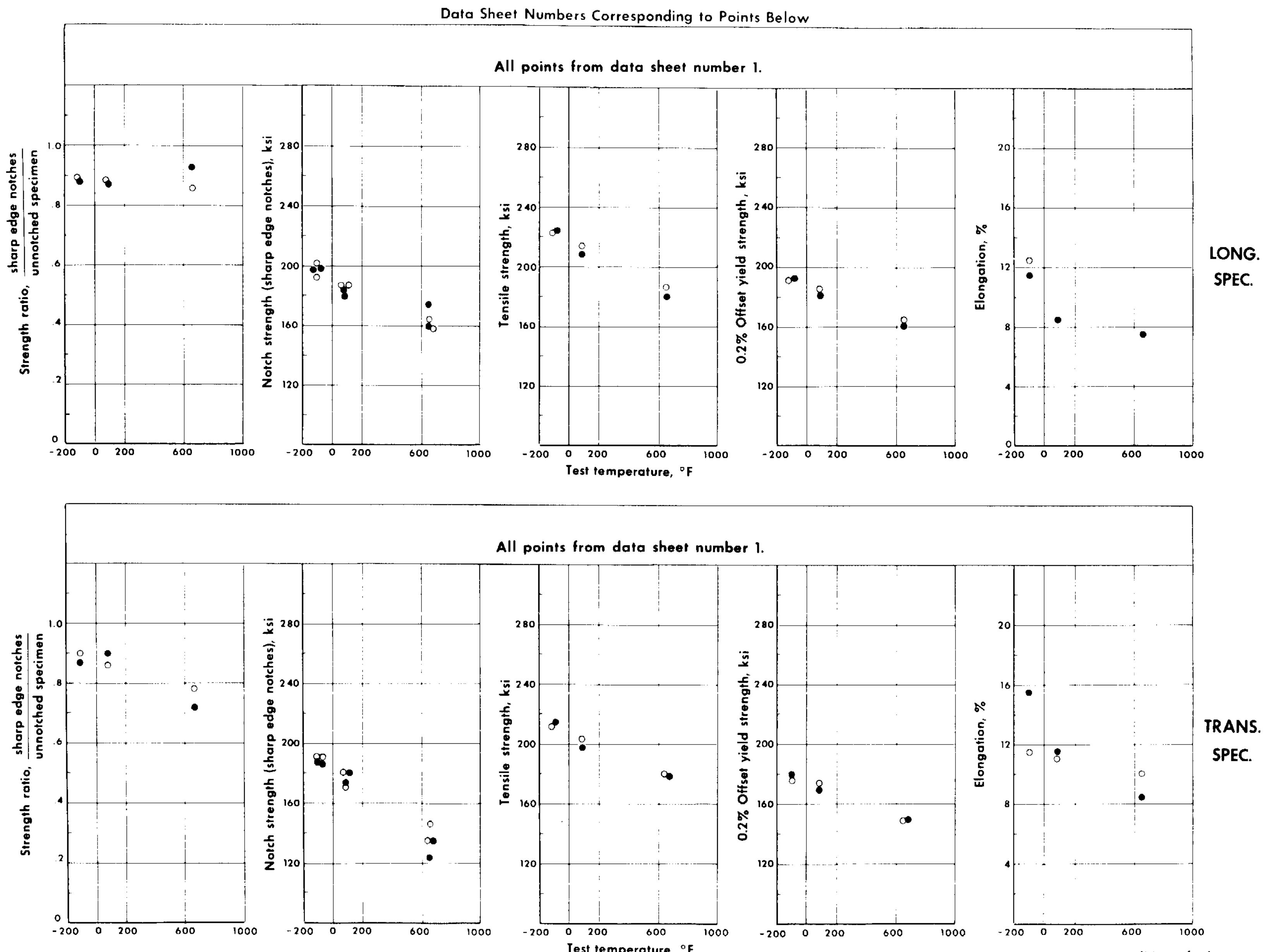
(a) Salt exposures

118



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Inconel W (C. R. 50%)

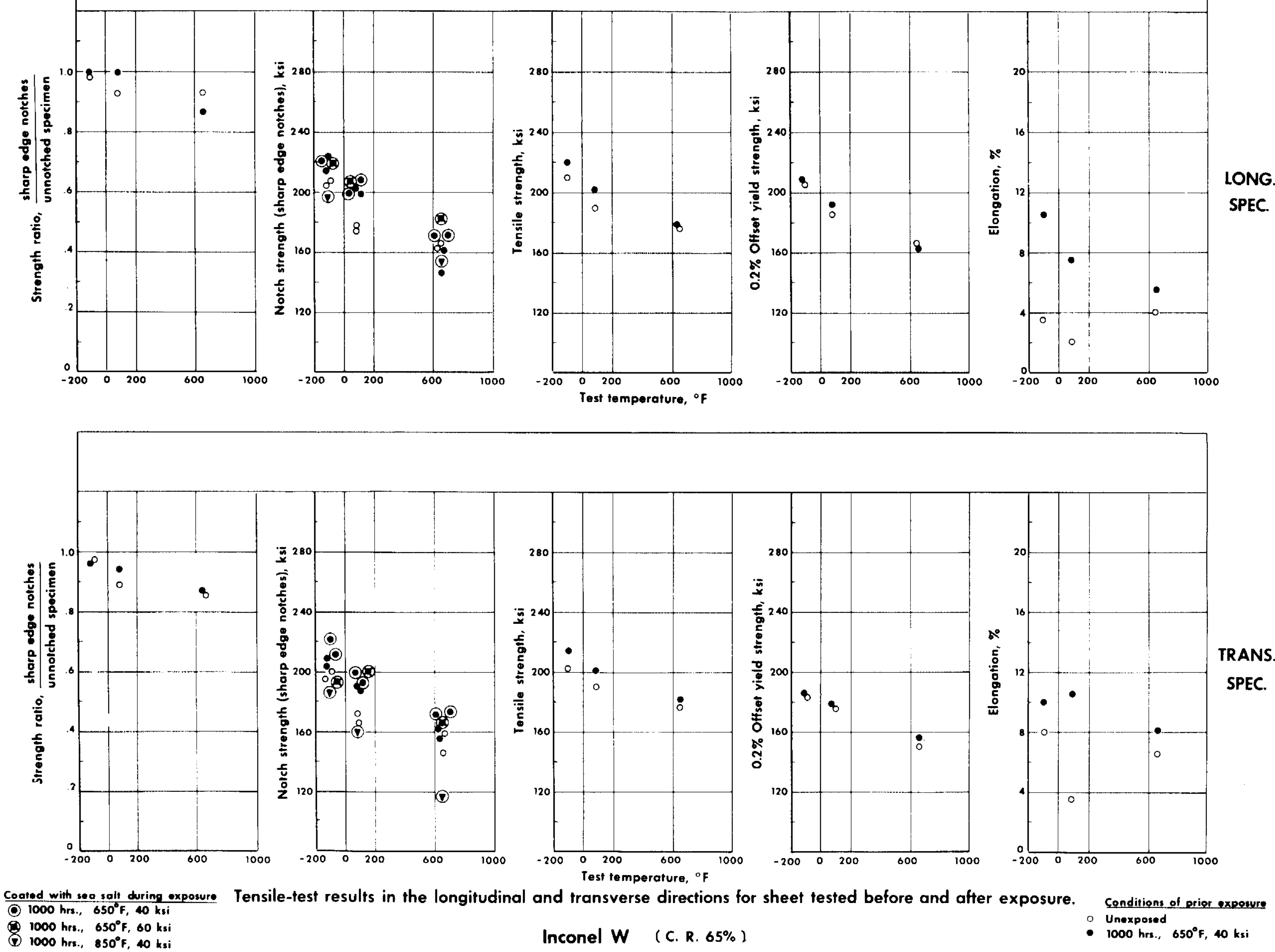


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Inconel W (C. R. 50% + 20 hrs. 1300°)

Data Sheet Numbers Corresponding to Points Below

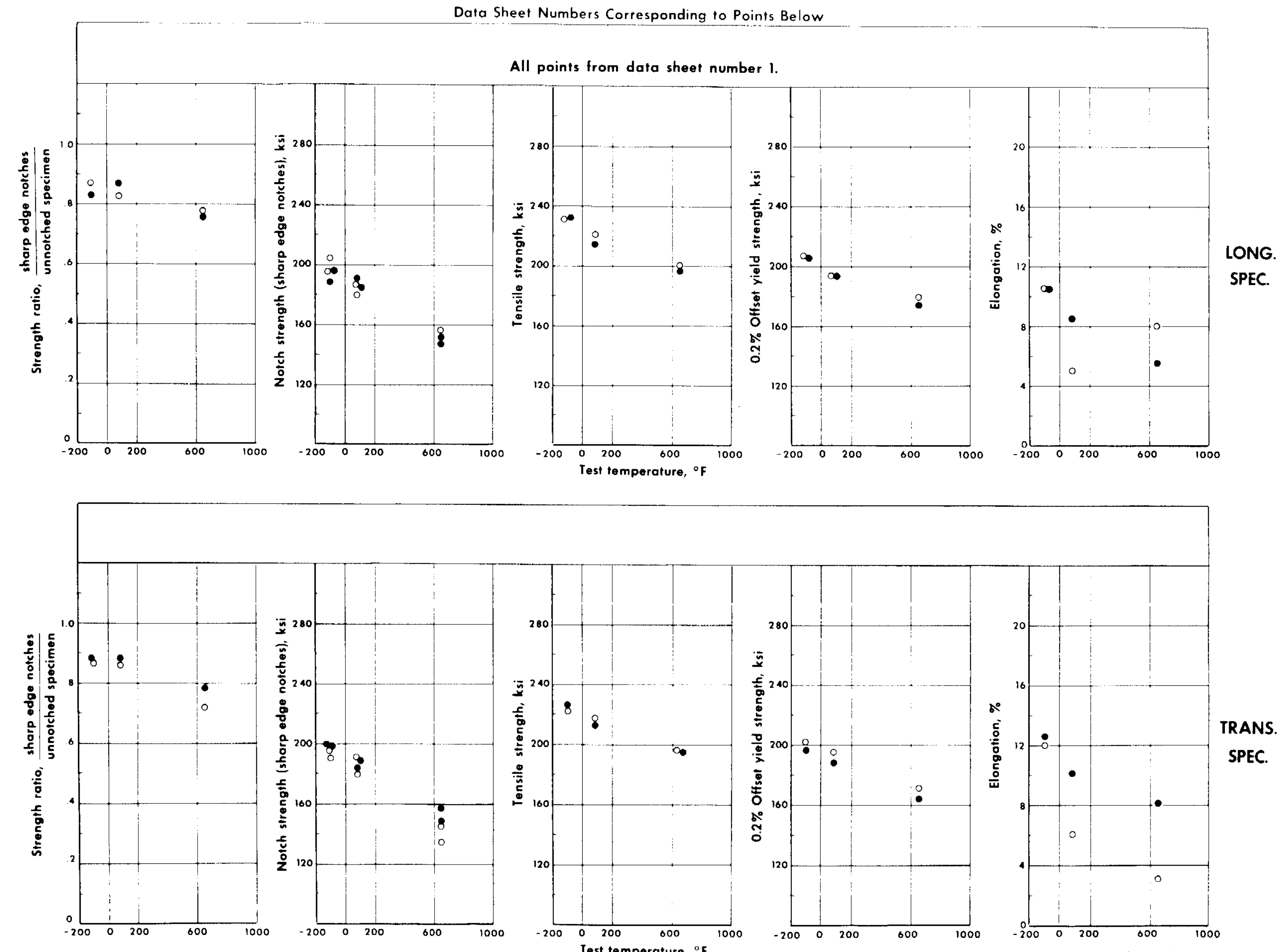
All points from data sheet number 1.



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Inconel W (C. R. 65%)

151



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Inconel W (C. R. 65% + 20 hrs. 1300°)

152

Alloy Designation: Inconel W | Contributor: Materials Research Laboratory, Inc. (Salt exposures); NASA, Lewis Research Center | Data Sheet No.: 1

Heat Treatment: As noted below | Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches				SALT EXPOSURES: Sharp edge notches[e]			
				Tensile strength, ksi		Yield strength,[b] ksi		Elong[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S		Tensile strength, ksi			
Temp. °F	Stress ksi	Time, hr.		L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
									50% cold rolled										
None			-110	195.0	190.0	185.2	167.5	12		8		196.8	192.6	1.02	1.00				
None			-110	-----	-----	-----	-----	----		----		202.1	188.8						
650	40	1000	-110	198.0	191.5	180.4	163.1	11.5		12.5		196.9	188.4	1.01	1.02				
650	40	1000	-110	-----	-----	-----	-----	----		----		201.6	200.0						
None			Room	178.4	170.9	164.7	147.6	2.5		6		180.8	174.3	1.00	1.02				
None			Room	-----	-----	-----	-----	----		----		175.4	174.2						
650	40	1000	Room	184.4	175.5	166.0	138.7	9.5		(f)		187.4	177.5	1.02	1.00				
650	40	1000	Room	-----	-----	-----	-----	----		----		187.5	173.1						
None			650	166.7	156.9	146.1	130.4	5.5		9.5		161.6	156.4	0.98	1.00				
None			650	-----	-----	-----	-----	----		----		164.9	155.6						
650	40	1000	650	162.7	157.7	147.0	124.0	(f)		10.5		138.7	130.3	0.92	0.84				
650	40	1000	650	-----	-----	-----	-----	----		----		161.0	133.2						
									50% cold rolled + 1300°F, 20 hours										
None			-110	222.7	212.1	191.2	176.3	12.5		11.5		202.2	191.2	0.89	0.90				
None			-110	-----	-----	-----	-----	----		----		192.5	191.1						
650	40	1000	-110	223.7	213.9	192.3	180.2	11.5		15.5		196.8	187.2	0.88	0.87				
650	40	1000	-110	-----	-----	-----	-----	----		----		197.9	186.7						
None			Room	213.7	203.0	186.2	174.2	(f)		11		186.9	179.8	0.88	0.86				
None			Room	-----	-----	-----	-----	----		----		187.3	170.2						
650	40	1000	Room	209.0	197.3	182.6	169.5	8.5		11.5		183.7	173.7	0.87	0.90				
650	40	1000	Room	-----	-----	-----	-----	----		----		179.5	180.4						
None			650	187.4	179.7	164.1	149.5	(f)		10		164.0	135.4	0.86	0.78				
None			650	-----	-----	-----	-----	----		----		157.7	146.0						
650	40	1000	650	180.0	179.4	161.0	150.0	7.5		8.5		159.0	134.5	0.93	0.72				
650	40	1000	650	-----	-----	-----	-----	----		----		174.0	124.2						
									65% cold rolled										
None			-110	210.4	202.6	205.8	182.5	3.5		8		207.4	195.2	0.98	0.97				
None			-110	-----	-----	-----	-----	----		----		204.8	199.5						
650	40	1000	-110	219.6	214.0	207.8	186.0	10.5		10		214.7	203.1	1.00	0.96	222.4	221.0		
650	40	1000	-110	-----	-----	-----	-----	----		----		223.6	208.9			-----	211.0		
650	60	1000	-110	-----	-----	-----	-----	----		----		-----	-----	----	----	220.0	212.7		
850	40	1000	-110	-----	-----	-----	-----	----		----		-----	-----	----	----	196.7	187.0		
None			Room	190.3	190.1	184.5	176.2	2		3.5		174.5	171.8	0.93	0.89				
None			Room	-----	-----	-----	-----	----		----		177.6	165.9						
650	40	1000	Room	201.6	201.2	191.9	177.5	7.5		10.5		200.5	190.5	1.00	0.94	200.0	199.0		
650	40	1000	Room	-----	-----	-----	-----	----		----		204.3	187.8			209.0	193.0		
650	60	1000	Room	-----	-----	-----	-----	----		----		-----	-----	----	----	208.0	200.0		
850	40	1000	Room	-----	-----	-----	-----	----		----		-----	-----	----	----	-----	159.8		
None			650	175.8	177.0	164.6	150.0	4		6.5		163.6	159.1	0.93	0.86				
None			650	-----	-----	-----	-----	----		----		165.1	145.7						
650	40	1000	650	178.4	182.3	162.7	155.9	5.5		8		146.6	161.8	0.87	0.87	171.6	173.0		
650	40	1000	650	-----	-----	-----	-----	----		----		162.4	155.5			171.4	172.0		
650	60	1000	650	-----	-----	-----	-----	----		----		-----	-----	----	----	182.2	166.0		
850	40	1000	650	-----	-----	-----	-----	----		----		-----	-----	----	----	153.8	116.7		
									65% cold rolled + 1300°F, 20 hours										
None			-110	231.4	221.9	206.8	201.8	10.5		12		205.3	190.4	0.87	0.87				
None			-110	-----	-----	-----	-----	----		----		195.8	195.7						
650	40	1000	-110	232.2	226.4	205.9	196.0	10.5		12.5		196.9	200.0	0.83	0.88				
650	40	1000	-110	-----	-----	-----	-----	----		----		189.2	198.9						
None			Room	221.4	217.0	193.9	195.0	5		6		186.8	191.4	0.83	0.86				
None			Room	-----	-----	-----	-----	----		----		180.8	179.8						
650	40	1000	Room	215.0	212.5	194.1	188.2	8.5		10		190.8	188.9	0.87	0.88				
650	40	1000	Room	-----	-----	-----	-----	----		----		184.5	184.0						
None			650	201.0	196.0	179.2	170.6	8		3		156.9	135.1	0.78	0.72				
None			650	-----	-----	-----	-----	----		----		-----	145.7						
650	40	1000	650	197.1	195.1	173.5	163.7	5.5		8		146.8	157.7	0.76	0.78				
650	40	1000	650	-----	-----	-----	-----	----		----		151.5	148.5						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] After exposure with a coating of natural sea salt. f = Broke outside gage marks.

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INCONEL X

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Lewis Research Center, NASA	--------	---------

154

Alloy Designation: Inconel X Contributor: NASA, Lewis Research Center Data Sheet No.: 1

Heat Treatment: As noted Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
Cold rolled 27%																			
None			650	136.0		118.6		15.5				131.6		0.97					
650	40	1000	650	128.6		112.1		18				113.9		0.88					
Cold rolled 67%																			
None			650	194.8	195.2	156.0	156.0	1		3.5		153.8	139.1	0.79	0.71				
650	40	1000	650	197.1	198.1	195.4	117.4	2.5		4.5		162.6	149.8	0.82	0.76				

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation

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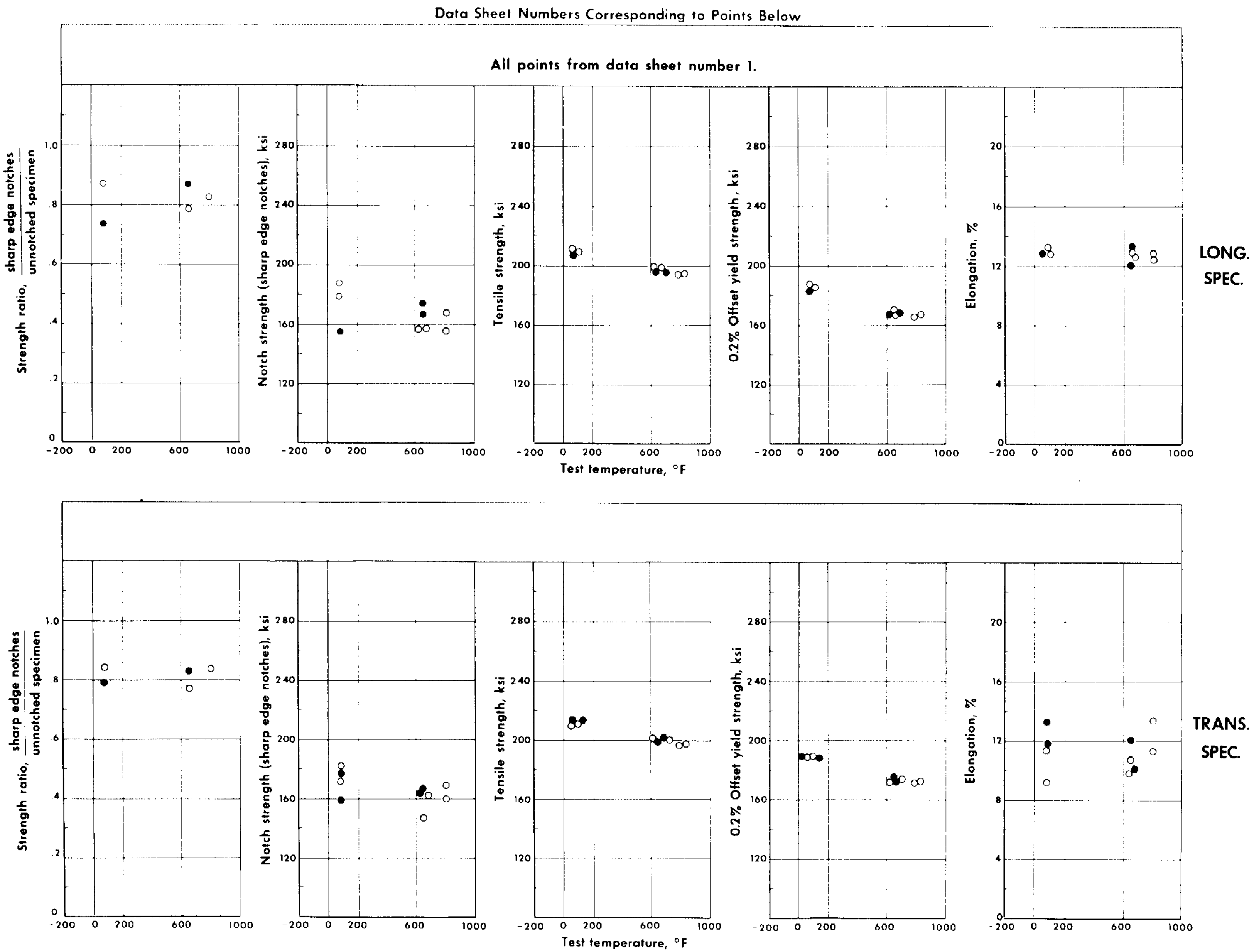
R 27

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Allegheny Ludlum Steel Corporation	Allegheny Ludlum	23676-4

Composition, percent

Data Sheet	C	Mn	Si	Cr	Ni	Fe	Cb	Ti	Al	B
1	0.08	0.24	0.03	15.2	44.8	Bal	4.6	2.1	0.35	0.011



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

R 27 (2050° WQ + 16 hrs. 1400° + 24 hrs. 1200°)

Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi

Alloy Designation: R-27 Contributor: Allegheny Ludlum Steel Corp. Data Sheet No.: 1

Heat Treatment: As noted below Sheet Thickness, inches: ____

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp. °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
2050°F, Water Quench																			
None			Room	104.0[e]		50.0[e]		55.0[e]				-----	-----	----	----				
2050°F, WQ + 1400°F, 16 hrs, AC + 1200°F, 24 hrs., AC																			
None			-320	261.4	269.0	214.0	226.2	14.7	2.25	14.2	2.25	208.0	192.5	0.82	0.73				
None			-320	261.4	268.4	214.4	225.5	12.9	2.25	13.3	2.25	221.7	199.2						
None			Room	211.1	210.9	187.6	189.4	12.9	2.25	11.4	2.25	179.4	171.6	0.87	0.84				
None			Room	209.4	210.3	185.0	189.0	13.1	2.25	9.1	2.25	188.0	181.5						
650	40	1000	Room	208.3	212.7	182.7	188.5	12.9	2.25	11.7	2.25	154.7	159.1	0.74	0.79				
650	40	1000	Room	-----	212.3	-----	188.9	----	----	13.3	2.25	-----	176.4						
None			650	197.7	199.8	168.1	171.0	12.7	2.25	10.7	2.25	156.6	162.0	0.79	0.77				
None			650	198.3	199.8	169.4	172.1	12.9	2.25	9.8	2.25	157.5	147.0						
650	40	1000	650	197.4	199.6	167.2	172.7	12.0	2.25	12.0	2.25	174.2	166.1	0.87	0.83				
650	40	1000	650	196.2	199.0	167.7	173.4	13.3	2.25	10.0	2.25	166.2	163.9						
None			800	194.0	196.3	165.6	171.7	12.4	2.25	11.3	2.25	167.5	159.9	0.83	0.84				
None			800	194.4	196.9	167.0	171.2	12.9	2.25	13.3	2.25	154.9	168.5						

BEND PROPERTIES (90° BEND)

HEAT TREATMENT	BEND SEVERITY (Radius/Sheet Thickness)	RESULTS L	RESULTS T
2050°F, WQ	0.5	Passed	Passed
2050°F, WQ + 1400°F, 16 hrs., AC	5.0	Failed	Failed
2050°F, WQ + 1400°F, 16 hrs., AC + 1200°F, 24 hrs., AC	5.0	Failed	Failed

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Testing direction not stated

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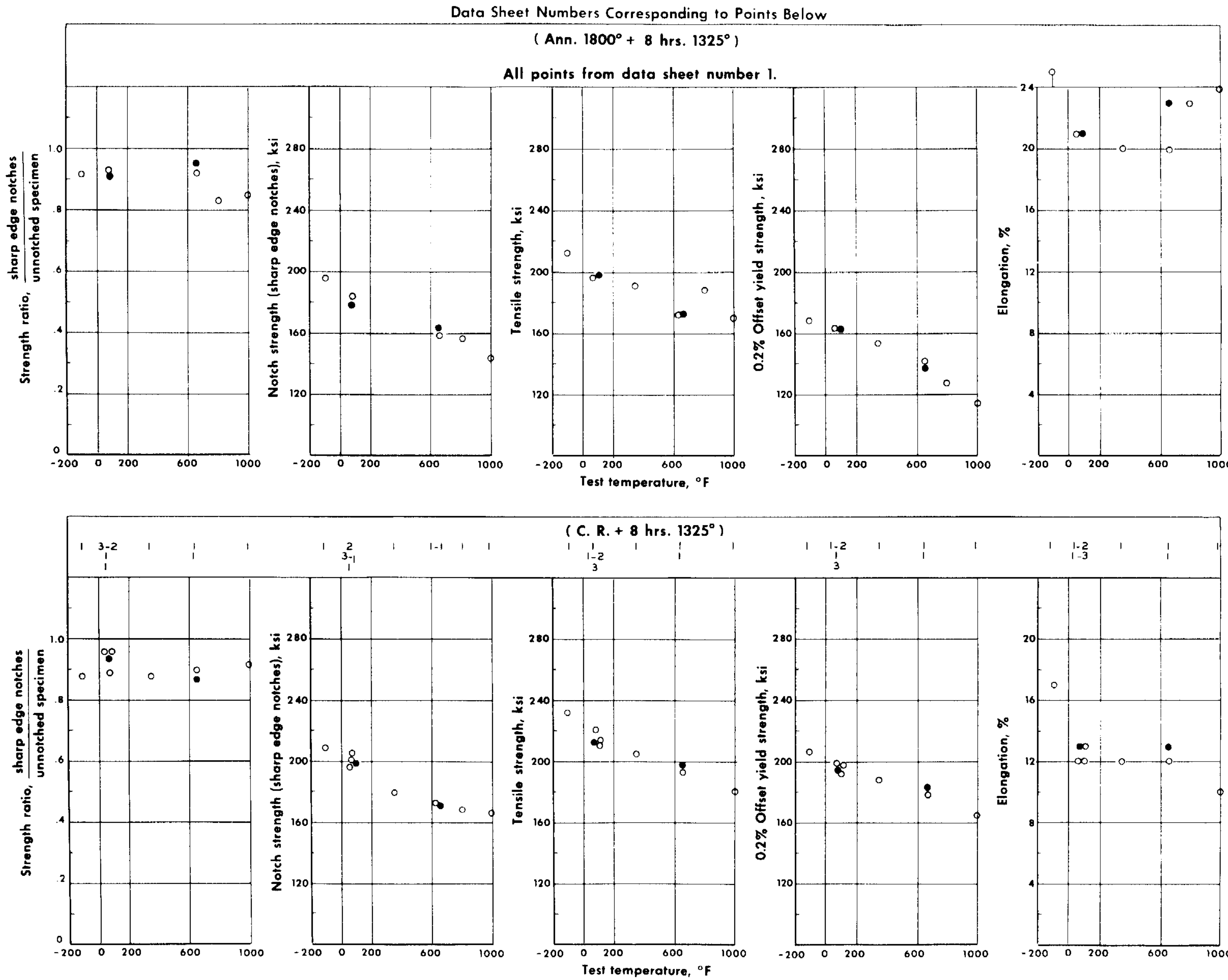
INCONEL 718

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	International Nickel Company, Inc. Huntington Alloy Products Division	International Nickel Company, Inc.	Y8455
2	" " " "	" " " "	Y8548
3	" " " "	" " " "	4680E
4	North American Aviation, Inc.	----	---
5	Lockheed Aircraft Corp., Calif. Co.	" " " "	Y8427

Composition, percent

Data Sheet	C	Mn	Fe	S	Si	Cu	Ni	Cr	Al	Ti	Mo	Cb + Ta
1	0.04	0.38	18.16	0.007	0.21	0.04	53.38	18.47	0.51	0.87	3.03	4.88
2	0.05	0.31	16.88	0.007	0.26	0.05	54.80	17.96	0.50	0.88	3.02	5.26
3	0.05	0.31	16.23	0.007	0.30	0.06	54.33	18.73	0.42	0.89	3.25	5.40
5	0.05	0.31	17.11	0.007	0.35	0.07	54.34	17.46	0.62	1.13	3.43	5.10



Tensile-test results in the transverse direction for sheet tested before and after exposure.

Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi

Inconel 718

Alloy Designation: Inconel 718 Contributor: Huntington Alloy Products Div., The International Nickel Co. Data Sheet No.: 1
Heat Treatment: As noted below Sheet Thickness, inches 0.027

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure Stress ksi	Prior exposure Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength, ksi T	Elong[c] % (L)	G.L., in. (L)	Elong % (T)	G.L., in. (T)	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
				Cold rolled + Annealed 1800°F, 1 hr. + 1325°F, 8 hrs., Furnace cooled 20°/hr. to 1150°F, then AC															
None			-110	-----	212.0	-----	168.5	----	----	25.0	----	-----	195.5	---	0.92				
None			Room	-----	196.0	-----	163.0	----	----	21.0	----	-----	185.0	---	0.93				
650	40	1000	Room	-----	197.0	-----	162.5	----	----	21.0	----	-----	178.0	---	0.91				
None			350	-----	191.0	-----	153.0	----	----	20.0	----	-----	-----	---	----				
None			650	-----	171.5	-----	141.5	----	----	20.0	----	-----	158.0	---	0.92				
650	40	1000	650	-----	172.0	-----	137.5	----	----	23.0	----	-----	163.0	---	0.95				
None			800	-----	188.0	-----	128.0	----	----	23.0	----	-----	156.0	---	0.83				
None			1000	-----	169.0	-----	114.0	----	----	24.0	----	-----	143.0	---	0.85				
				Cold rolled + 1325°F, 8 hrs, Furnace cooled 20°/hr. to 1150°F, then air cooled															
None			-320	-----	260.5	-----	229.0	----	----	13.0	----	-----	236.5	---	0.91				
None			-110	-----	232.0	-----	206.5	----	----	17.0	----	-----	209.0	---	0.88				
None			Room	-----	221.0	-----	198.5	----	----	12.0	----	-----	196.5	---	0.89				
650	40	1000	Room	-----	212.0	-----	195.5	----	----	13.0	----	-----	199.0	---	0.94				
None			350	-----	205.0	-----	188.5	----	----	12.0	----	-----	179.7	---	0.88				
None			650	-----	193.5	-----	179.0	----	----	12.0	----	-----	173.5	---	0.90				
650	40	1000	650	-----	198.5	-----	182.0	----	----	13.0	----	-----	172.0	---	0.87				
None			800	-----	-----	-----	-----	----	----	----	----	-----	169.0	---	----				
None			1000	-----	180.5	-----	165.3	----	----	10.0	----	-----	166.5	---	0.92				

Alloy Designation: Inconel 718 Contributor: Huntington Alloy Products Div., The International Nickel Co. Data Sheet No.: 2
Heat Treatment: Cold Rolled + Aged 1325°F, 8 hours; Furnace Cooled 20°/hr to 1150°F; Air Cooled Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure Stress ksi	Prior exposure Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength, ksi T	Elong[c] % (L)	G.L., in. (L)	Elong % (T)	G.L., in. (T)	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
None			Room	-----	214.5	-----	197.5	----	----	13.0	----	-----	205.5	---	0.96				

Alloy Designation: Inconel 718 Contributor: Huntington Alloy Products Div., The International Nickel Co. Data Sheet No.: 3
Heat Treatment: Cold Rolled + Aged 1325°F, 8 hours; Furnace Cooled 20°/hr to 1150°F; Air Cooled Sheet Thickness, inches 0.050

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure Stress ksi	Prior exposure Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength, ksi T	Elong[c] % (L)	G.L., in. (L)	Elong % (T)	G.L., in. (T)	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
None			Room	------	210.5	-----	193.5	----	----	12.0	----	-----	201.5	---	0.96				

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified. [d]L = longitudinal orientation T = transverse orientation

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Alloy Designation: Inconel 718 Contributor: North American Aviation, Inc. Data Sheet No.: 4
Heat Treatment: Ann + aged according to strength; Brazed at 1900°F and air cooled + heated at 1600°F for 4 hours and air cooled + 16 hours at 1325°F and air cooled Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES [d]

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi	Yield strength,[b] ksi	Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	L	T	L	T
None			Room	189	142	21.5											
None			Room	191	143	16											
None			Room	190	137	23											

Comments: [a]Conditions of exposure, if any, between heat treatment and testing. [b]0.2% offset yield strength unless otherwise specified.
[c]Gage length was 2 inches unless otherwise specified.
[d]Test direction not stated

STRESS-CORROSION TESTS

Cantilever beam tests at 650°F in circulating air furnace.

Salt coated by dipping in hot concentrated 6 parts NaCl + 1 part $MgCl_2$ and drying.

Smooth and Notched Specimens Tested - 60°V-notches, 0.010-inch deep with 0.005-inch root radius, machined across flat surface at point of maximum stress and at a point of very low stress.

Test Condition	Maximum Stresses: Smooth (ksi)	Notched (ksi)	Status at 4700 Hours[(a)]
Bare Surface - continuously exposed	40.5, 39.1, 40.8	102.8, 102.8	No comment
Salt Coated - continuously exposed[(b)]	38.7, 37.6, 39.6	98.8, 105.5	Darkening of surface and a few rust-like spots
Braze Coated - continuously exposed	34.0, 36.1, 36.0	99.1, 95.9	Slight darkening
Braze + Salt Coated - continuously exposed	36.0, 35.6, 35.9	92.4, 92.4	No comment
Salt Coated - 2 weeks at 650°F + 2 weeks in humidity cabinet at 100°F intermittently	39.4, 38.7, 38.6, 39.5	-----	Rough surface and rusting

(a) All specimens unbroken at 4700 hours
(b) Salt coating appeared spotty at 4700 hours

Alloy Designation: Inconel 718 Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 5
Heat Treatment: As noted below Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data: Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	Control Coupon Data: F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
Solution Treated and Aged 16 hrs. at 1400°F										
-65	T	0.0630	8.99	76250	134.7	1.87	1859	173.6	210.1	15.8
-65	T	0.0623	8.98	61250	109.6	3.10	2248			
Room	T	0.0631	8.99	75750	133.5	1.61	1553	155.5	194.7	20.4
Room	T	0.0626	9.00	58300	103.5	2.88	1816			
600	T	0.0613	9.00	69200	125.4	1.83	1747	145.4	179.6	18.9
600	T	0.0623	9.00	55800	99.5	2.66	1695			
Cold Rolled and Aged 16 hrs. at 1400°F										
-65	T	0.0609	9.12	72750	131.0	1.79	1675	196.3	218.6	13.5
-65	T	0.0603	9.09	49000	89.4	2.87	1346			
Room	T	0.0605	9.07	67900	123.7	1.87	1564	184.9	205.3	12.3
Room	T	0.0602	9.12	51400	93.6	2.97	1544			
600	T	0.0599	9.08	64300	118.2	2.03	1742	173.2	193.0	9.9
600	T	0.0600	9.02	48800	90.2	2.60	1355			

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RENE' 41

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	The University of Michigan	General Electric Company Metallurgical Products Division	R217
2	" " " "	" " "	R216
3	Northrup Corporation	Eastern Stainless	----
4	North American Aviation, Inc.	---------	----
5	The University of Michigan	General Electric Company Metallurgical Products Division	----
6	Lockheed Aircraft Corporation, California Co.	Cannon-Muskegon	VB-66

Composition, percent

Data Sheet	C	Si	Mn	Cr	Co	Mo
1	0.09	0.07	0.06	18.97	11.20	9.75
2	0.10	0.06	0.06	18.48	10.43	9.37
3	0.10	0.01	0.10	18.44	11.55	9.82
6	0.08	0.06	<0.02	18.70	11.50	9.57

	Ti	Al	S	B	Fe	Ni
	3.20	1.50	0.006	0.0045	<0.30	Bal
	3.19	1.42	0.007	0.0047	2.20	Bal
	3.09	1.55	-----	0.005	0.26	Bal
	3.26	1.59	0.011	0.003	0.08	Bal

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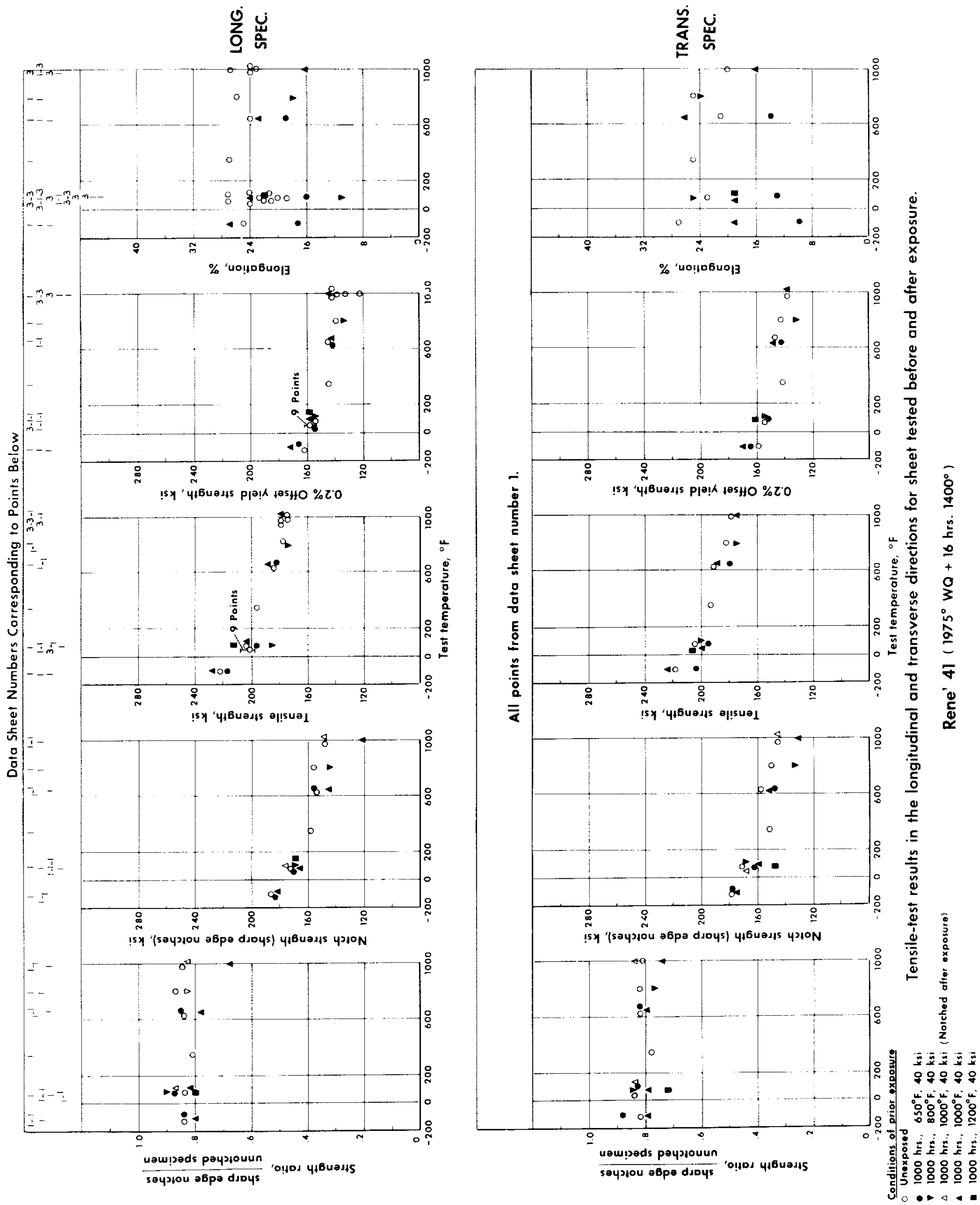

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Rene' 41 (1975° WQ + 16 hrs. 1400°)

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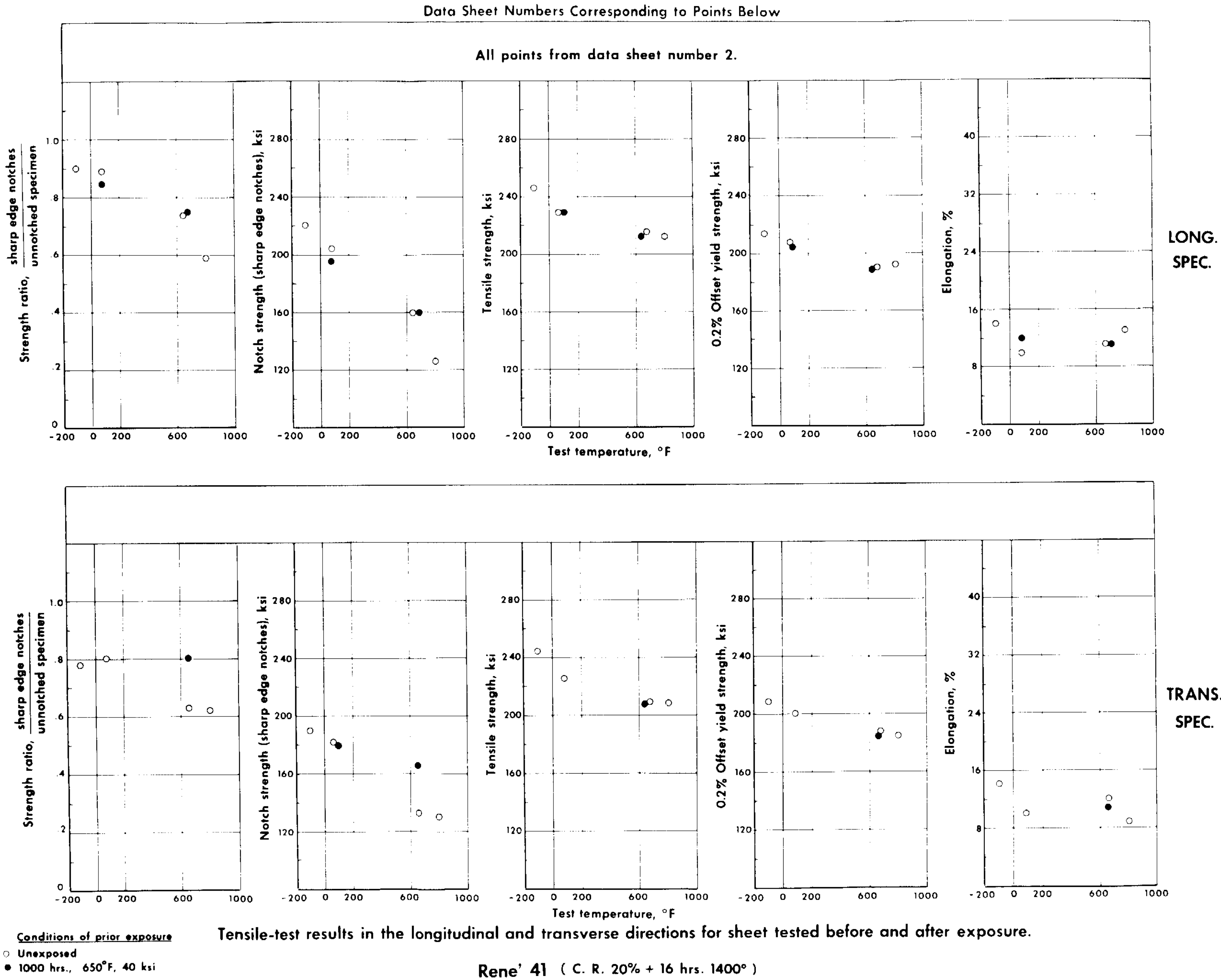
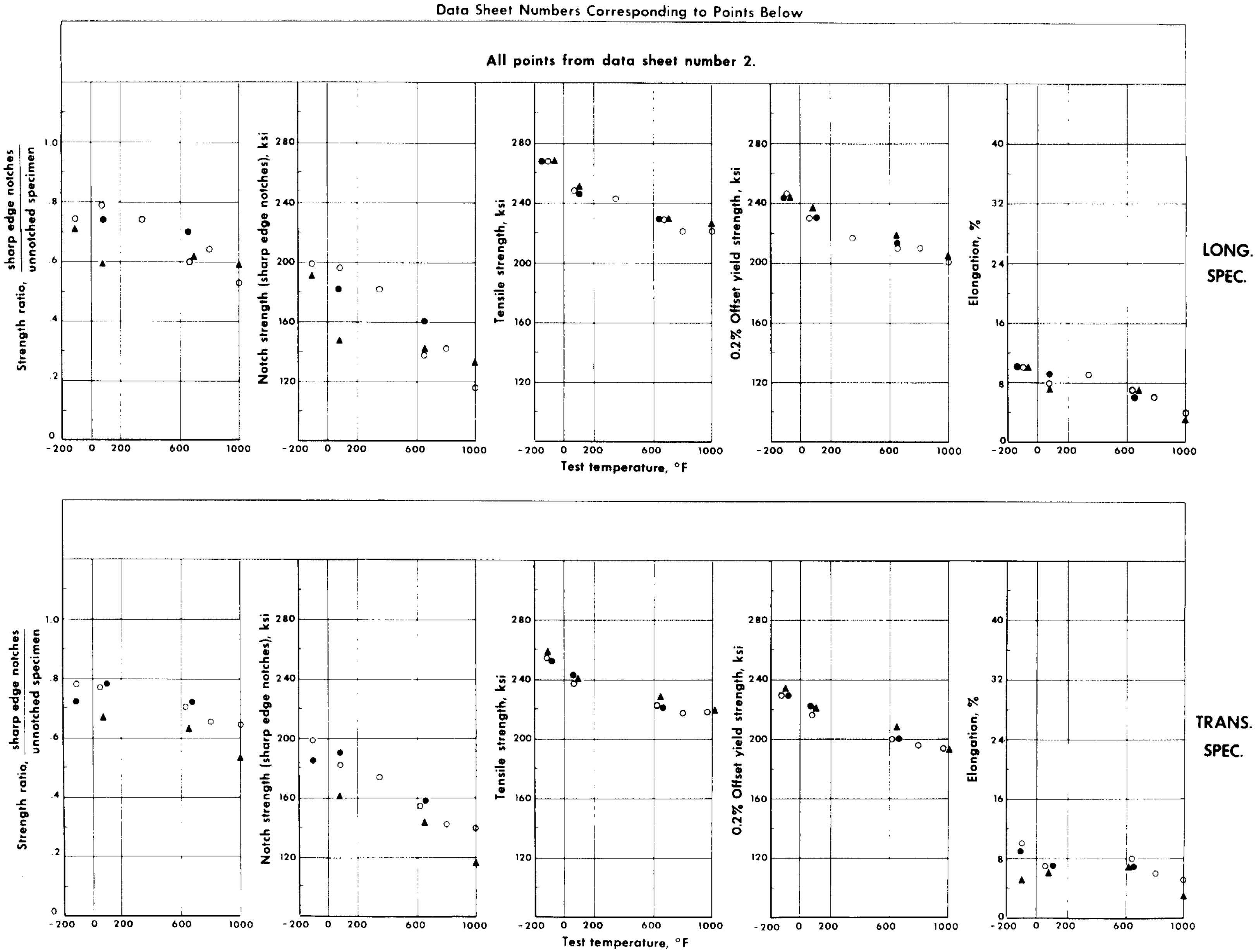


Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

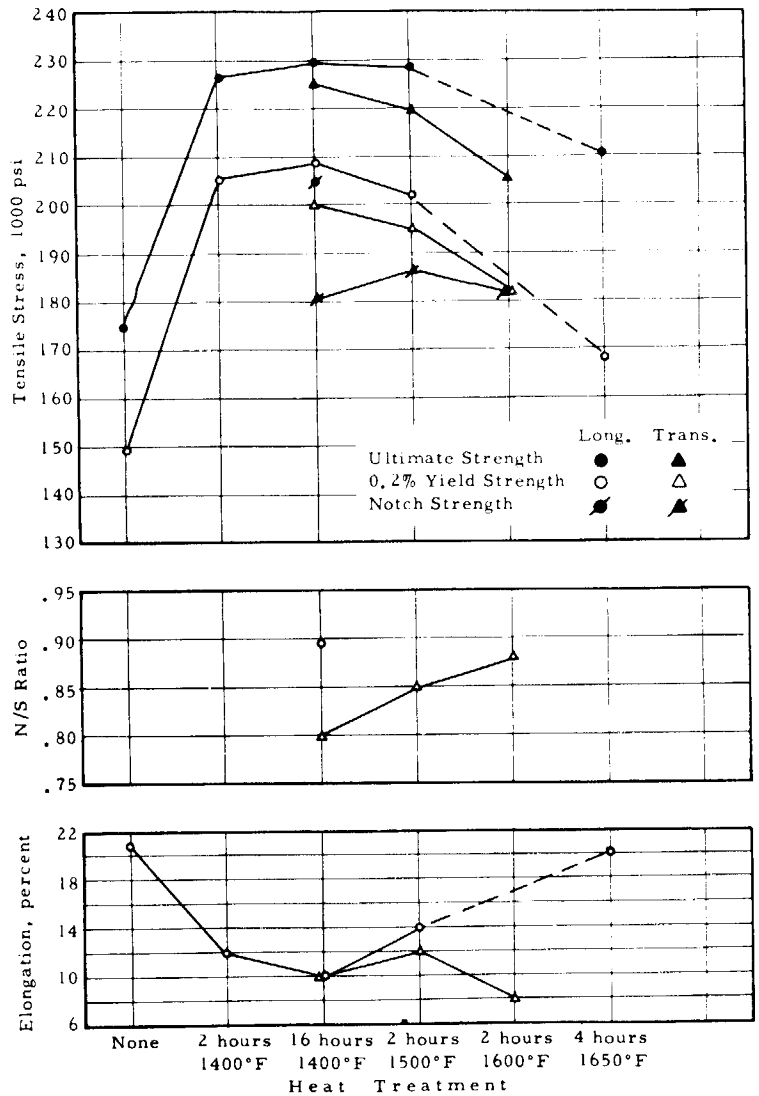
Rene' 41 (C. R. 20% + 16 hrs. 1400°)



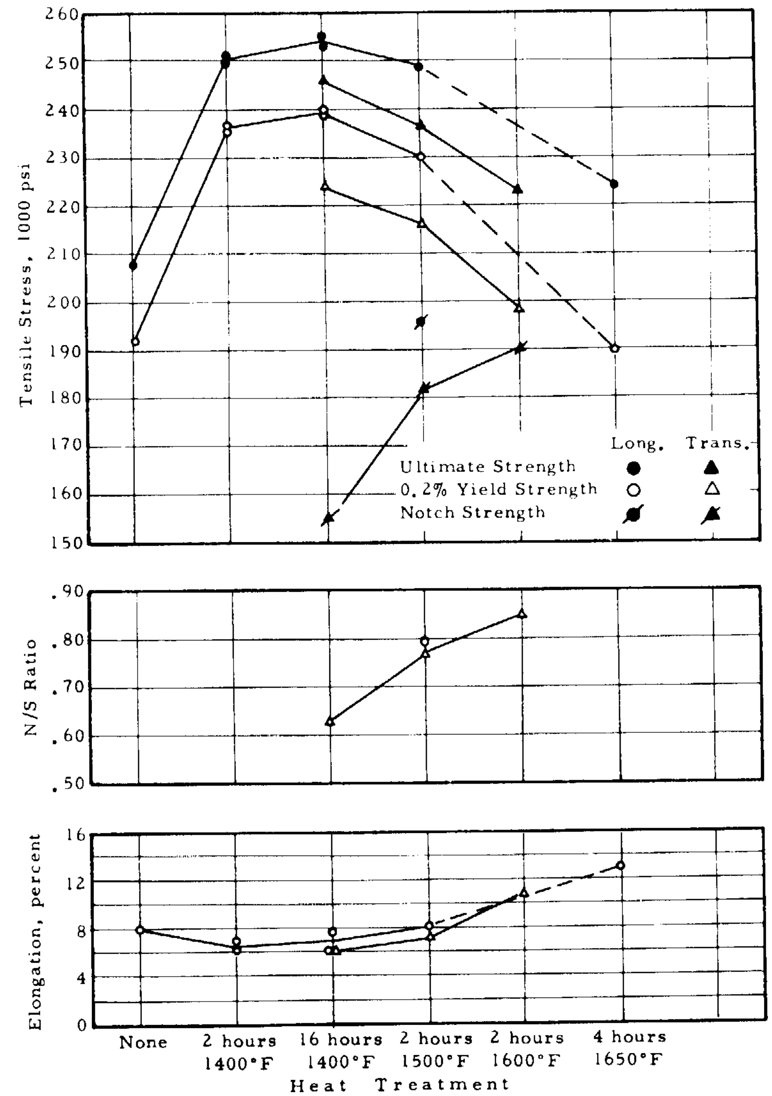
Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ▲ 1000 hrs., 1000°F, 40 ksi

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Rene' 41 (C. R. 35% + 2 hrs. 1500°)



Results for 20-percent cold worked sheet.



Results for 35-percent cold worked sheet.

Effect of heat treatment on the room-temperature tensile properties of Rene' 41 alloy.

Alloy Designation: Rene' 41 Contributor: The University of Michigan (NASA sponsored) Data Sheet No.: 1
Heat Treatment: 1975°F, W.Q. + 1400°F, 16 hrs., A.C. Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure[a] Stress ksi	Prior exposure[a] Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
None			-110	222	219	162	159	25		27		186	179	0.84	0.82				
650	40	1000	-110	217	203	166	164	17		10		183	178	0.84	0.88				
1000	40	1000	-110	227	223	171	170	27		19		182	176	0.80	0.79				
None			Room	204	204	154	154	22		23		172	171	0.84	0.84				
650	40	1000	Room	196	195	155	152	16		13		170	162	0.87	0.83				
800	40	1000	Room	187	201	156	154	11		25		169	169	0.90	0.84				
1000	40	1000	Room	203	201	157	---	24		19		166	159	0.82	0.79				
1000	40	1000	Room	---	---	---	---	--		--		176[e]	169[e]	0.87	0.84				
1200	40	1000	Room	213	206	167	161	22		19		170	148	0.80	0.72				
None			350	196	193	145	141	27		25		158	151	0.81	0.78				
None			650	184	191	145	147	24		21		154	157	0.84	0.82				
650	40	1000	650	183	180	142	143	19		14		156	148	0.85	0.82				
1000	40	1000	650	186	188	143	149	23		26		146	151	0.78	0.80				
None			800	179	182	139	143	26		25		156	150	0.87	0.82				
800	40	1000	800	174	175	134	132	18		24		145	134	0.83	0.76				
															0.77				
None			1000	175	178	133	138	24		20		148	145	0.85	0.81				
1000	40	1000	1000	179	176	145	138	16		16		121	131	0.68	0.74				
1000	40	1000	1000	---	---	---	---	--		--		149[e]	147[e]	0.83	0.84				
None			1200	183	184	131	131	20		19		136	140	0.74	0.76				
1200	40	1000	1200	183	183	138	138	12		11		137	134	0.75	0.73				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.
[b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.
[d] L = longitudinal orientation T = transverse orientation
[e] Notch machined after exposure

Alloy Designation: Rene' 41 Contributor: The University of Michigan Data Sheet No.: 2
Heat Treatment: As noted below Sheet Thickness, inches 0.030

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Prior exposure[a] Stress ksi	Prior exposure[a] Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	Tensile strength, ksi T	Yield strength,[b] ksi L	Yield strength,[b] ksi T	Elong.[c] % L	G.L., in. L	Elong. % T	G.L., in. T	Sharp edge notches: Tensile strength, ksi L	Tensile strength, ksi T	Strength ratio, N/S L	Strength ratio, N/S T	L	T	L	T
Cold reduced 20% + 16 hours, 1400°F																			
None			-110	247	244	214	209	14		14		221	190	0.90	0.78				
None			Room	229	226	208	200	10		10		205	181	0.89	0.80				
650	40	1000	Room	230	---	205	---	12		--		196	180	0.85	----				
None			650	215	209	190	188	11		12		160	132	0.74	0.63				
650	40	1000	650	213	208	189	185	11		11		160	166	0.75	0.80				
None			800	213	208	192	185	13		9		126	130	0.59	0.62				
Cold reduced 35% + 2 hours, 1500°F																			
None			-110	268	255	246	229	10		10		199	199	0.74	0.78				
650	40	1000	-110	268	254	244	229	10		9		---	184	---	0.72				
1000	40	1000	-110	269	258	244	234	10		5		190	---	0.71	---				
None			Room	249	237	230	216	8		7		196	182	0.79	0.77				
650	40	1000	Room	246	242	230	222	9		7		182	190	0.74	0.78				
1000	40	1000	Room	251	240	237	221	7		6		147	161	0.59	0.67				
None			350	243	---	217	---	9		--		181	174	0.74	---				
None			650	229	222	210	200	7		8		138	155	0.60	0.70				
650	40	1000	650	229	221	213	200	6		7		160	158	0.70	0.72				
1000	40	1000	650	230	228	219	218	7		7		140	143	0.61	0.63				
None			800	221	217	210	196	6		6		142	142	0.64	0.65				
None			1000	221	218	201	194	3.8		5		116	140	0.53	0.64				
1000	40	1000	1000	227	219	206	193	3.0		3.5		133	116	0.59	0.53				
None			1200	228	223	189	183	15		10		119	115	0.52	0.52				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.
[b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.
[d] L = longitudinal orientation T = transverse orientation

Alloy Designation: Rene' 41 Contributor: Northrup Corp. - Norair Division Data Sheet No.: 3
Heat Treatment: As noted below Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	[c] Unnotched (smooth) specimens								Sharp edge notches							
Temp °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
				L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
1975°F, 1/2 hr., WQ + 1400°F, 16 hrs., AC																			
None			Room	203		156		20.0											
None			Room	206		157		21.5											
None			Room	207		158		21.0											
None			Room	205		161		24.0											
None			Room	205		162		24.0											
None			Room	206		158		27.0											
None			Room	197		154		27.0											
None			Room	207		159		22.5											
None			Room	202		159		19.0											
None			1000	176		139		24.0											
None			1000	179		142		27.0											
None			1000	179		142		23.0											
None			1300	173		139		10.0											
None			1300	172		138		10.0											
None			1300	174		138		10.0											
1975°F, 1/2 hr., WQ + 1400°F, 16 hrs., AC + 1950°F, 1/2 hr., AC + 1400°F, 16 hrs., AC																			
None			Room	204		156		26											
None			Room	206		159		25											

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation
[e] Not stated whether L or T

Alloy Designation: Rene' 41 Contributor: North American Aviation, Inc. Data Sheet No.: 4
Heat Treatment: Ann. + aged; Brazed at 1950°F and air cooled + 6 hours at 1400°F and air cooled Sheet Thickness, inches 0.040

SHORT-TIME TENSILE PROPERTIES[d]

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches							
Temp °F	Stress ksi	Time, hr.		Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S					
										T		L	T	L	T	L	T	L	T
None			Room	197.5		148.5		13.8											
None			Room	194.		147.5		12.6											
None			Room	194.		146.5		13.5											

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.
[c] Gage length was 2 inches unless otherwise specified.
[d] Test direction not stated

STRESS-CORROSION TESTS

Cantilever beam tests at 650°F in circulating air furnace.

Salt coated by dipping in hot concentrated 6 parts NaCl + 1 part $MgCl_2$ and drying.

Smooth and Notched Specimens Tested - 60°V-notches, 0.010-inch deep with 0.005-inch root radius, machined across flat surface at point of maximum stress and at a point of very low stress.

Test Condition	Maximum Stresses Smooth (ksi)	Maximum Stresses Notched (ksi)	Status at 4700 Hours[a]
Bare Surface - continuously exposed	54.5, 55.0, 55.6	147.2, 146.8	No comment
Salt Coated - continuously exposed[b]	55.3, 53.8, 54.2	145.3, 150.4	Darkening of surface and a few rust-like spots
Braze Coated - continuously exposed	49.0, 48.6, 49.5	130.6, 126.8	Slight darkening
Braze + Salt Coated - continuously exposed	49.9, 50.0, 48.8	128.2, 130.3	No comment
Salt Coated - 2 weeks at 650°F + 2 weeks in humidity cabinet at 100°F intermittently	55.9, 55.0, 57.4, 54.7	-----	Rough surface and slight rusting

(a) All specimens unbroken
(b) Salt coating appeared spotty at 4700 hours

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Alloy Designation: Rene' 41 Contributor: The University of Michigan (NASA Sponsored) Data Sheet No.: 5
Heat Treatment: As noted below Sheet Thickness, inches 0.030

EVALUATION OF HEAT TREATMENT
RENE' 41 ALLOY

(all tests at room temperature)

Heat Treatment	Direction (a)	CONDITION OF MATERIAL PRIOR TO AGING: ANNEALED					COLD WORKED 20%					COLD WORKED 35%				
		UTS(b) (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S
None	L	---	---	---	---	---	175	149	21	---	---	208	192	8	---	---
	T	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
2 hrs at 1400°F	L	---	---	---	---	---	227	205	12	---	---	251	237	7	---	---
	L	---	---	---	---	---	---	---	--	---	---	250	236	6	---	---
	T	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
16 hrs at 1400°F	L	204	151	20	172	.84	229	208	10	205	.89	253	240	6	---	---
	L	204	156	24	---	---	---	---	--	---	---	255	239	7.5	---	---
	T	206	153	21	171	.83	225	200	10	181	.80	246	224	6	155	.63
	T	203	154	25	---	---	---	---	--	---	---	---	---	---	---	---
2 hrs at 1500°F	L	---	---	---	---	---	228	202	14	---	---	249	230	8	196	.79
	T	---	---	---	---	---	220	195	12	187	.85	237	216	7	182	.77
2 hrs at 1600°F	L	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---
	T	---	---	---	---	---	206	182	8	182	.88	223	198	11	190	.85
4 hrs at 1650°F	L	---	---	---	---	---	211	168	20	---	---	224	190	13	---	---
	T	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---

(a) L = Longitudinal
T = Transverse
(b) UTS - ultimate tensile strength; YS - 0.2-percent offset yield strength; Elong. - elongation in 2 inches; NS - tensile strength of sharp edge notch sample; N/S - ratio of notch strength to unnotched tensile strength.

Alloy Designation: Rene' 41 Contributor: Lockheed Aircraft Corporation, California Company Data Sheet No.: 6
Heat Treatment: Solution treated at 1975°F, W.Q., and aged 16 hrs. at 1400°F Sheet Thickness, inches

TEAR-TEST DATA

Test Temp (°F)	Test Direction	Thickness (in.)	Width (in.)	Crack Propagation Data: Load (lbs.)	F_g (ksi)	Crack Length (in.)	dw/da	Control Coupon Data: F_{ty} (ksi)	F_{tu} (ksi)	Elongation (%)
Room	L	0.061	8.98	61000	111	1.39	872	126	178	27
Room	L	0.061	8.99	52500	94.3	2.37	1130			

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WASPALOY

INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	The University of Michigan	General Electric Company Metallurgical Products Division	B-119

Composition, percent

Data Sheet	C	Si	Mn	Cr	Co	Mo	Ti
1	0.08	0.07	0.04	19.63	13.49	4.26	2.99

Al	Ni	Fe	P	S	B	Zr
1.40	Bal	2.30	--	0.007	0.0048	0.03

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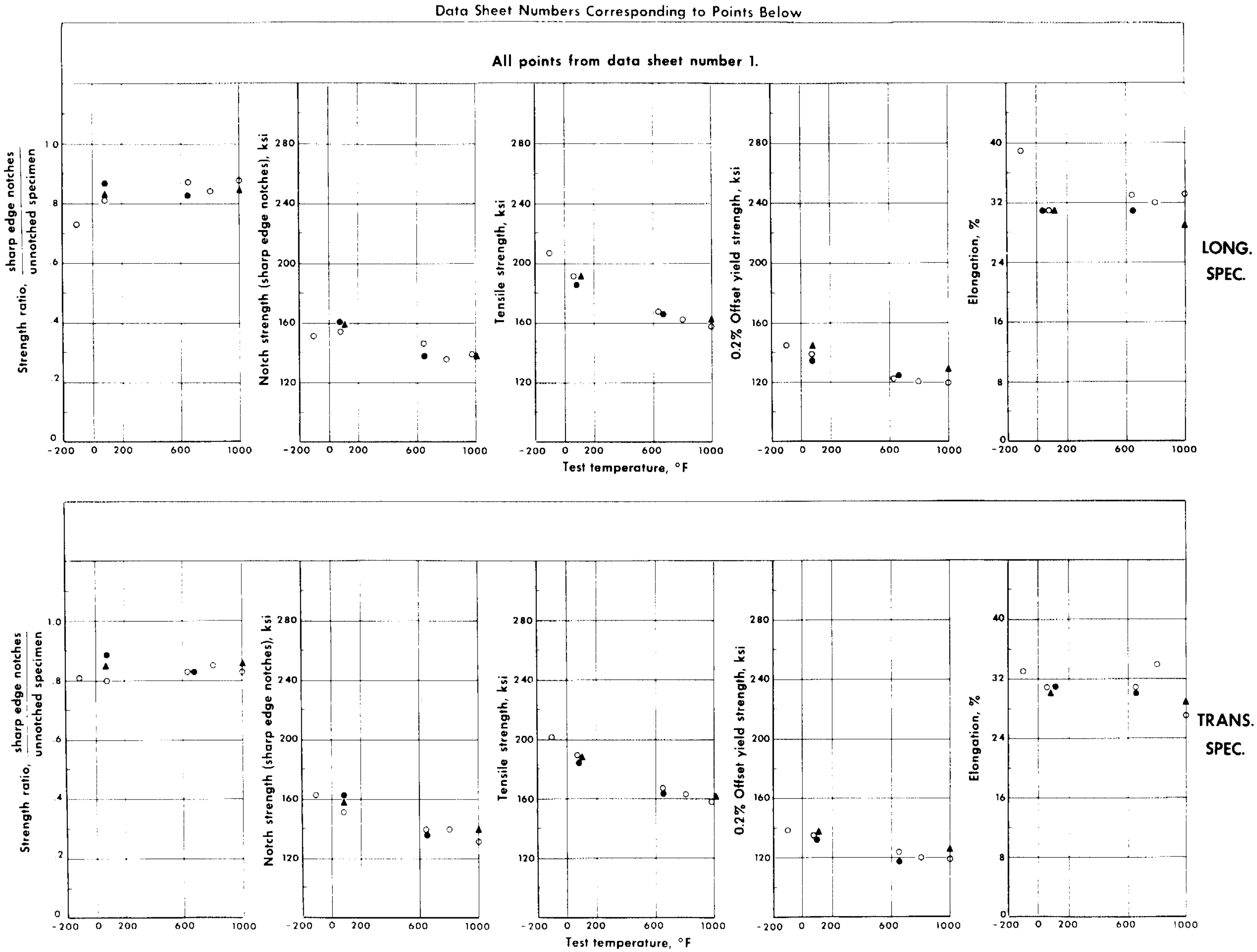
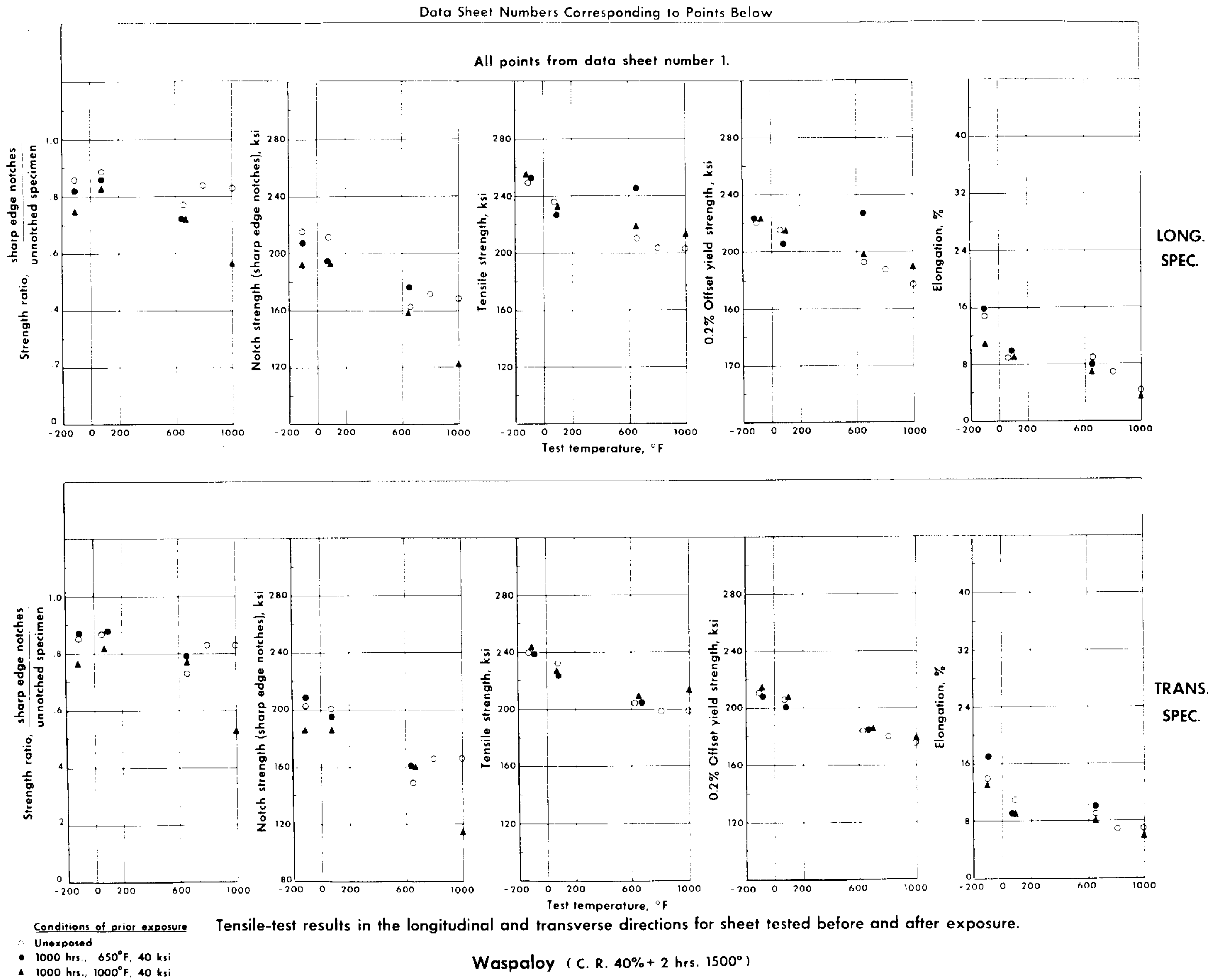


Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ▲ 1000 hrs., 1000°F, 40 ksi

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Waspaloy (Annealed + 16 hrs. 1400°)



Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

Waspaloy (C. R. 40% + 2 hrs. 1500°)

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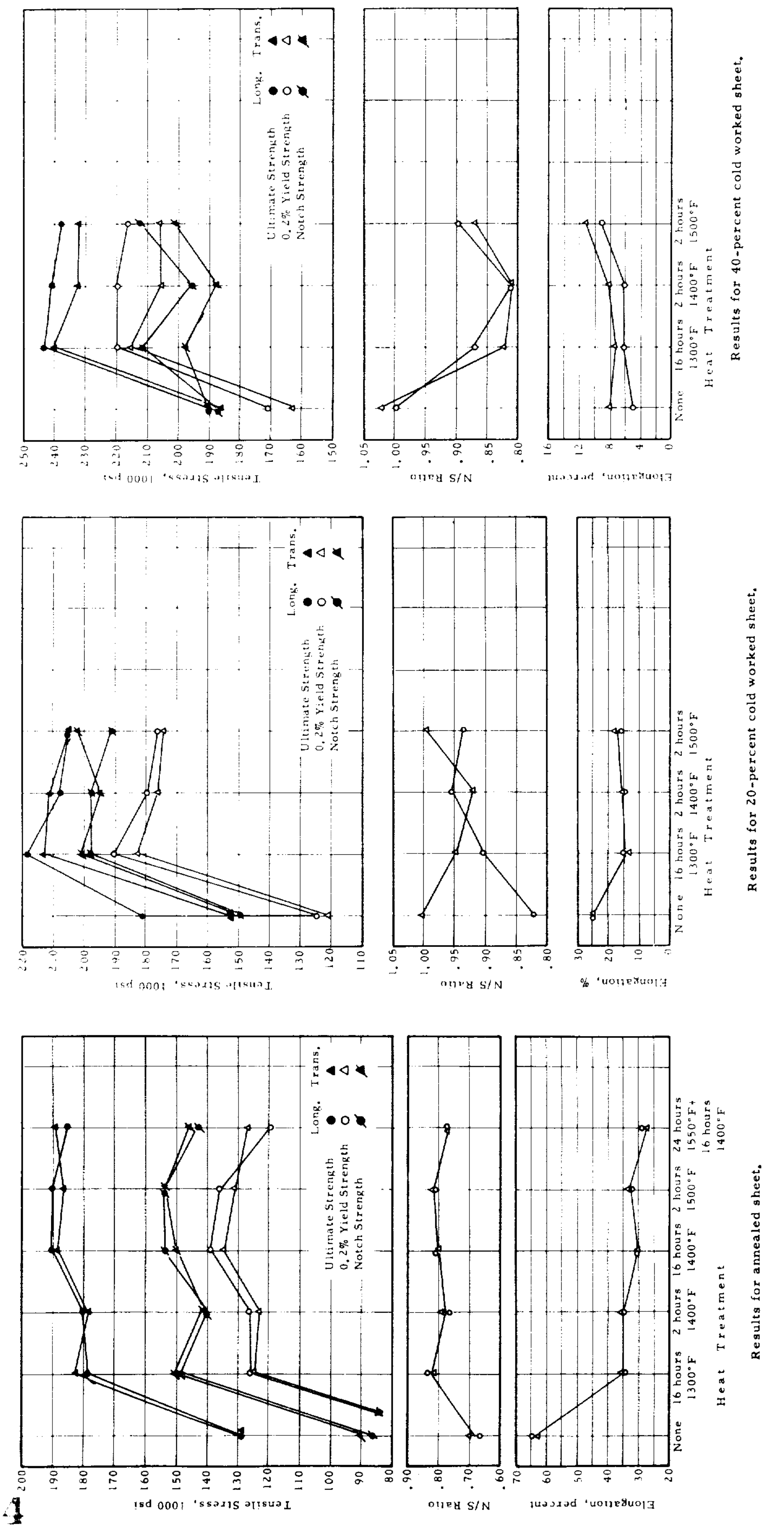

Results for annealed sheet.

Results for 20-percent cold worked sheet.

Results for 40-percent cold worked sheet.

Effect of heat treatment on the room-temperature tensile properties of Waspaloy alloy.

Alloy Designation: Waspaloy Contributor: The University of Michigan Data Sheet No.: 1

Heat Treatment: As noted below Sheet Thickness, inches 0.030

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a] Temp. °F	Stress ksi	Time, hr.	Test Temp. °F	Unnotched (smooth) specimens: Tensile strength, ksi L[d]	T	Yield strength,[b] ksi L	T	Elong.[c] % L	G.L., in.	Elong. % T	G.L., in.	Sharp edge notches: Tensile strength, ksi L	T	Strength ratio, N/S L	T	L	T	L	T
Annealed + Aged 16 hours at 1400°F																			
None			-110	207	201	145	139	39		33		151	163	0.73	0.81				
None			Room	191	190	139	135	31		31		154	151	0.81	0.80				
650	40	1000	Room	186	184	135	132	31		31		161	163	0.87	0.89				
1000	40	1000	Room	192	187	144	137	31		30		159	159	0.83	0.85				
None			650	167	167	122	124	33		31		146	139	0.87	0.83				
650	40	1000	650	166	163	124	118	31		30		138	136	0.83	0.83				
None			800	162	163	120	120	32		34		136	139	0.84	0.85				
None			1000	158	158	119	119	33		27		139	131	0.88	0.83				
1000	40	1000	1000	163	162	129	126	29		29		138	140	0.85	0.86				
Cold reduced 40% + Aged 2 hours at 1500°F																			
None			-110	250	240	221	210	15.		14		216	203	0.86	0.85				
650	40	1000	-110	253	239	224	208	16.		17		208	209	0.82	0.87				
1000	40	1000	-110	255	244	223	214	11.		13		192	186	0.75	0.76				
None			Room	237	232	216	206	9.		11		212	201	0.89	0.87				
650	40	1000	Room	227	224	206	201	10.		9		196	196	0.86	0.88				
1000	40	1000	Room	234	228	215	208	9.		9		193	186	0.83	0.82				
None			650	211	204	193	184	9.		9		163	149	0.77	0.73				
650	40	1000	650	246	204	228	184	8.		10		176	161	0.72	0.79				
1000	40	1000	650	219	209	198	186	7.		8		158	160	0.72	0.77				
None			800	204	199	188	180	7.		7		172	166	0.84	0.83				
None			1000	204	199	177	176	4.5		7		169	166	0.83	0.83				
1000	40	1000	1000	213	214	190	180	3.5		6		122	114	0.57	0.53				

Comments: [a] Conditions of exposure, if any, between heat treatment and testing.
[c] Gage length was 2 inches unless otherwise specified.
[b] 0.2% offset yield strength unless otherwise specified.
[d] L = longitudinal orientation T = transverse orientation

EVALUATION OF HEAT TREATMENT
WASPALOY

(all tests at room temperature)

Heat Treatment	Direction[(a)]	ANNEALED UTS[(b)] (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	COLD WORKED 20% UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S	COLD WORKED 40% UTS (1000 psi)	YS (1000 psi)	Elong. (%)	NS (1000 psi)	N/S
None	L	129	62	64	87	.67	181	124	25	149	.82	189	171	5	187	.99
	T	129	61	63	91	.70	152	121	25	152	1.00	186	162	8	190	1.02
16 hrs at 1300°F	L	179	127	34	148	.83	218	190	15	197	.90	243	219	6	212	.87
	T	183	125	36	151	.82	213	183	13	201	.94	240	215	7	198	.82
2 hrs at 1400°F	L	181	127	34	140	.77	207	179	14	197	.95	241	219	6	195	.81
	T	179	123	36	141	.79	211	176	15	194	.92	232	205	8	187	.81
16 hrs at 1400°F	L	191	139	31	154	.81	---	---	---	---	---	---	---	---	---	----
	T	190	135	31	151	.80	---	---	---	---	---	---	---	---	---	----
2 hrs at 1500°F	L	190	136	32	154	.81	205	176	16	191	.93	237	216	9	212	.89
	T	187	132	33	154	.82	204	174	18	202	.99	232	206	11	201	.87
24 hrs at 1550°F +	L	186	120	28	143	.77	---	---	---	---	---	---	---	---	---	----
16 hrs at 1400°F	T	190	128	27	147	.77	---	---	---	---	---	---	---	---	---	----

(a) L = Longitudinal
T = Transverse
(b) UTS - ultimate tensile strength; YS - 0.2-percent offset yield strength; Elong. - elongation in 2 inches; NS - tensile strength of sharp edge notch sample; N/S - ratio of notch strength to unnotched tensile strength.

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INDEX OF MATERIALS

Data Sheet	Organization Reporting Data	Alloy Producer	Heat Number
1	Lewis Research Center, NASA	Allegheny Ludlum	22021-2 CEVM
2	Materials Research Laboratory, Inc.	" "	"

Composition, percent

Data Sheet	C	Mn	Si	P	S	Cr	Co
1 & 2	0.291	0.91	0.20	0.008	0.013	24.85	40.36

Ni	Mo	Al	Fe	Cb	W
20.26	3.92	2.12	2.47	1.60	2.12

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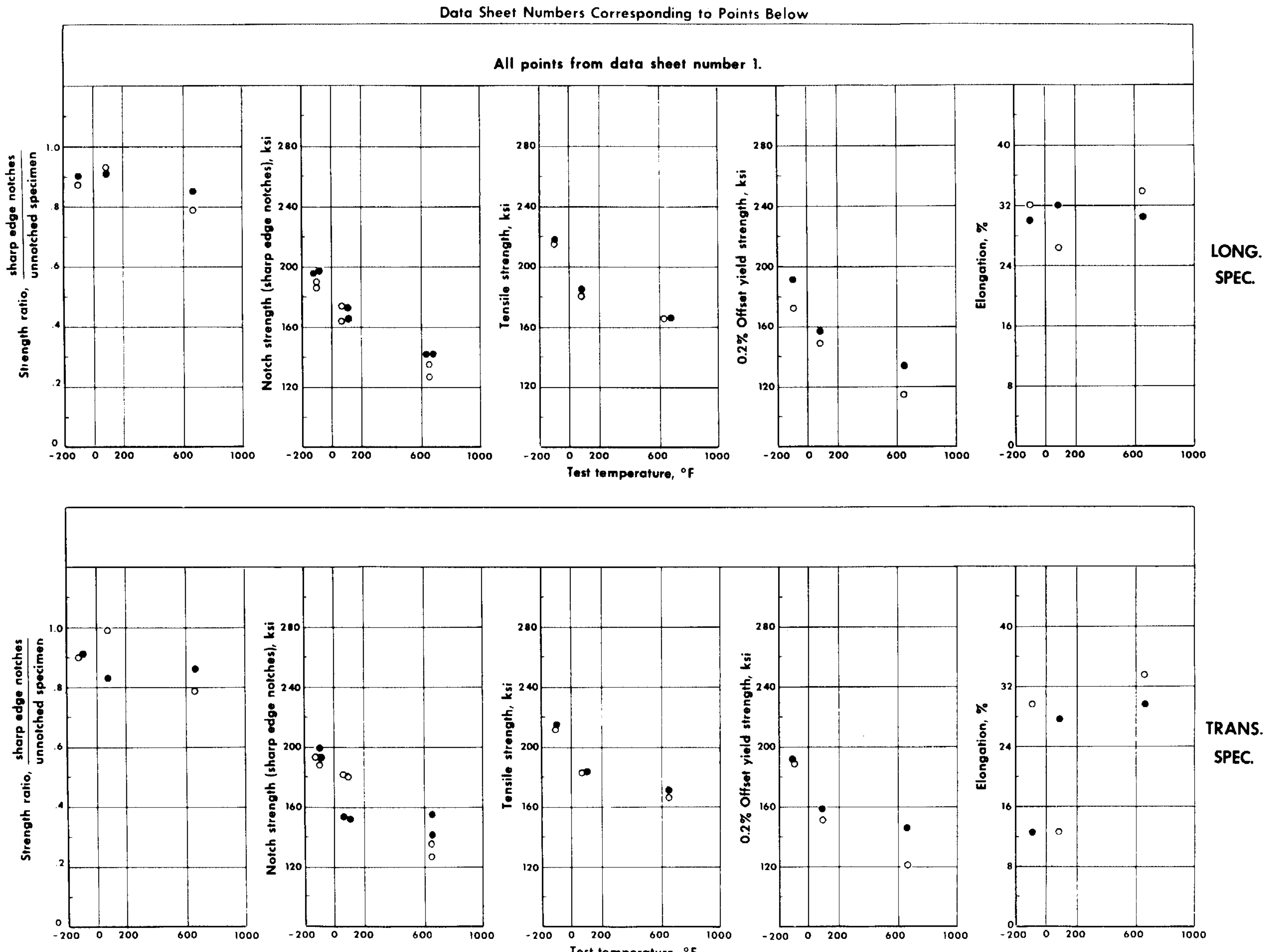

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

V 36 (C. R. 20%)

Conditions of prior exposure
○ Unexposed
● 1000 hrs., 650°F, 40 ksi

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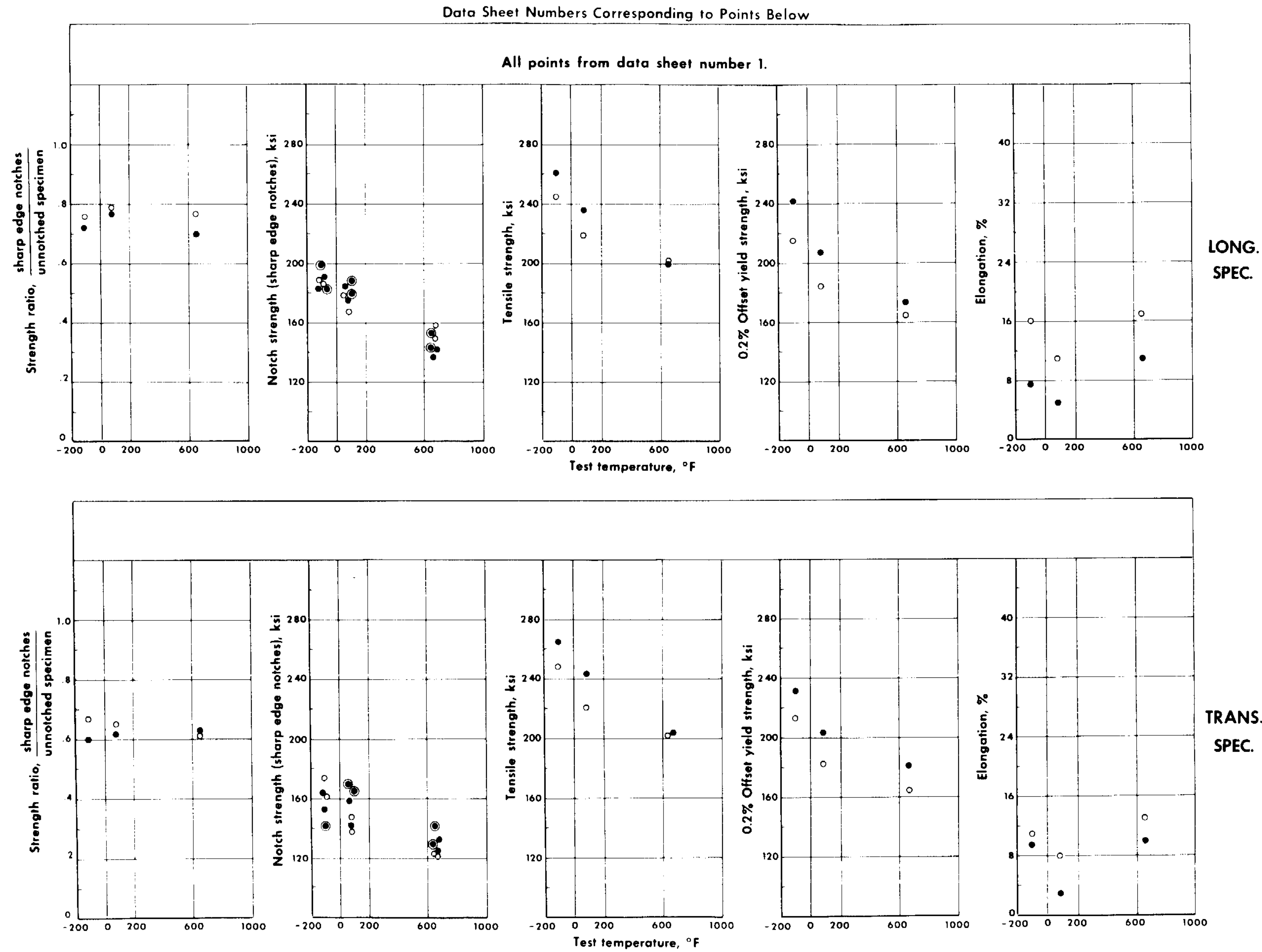
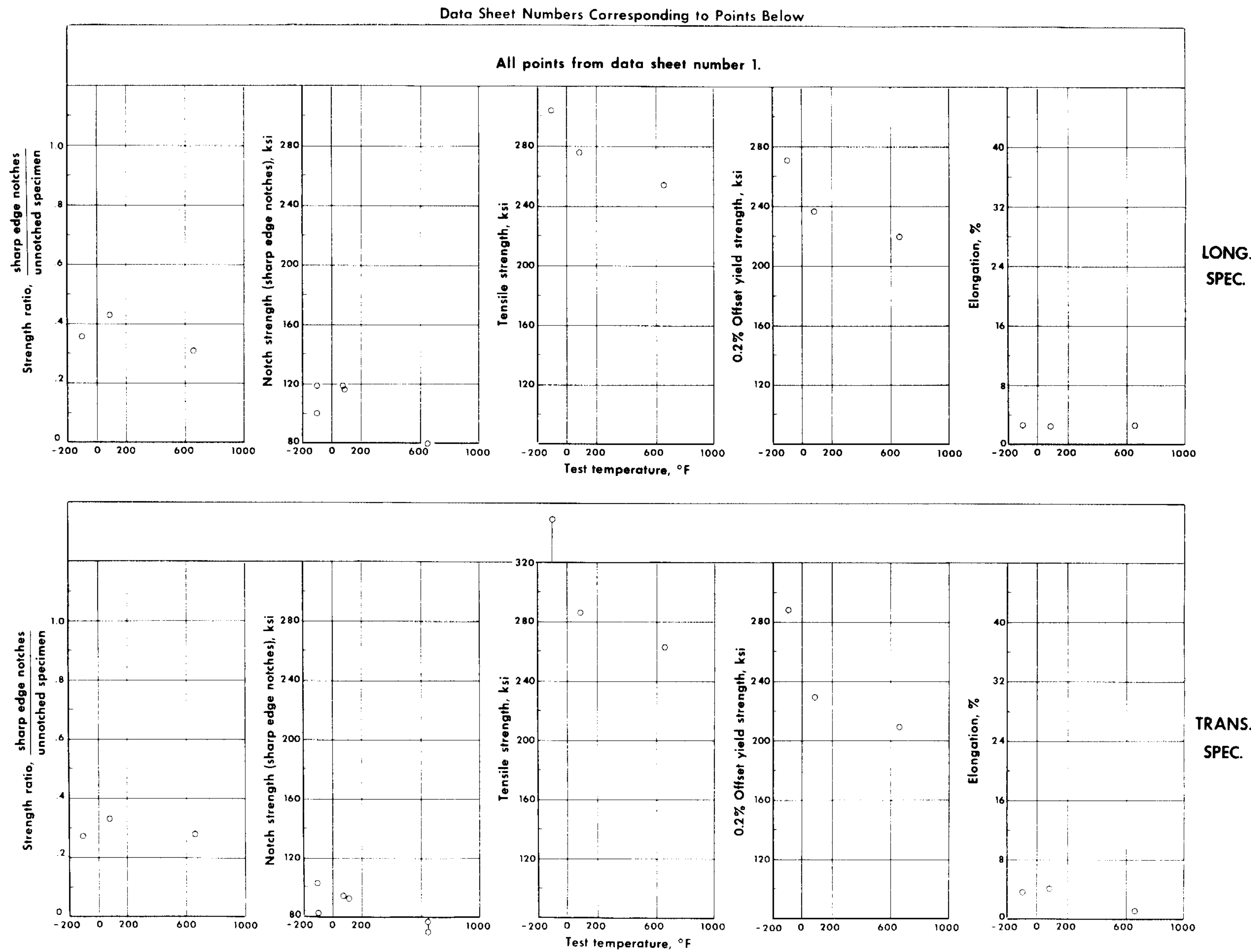


Conditions of prior exposure
- ○ Unexposed
- ● 1000 hrs., 650°F, 40 ksi
- ◉ 1000 hrs., 650°F, 40 ksi (Coated with sea salt)

Tensile-test results in the longitudinal and transverse directions for sheet tested before and after exposure.

V 36 (C. R. 30%)



Tensile-test results in the longitudinal and transverse directions for sheet tested before exposure.

V 36 (C. R. 50%)

Alloy Designation: V-36 Contributor: { Materials Research Laboratory, Inc. (Salt exposures) / NASA Lewis Research Center } Data Sheet No.: 1

Heat Treatment: As noted below. Sheet Thickness, inches 0.025

SHORT-TIME TENSILE PROPERTIES

Prior exposure[a]			Test Temp. °F	Unnotched (smooth) specimens								Sharp edge notches				SALT EXPOSURES Sharp edge notches			
				Tensile strength, ksi		Yield strength,[b] ksi		Elong.[c] %	G.L., in.	Elong. %	G.L., in.	Tensile strength, ksi		Strength ratio, N/S		Tensile strength, ksi			
Temp °F	Stress ksi	Time, hr.		L[d]	T	L	T	L		T		L	T	L	T	L	T	L	T
20% cold rolled																			
None			-110	215.2	212.3	172.0	188.6	32		29.5		190.3	193.7	0.87	0.90				
None			-110	-----	-----	-----	-----	----		----		186.2	187.8						
650	40	1000	-110	218.0	215.1	192.0	192.1	30		12.5		196.0	199.7	0.90	0.91				
650	40	1000	-110	-----	-----	-----	-----	----		----		197.5	192.3						
None			Room	181.2	183.2	149.0	151.5	26.5		12.5		174.1	181.4	0.93	0.99				
None			Room	-----	-----	-----	-----	----		----		164.5	179.9						
650	40	1000	Room	185.1	183.6	156.7	158.6	32		27.5		165.1	153.7	0.91	0.83				
650	40	1000	Room	-----	-----	-----	-----	----		----		173.0	152.6						
None			650	166.3	166.3	115.4	121.2	34		33.5		127.1	135.7	0.79	0.79				
None			650	-----	-----	-----	-----	----		----		135.4	126.5						
650	40	1000	650	166.7	171.3	134.3	145.5	30.5		29.5		142.2	141.3	0.85	0.86				
650	40	1000	650	-----	-----	-----	-----	----		----		142.1	154.7						
30% cold rolled																			
None			-110	245.5	248.6	215.7	213.7	16		11		188.4	161.1	0.76	0.67				
None			-110	-----	-----	-----	-----	----		----		186.8	174.1						
650	40	1000	-110	261.6	265.3	242.0	231.7	7.5		9.5		182.5	164.0	0.72	0.60	182.6	140.2		
650	40	1000	-110	-----	-----	-----	-----	----		----		191.5	152.6			198.3	-----		
None			Room	218.7	220.9	184.8	182.1	11		8		167.7	137.6	0.79	0.65				
None			Room	-----	-----	-----	-----	----		----		178.8	147.6						
650	40	1000	Room	236.1	243.6	207.9	204.0	5		3		185.0	142.0	0.77	0.62	179.4	164.4		
650	40	1000	Room	-----	-----	-----	-----	----		----		176.5	158.5			188.0	170.0		
None			650	201.0	202.0	164.4	164.4	17		13		150.3	123.2	0.77	0.61				
None			650	-----	-----	-----	-----	----		----		157.9	122.8						
650	40	1000	650	199.5	203.4	173.5	181.4	11		10		137.2	131.4	0.70	0.63	143.2	129.2		
650	40	1000	650	-----	-----	-----	-----	----		----		141.1	124.2			153.7	141.0		
50% cold rolled																			
None			-110	304.0	349.0	271.0	287.5	2.5		3.5		119.0	82.3	0.36	0.27				
None			-110	-----	-----	-----	-----	----		----		100.5	103.3						
None			Room	276.0	286.0	236.0	229.0	2.5		4		119.3	94.3	0.43	0.33				
None			Room	-----	-----	-----	-----	----		----		117.7	93.2						
None			650	254.5	262.7	219.7	208.9	2.5		1		79.1	71.3	0.31	0.28				
None			650	-----	-----	-----	-----	----		----		-----	77.0						

Comments: [a] Conditions of exposure, if any, between heat treatment and testing. [b] 0.2% offset yield strength unless otherwise specified.

[c] Gage length was 2 inches unless otherwise specified. [d] L = longitudinal orientation T = transverse orientation

ALLOY COMPARISON SUMMARY FIGURES

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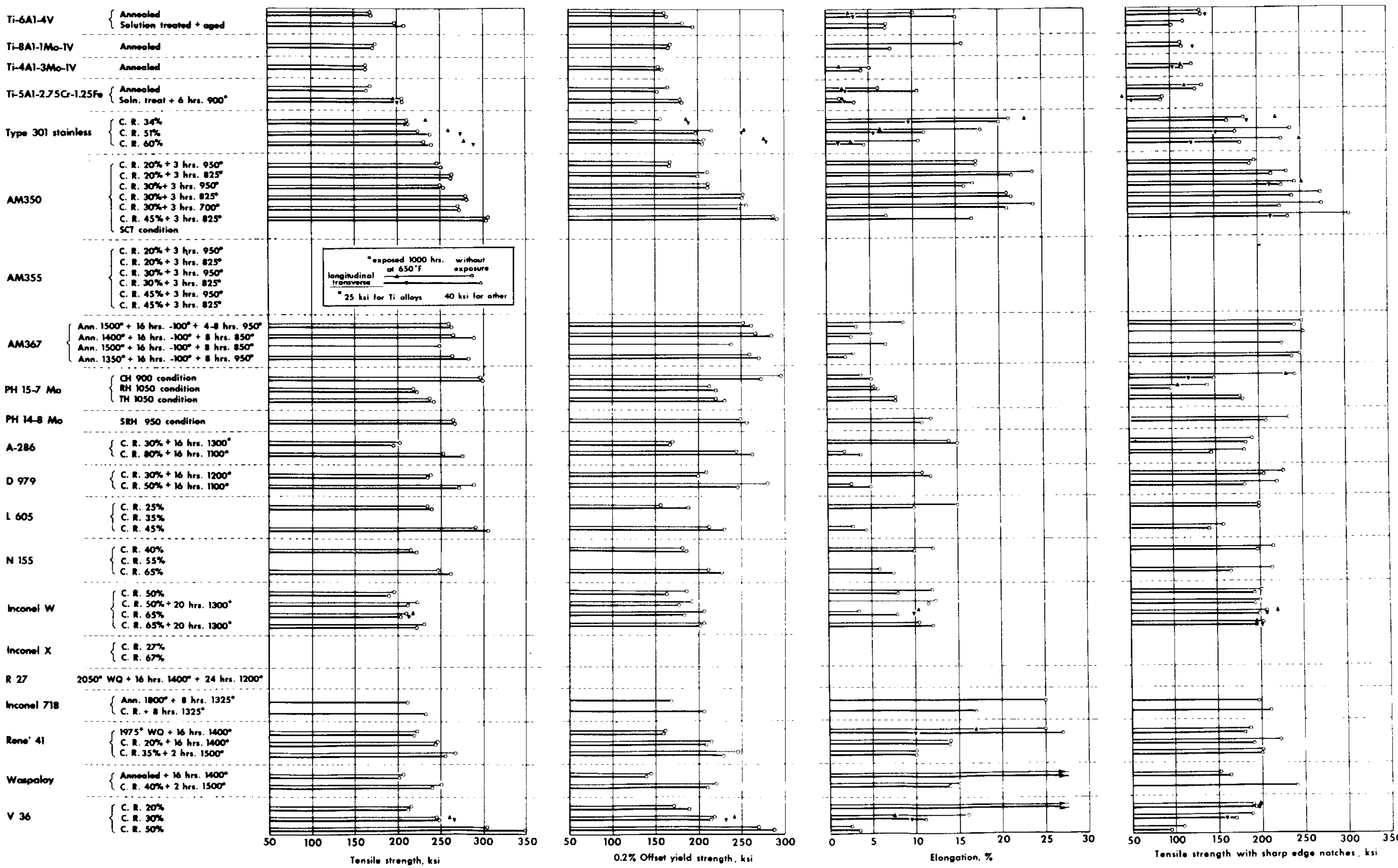
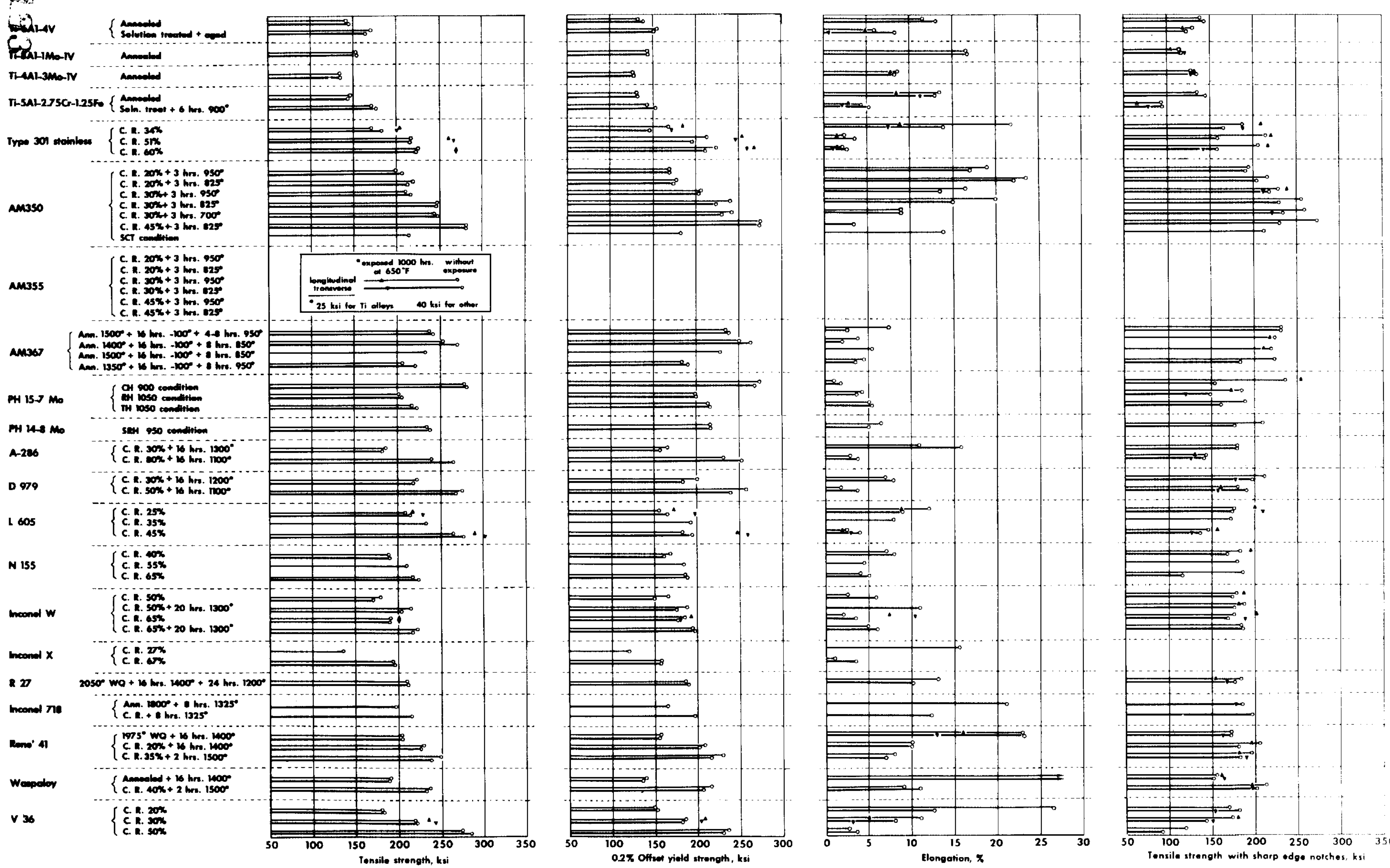
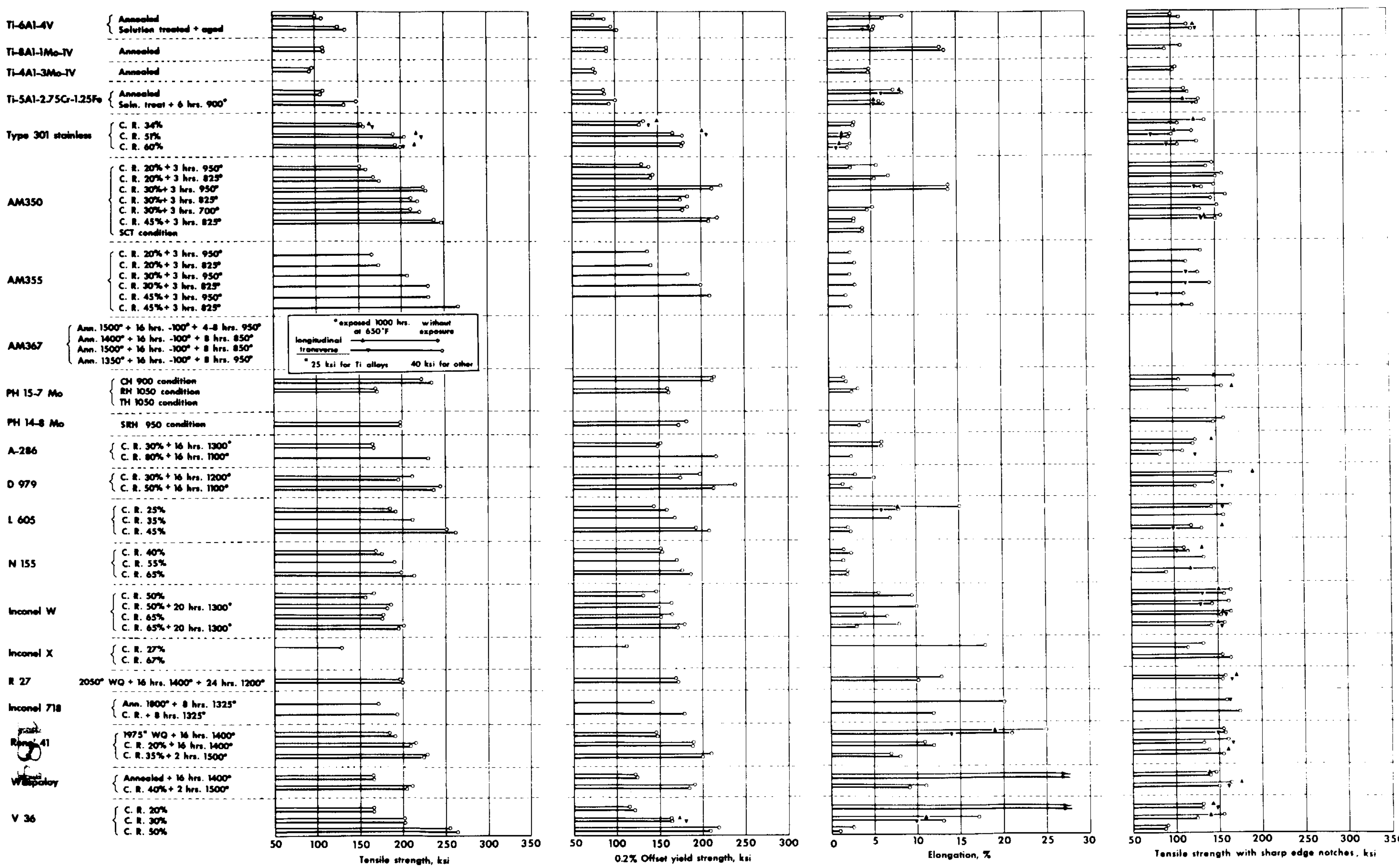
Averages of the reported tensile properties for sheet materials tested at - 110°F



Averages of the reported tensile properties for sheet materials tested at room temperature

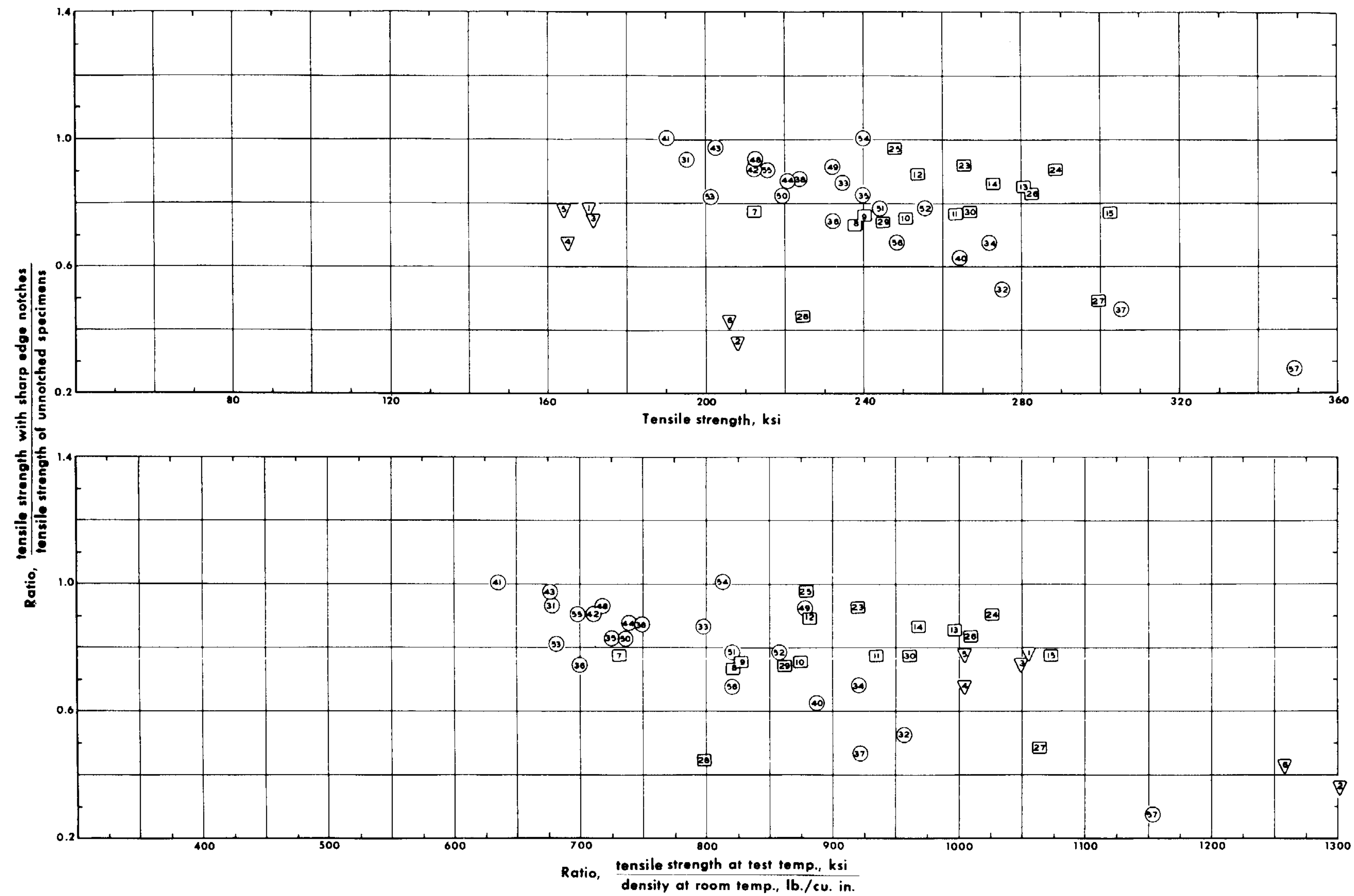


Averages of the reported tensile properties for sheet materials tested at 650°F



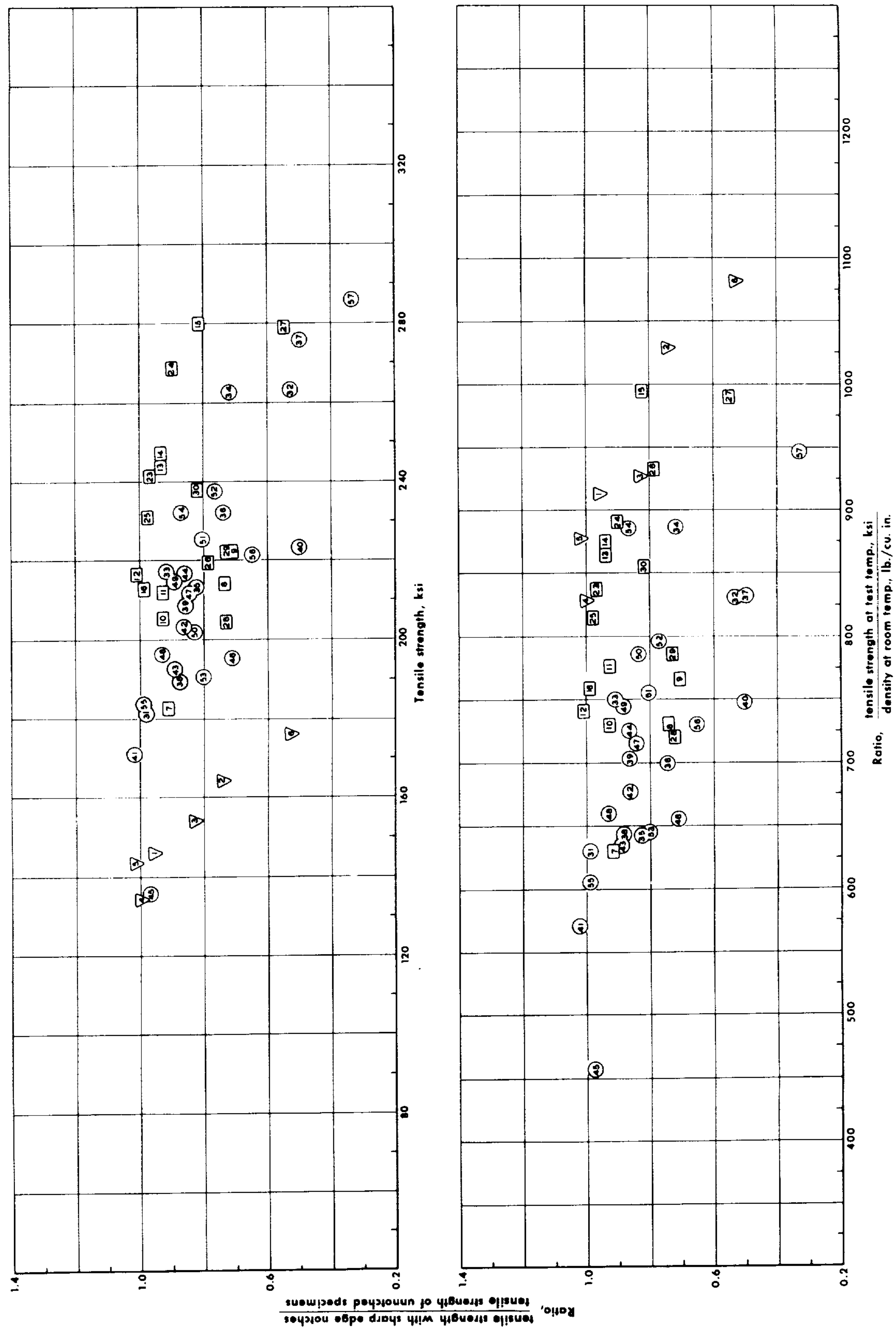
Identification key for notch-strength ratio plots

Ti-6Al-4V	Annealed	▽ 1	Titanium alloys
	Solution treated + aged	▽ 2	
Ti-8Al-1Mo-1V	Annealed	▽ 3	
Ti-4Al-3Mo-1V	Annealed	▽ 4	
Ti-5Al-2.75Cr-1.25Fe	Annealed	▽ 5	
	Soln. treat + 6 hrs. 900°	▽ 6	
Type 301 stainless	C. R. 34%	□ 7	Stainless steels
	C. R. 51%	□ 8	
	C. R. 60%	□ 9	
AM350	C. R. 20% + 3 hrs. 950°	□ 10	
	C. R. 20% + 3 hrs. 825°	□ 11	
	C. R. 30% + 3 hrs. 950°	□ 12	
	C. R. 30% + 3 hrs. 825°	□ 13	
	C. R. 30% + 3 hrs. 700°	□ 14	
	C. R. 45% + 3 hrs. 825°	□ 15	
	SCT condition	□ 16	
AM355	C. R. 20% + 3 hrs. 950°	□ 17	
	C. R. 20% + 3 hrs. 825°	□ 18	
	C. R. 30% + 3 hrs. 950°	□ 19	
	C. R. 30% + 3 hrs. 825°	□ 20	
	C. R. 45% + 3 hrs. 950°	□ 21	
	C. R. 45% + 3 hrs. 825°	□ 22	
AM367	Ann. 1500° + 16 hrs. -100° + 4-8 hrs. 950°	□ 23	
	Ann. 1400° + 16 hrs. -100° + 8 hrs. 850°	□ 24	
	Ann. 1500° + 16 hrs. -100° + 8 hrs. 850°	□ 25	
	Ann. 1350° + 16 hrs. -100° + 8 hrs. 950°	□ 26	
PH 15-7 Mo	CH 900 condition	□ 27	
	RH 1050 condition	□ 28	
	TH 1050 condition	□ 29	
PH 14-8 Mo	SRH 950 condition	□ 30	
A-286	C. R. 30% + 16 hrs. 1300°	○ 31	Super alloys
	C. R. 80% + 16 hrs. 1100°	○ 32	
D 979	C. R. 30% + 16 hrs. 1200°	○ 33	
	C. R. 50% + 16 hrs. 1100°	○ 34	
L 605	C. R. 25%	○ 35	
	C. R. 35%	○ 36	
	C. R. 45%	○ 37	
N 155	C. R. 40%	○ 38	
	C. R. 55%	○ 39	
	C. R. 65%	○ 40	
Inconel W	C. R. 50%	○ 41	
	C. R. 50% + 20 hrs. 1300°	○ 42	
	C. R. 65%	○ 43	
	C. R. 65% + 20 hrs. 1300°	○ 44	
Inconel X	C. R. 27%	○ 45	
	C. R. 67%	○ 46	
R 27	2050° WQ + 16 hrs. 1400° + 24 hrs. 1200°	○ 47	
Inconel 718	Ann. 1800° + 8 hrs. 1325°	○ 48	
	C. R. + 8 hrs. 1325°	○ 49	
Rene' 41	1975° WQ + 16 hrs. 1400°	○ 50	
	C. R. 20% + 16 hrs. 1400°	○ 51	
	C. R. 35% + 2 hrs. 1500°	○ 52	
Waspaloy	Annealed + 16 hrs. 1400°	○ 53	
	C. R. 40% + 2 hrs. 1500°	○ 54	
V 36	C. R. 20%	○ 55	
	C. R. 30%	○ 56	
	C. R. 50%	○ 57	



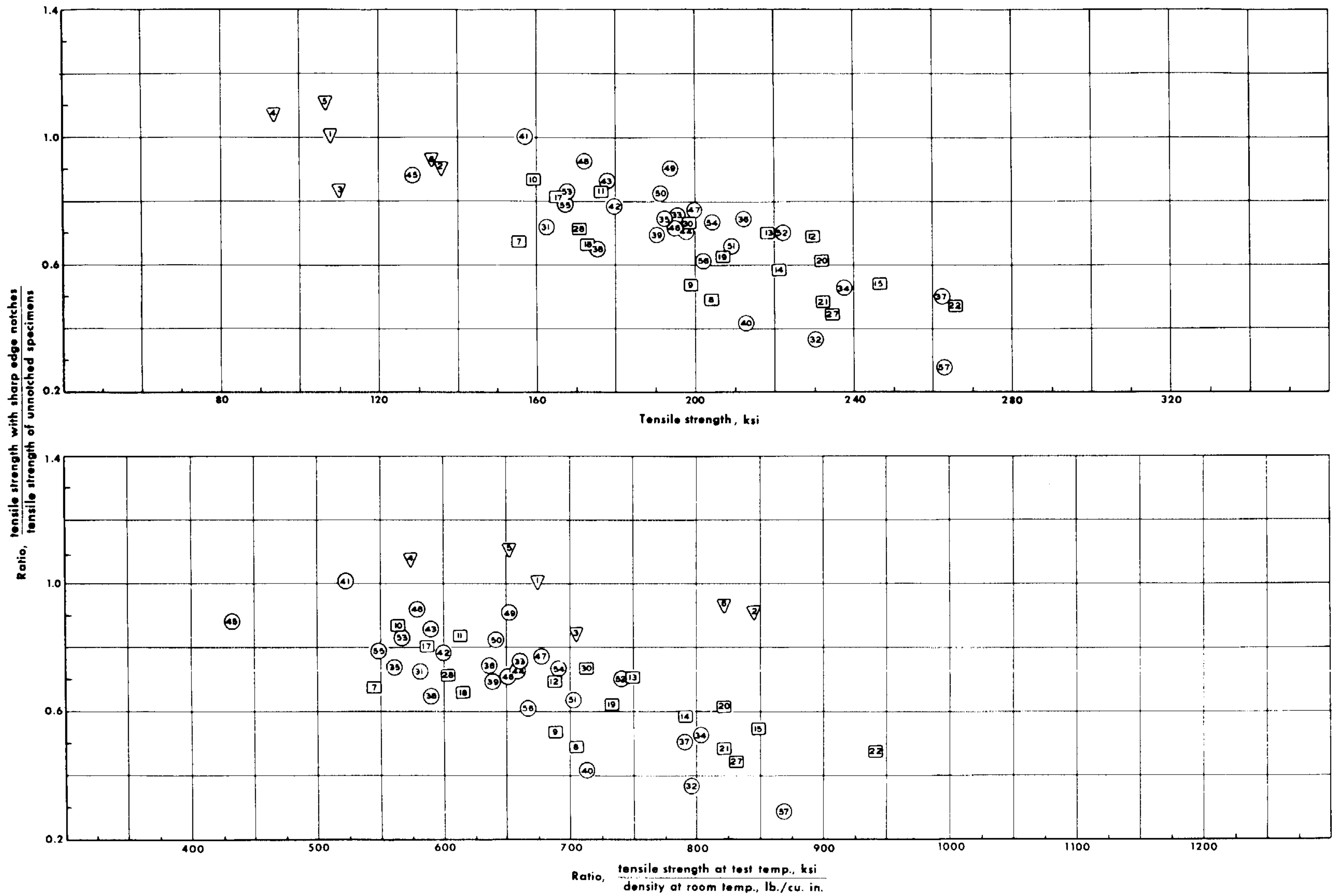
Relative notch strengths at -110°F, in terms of unnotched tensile strengths.

(Averages of transverse properties before exposure; sharp edge notches)



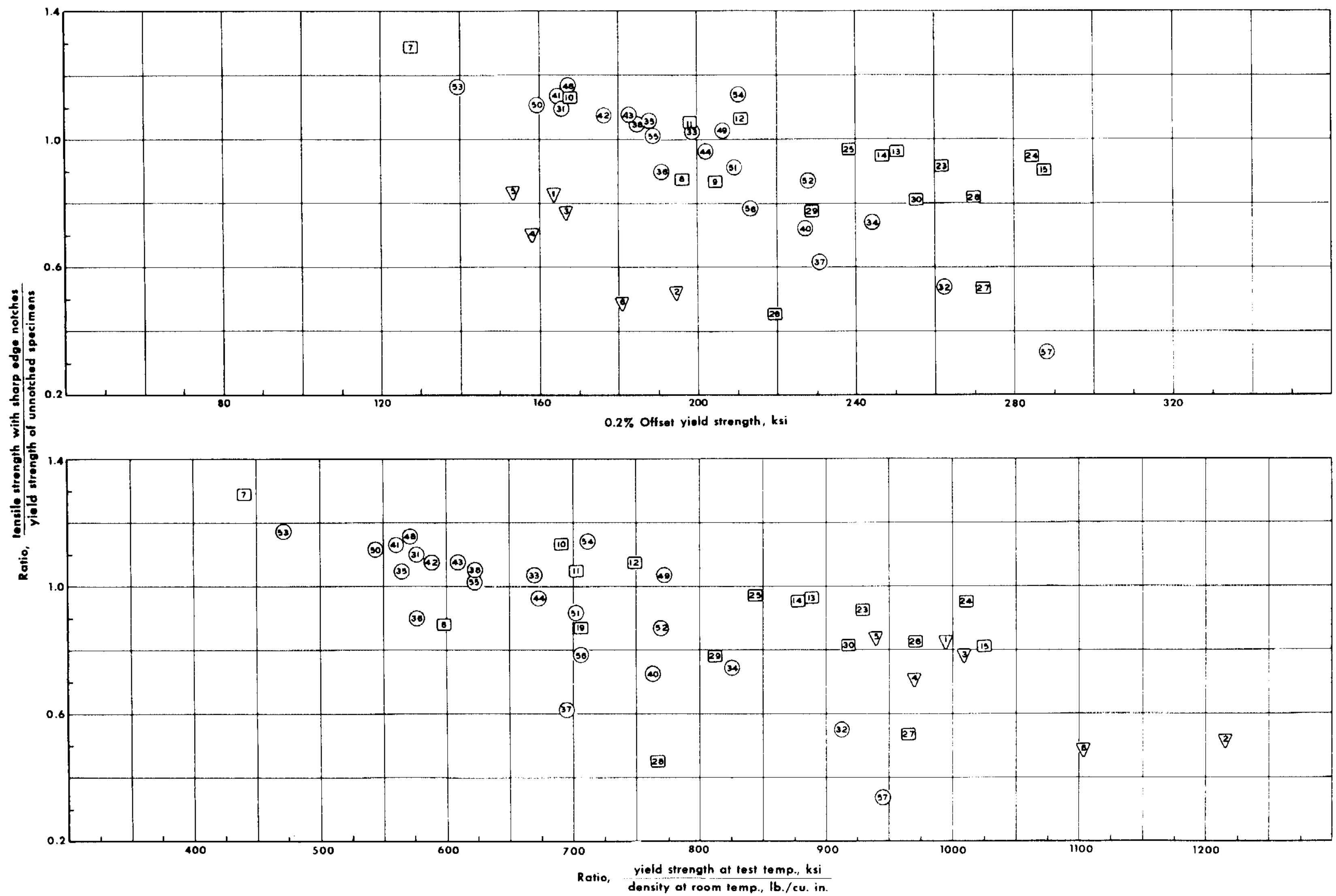
Relative notch strengths at room temperature, in terms of unnotched tensile strengths.

(Averages of transverse properties before exposure; sharp edge notches)



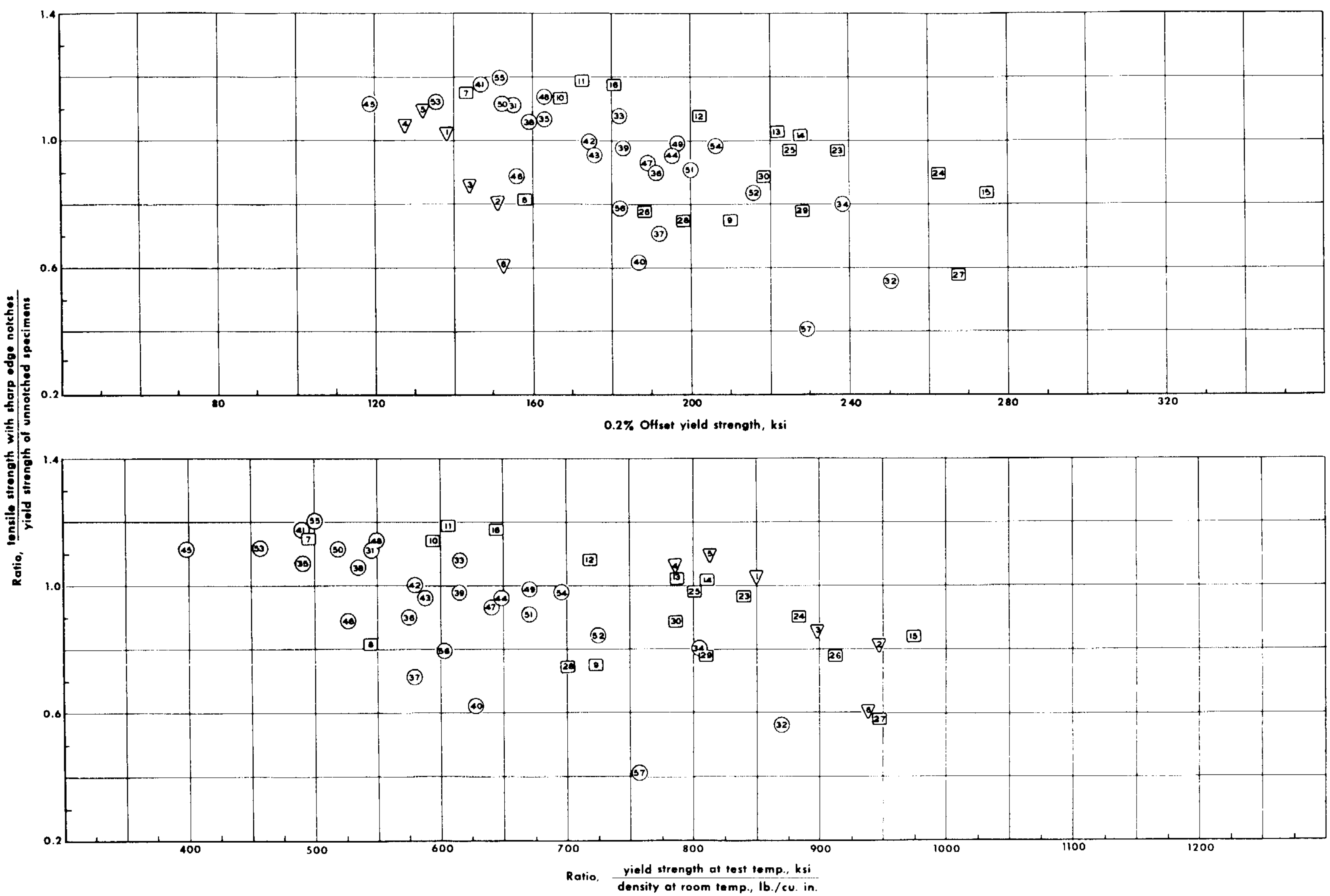
Relative notch strengths at 650°F, in terms of unnotched tensile strengths.

(Averages of transverse properties before exposure; sharp edge notches)



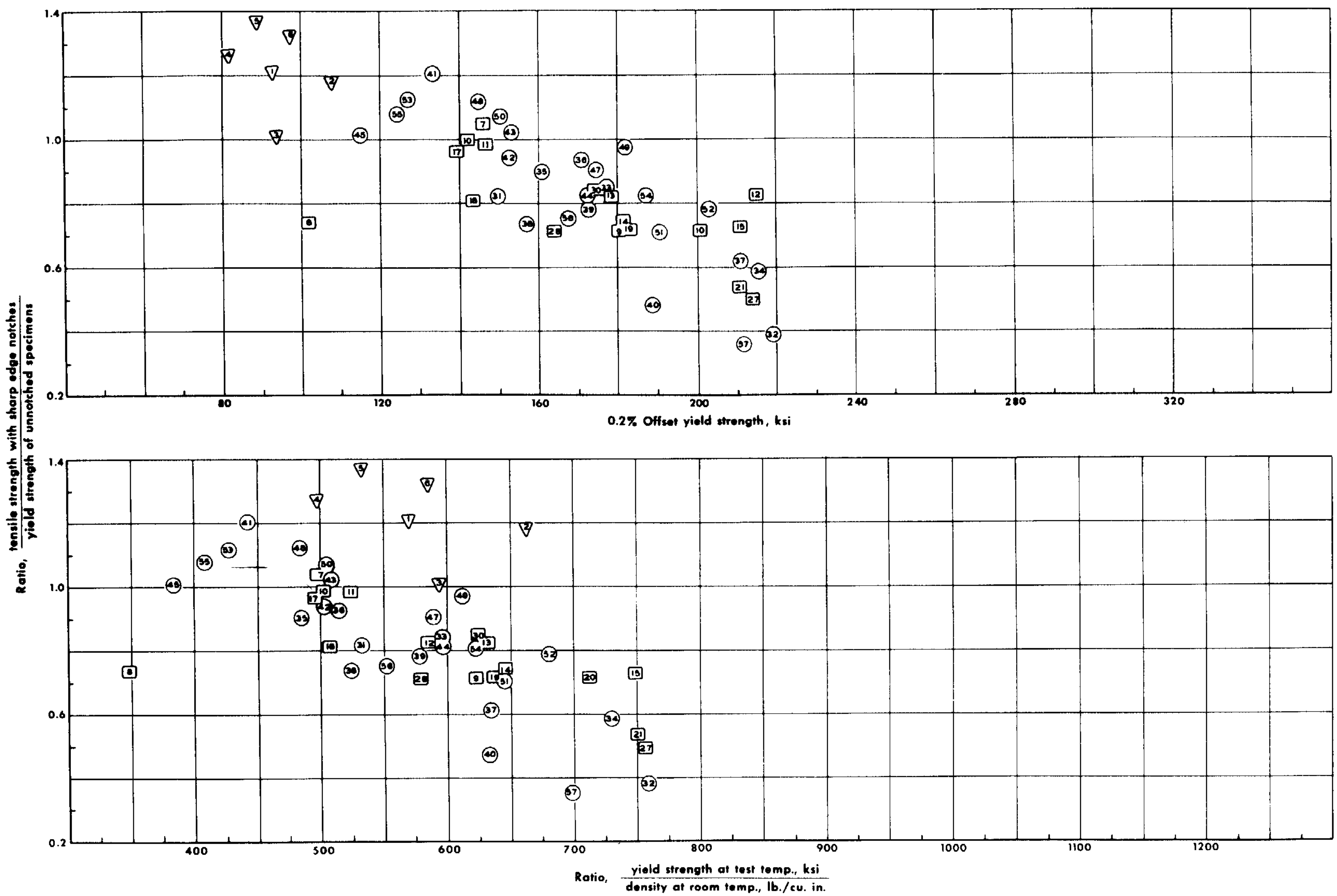
Relative notch strengths at -110°F, in terms of unnotched yield strengths.

(Averages of transverse properties before exposure; sharp edge notches)



Relative notch strengths at room temperature, in terms of unnotched yield strengths.

(Averages of transverse properties before exposure; sharp edge notches)



Relative notch strengths at 650°F, in terms of unnotched yield strengths.

(Averages of transverse properties before exposure; sharp edge notches)