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STABILITY OF FOUR TITANIUM-ALLOY AND FOUR STAINLESS-STEEL SHEET MATERIALS AFTER EXPOSURES UP TO 22 000 HOURS AT 550° F (561° K)

by George J. Heimerl, Robert M. Baucom, Charles R. Manning, Jr., and David N. Braski

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SUMMARY

Results are presented of an investigation of the stability of four titanium-alloy and four stainless-steel sheet materials after prolonged exposure without stress at 550° F (561° K); these materials are representative of the types considered for the skin of a supersonic transport. The effect of exposures up to 22 000 hours was determined from changes in the tensile and notch properties at room temperature (80° F (300° K)) and at -110° F (194° K) and from changes in strain-rate sensitivity and tensile spot-weld strength at room temperature. Metallurgical studies were made to determine microstructural changes in the materials due to the exposure. With the exception of one titanium alloy and one stainless steel, the materials were apparently stable for the exposure times completed so far. A marked deterioration in the tensile spot-weld strength, however, was obtained for the titanium alloys and some of the stainless steels due to the exposure.

INTRODUCTION

Many considerations are involved in the selection of a skin material for a supersonic transport capable of speeds up to a Mach number of 3. In the screening program of titanium-alloy, stainless-steel, and superalloy sheet materials (ref. 1), the emphasis was mainly on short-time properties obtained under accelerated test conditions, so as to obtain the most information in the shortest time. Before any material can be seriously considered for such an application, however, its stability or ability to withstand operational temperatures up to 30 000 or more hours without serious degradation must be known. Depending on the location, skin temperatures for a Mach 3 transport vary from about 440° F to 600° F (approximately 500° K to 590° K) because of aerodynamic heating, except for the hotter areas near the engines. (See ref. 2.) With the exception of 1000-hour data obtained in the screening program and some new data from followup programs, information on prolonged temperature effects is lacking for these materials.

In order to provide such information, an investigation was begun at the Langley Research Center almost 3 years ago to determine the stability of a few selected titanium-alloy and stainless-steel sheet materials after exposures up to 40 000 hours at 550° F (561° K). The effects of exposure on the unstressed specimens were to be determined from changes in the tensile and notch properties at room temperature and at -110° F (194° K) and from changes in the strain-rate sensitivity of the materials at room temperature. Long-time temperature effects on the tensile spot-weld strength were also to be obtained. Metallurgical studies were included to investigate the extent and nature of possible metallurgical changes due to the exposure.

This report summarizes the results obtained to date on the stability of four titanium-alloy and four stainless-steel sheet materials after exposures without stress up to 22 000 hours at 550° F (561° K). The titanium alloys are Ti-8Al-1Mo-1V (single, or mill, annealed), Ti-6Al-4V (annealed), Ti-4Al-3Mo-1V (solution treated and aged), and Ti-13V-11Cr-3Al (aged and double aged). The stainless steels are AM-350 (in the cold rolled and tempered, or CRT, condition and in the double aged, or DA, condition), PH 15-7 Mo (transformation and precipitation hardened, or TH1050, condition), PH 14-8 Mo (subzero transformation and precipitation hardened, or SRH950, condition), and AISI 301 (cold rolled, or CR, condition).

The units used for the physical quantities appearing in this paper are given in both the U.S. customary units and the International System of Units, SI. (See ref. 3.)

SYMBOLS

a lattice parameter in face of body-centered cubic lattice and lattice parameter of base in body-centered tetragonal system, Å

c lattice parameter in vertical direction of body-centered tetragonal system, Å

D diameter, in. (cm)

P load, lb (N)

R radius, in. (cm)

r radius at base of notch, in. (cm)

Subscript:

o base or reference property before exposure

Abbreviations:

A	aged
AN	annealed
CR	cold rolled
CRT	cold rolled and tempered
DA	double aged
SA	single aged
SRH	subzero transformation and precipitation hardened
STA	solution treated and aged
TH	transformation and precipitation hardened

MATERIALS AND SPECIMENS

Materials

Compared with the large number of materials and material conditions in the screening program (ref. 1), only a few were included in this investigation because of the large number of specimens and tests required for each material. The materials selected were chosen because they were then considered to be among the most promising or were representative of an important class or type of material. Information on the sheet thickness, heat treatment, and condition of the titanium-alloy and stainless-steel sheet materials is given in table I. The chemical composition of the materials is listed in table II.

Specimens

Four tensile specimens - the standard, the sharp V-notch, the rapid loading, and the spot weld - are shown in figure 1. Specimens were cut from both the longitudinal and transverse rolling directions of the sheets. The standard specimen conforms to the specification prescribed by the American Society for Testing and Materials (ASTM). (See ref. 4.) The sharp V-notch specimen is 1 inch (2.54 cm) wide and is recommended by a special ASTM committee. (See ref. 5.) The radius at the base of the notch varied from about 5×10^{-4} to 7×10^{-4} inches $\left(\text{approximately } 13 \times 10^{-4} \text{ to } 18 \times 10^{-4} \text{ cm}\right)$. The last step in finishing the radius was performed by hand drawing a shaping tool through the notch. This operation was done repeatedly until the desired radius was obtained. The rapid-loading specimen is a modification of the standard tensile specimen. The tensile spot-weld specimen is the cross-tension type

having a single spot weld holding two pieces of sheet together, each 1 inch (2.54 cm) square. Qualifying spot-weld shear tests were made for each material in accordance with reference 6.

PROCEDURES

The specimens were thoroughly cleaned before exposure. Where heat treating was required, specimens were cleaned both before and after heat treatment. The cleaning procedures are outlined in appendix A.

After having been cleaned, the specimens were placed in air-circulating electric ovens operating at 550° F (561° K). Specimens of each type were removed at predetermined times for testing at room temperature and at -110° F (194° K). The exposure schedule was 2000, 4000, 7000, 10 000, 14 000, 18 000, and 22 000 hours for most of the materials, but some exposures up to 40 000 hours are planned. None of the specimens were stressed during exposure. The testing procedures are described in appendix B.

The metallurgical investigation was based on X-ray diffraction studies, hardness measurements, and microstructure examinations at room temperature of small coupons which were exposed at 550° F (561° K) for the same times as other specimens. The procedures are given in appendix C.

MECHANICAL PROPERTIES BEFORE EXPOSURE

The mechanical properties of the titanium-alloy and stainless-steel sheet materials, obtained in the static and rapid-loading tests before the materials were exposed, are reviewed. The data are given in tables III to VIII, and representative or average results are shown in figures 2 to 8.

Static Properties

Tensile stress-strain characteristics.- Representative tensile stress-strain curves for the titanium-alloy and stainless-steel sheet materials at room temperature and at -110° F (194° K) are shown in figure 2 for both the longitudinal and the transverse grain directions. The longitudinal and transverse characteristics are approximately the same for each material at each temperature with the exception of Ti-4Al-3Mo-1V (STA) and AISI 301 (CR). The directional effects obtained for the titanium alloy are attributed to the fact that this material, according to the producer, was produced as a strip product rather than by current sheet-product methods; the directional effects in the stainless steel result from the 56-percent cold reduction.

Tensile strength and elongation.- The tensile strength and elongation in 2 inches (5.08 cm) of the titanium alloys and stainless steels at room temperature and at -110° F (194° K) are summarized in figures 3 and 4. The tensile

strengths at room temperature of the titanium alloys varied from about 140 to 180 ksi (965 to 1240 MN/m^2), and the strengths for the stainless steels ranged from about 180 to 220 ksi (1240 to 1520 MN/m^2).

Relation between uniform elongation and elongation in 2 inches.- Because of the questionable significance and usefulness of the elongation in 2 inches (5.08 cm) as a measure of ductility, the uniform elongation was also measured. (See tables III to VI.) Values of the ratio of the uniform elongation to the elongation in 2 inches are also given therein. The uniform elongation was measured from the increase in length between transverse parallel lines spaced 0.50 inch (1.27 cm) apart on the reduced section of the specimen. This measurement was made after fracture outside the region where necking occurred. The uniform elongation is the permanent strain which ordinarily occurs up to the time when the maximum load is reached and necking begins. (See ref. 7.)

An examination of the results (tables III to VI) shows that the test temperature, as well as the exposure at 550° F (561° K), had no discernible effect on the elongation ratios, except in the case of AISI 301. Disregarding the extreme scatter and irregularities which are inherent in elongation measurements, it was found that average values of the ratio obtained for all the tests varied from about 0.6 to 0.8 for the titanium alloys and from about 0.4 to 0.9 for the stainless steels. An average value of about 0.7 was obtained for both the titanium alloys and the stainless steels (except for AM-350 at 0.8). The ratio was temperature dependent for AISI 301, however, as it varied from about 0.4 at room temperature to 0.9 at -110° F (194° K). Such ratios can be used to estimate the uniform elongation when the commonly available elongation in 2 inches is given.

The uniform elongation is of considerable importance with regard to forming operations and strength analyses which preclude necking. Thus, it is a practical measure of ductility which warrants reporting by material fabricators and in material investigations. On the other hand, the commonly reported elongation in 2 inches involves the necking phenomena, specimen geometry, and testing conditions, and its value in fabrication or structural applications is doubtful.

Young's modulus.- Values of Young's modulus at room temperature, obtained from Tuckerman optical strain-gage measurements, are listed in table VII. Measurements of Young's modulus obtained in the routine tensile tests employing the transformer type of gages are not reported; these gages were used primarily to determine the yield strength and shape of the stress-strain curve rather than precise values of the elastic constant.

Notch strength.- The notch and tensile strengths obtained at room temperature and at -110° F (194° K) are summarized in figure 5. The notch strength is based upon the net-section stress.

The ratio of the notch strength to the tensile strength, or the notch strength ratio, tends to decrease at -110° F from that at room temperature for both the titanium alloys and stainless steels, mainly because of the increase in tensile strength at the low temperature. The notch strength ratios for Ti-6Al-4V and Ti-4Al-3Mo-1V are almost unity at room temperature, but this

ratio is only about 0.7 for Ti-8Al-1Mo-1V (AN) in the transverse direction and 0.5 for Ti-13V-11Cr-3Al (SA).

Another indication of the notch sensitivity of the materials is given by the amount of shear lip occurring at fracture. (See tables III to VI.) Ductile, shear type of fractures with shear-lip values above 50 percent were obtained for most of the materials at both normal and low temperatures but were not obtained at -110° F (194° K) for Ti-13V-11Cr-3Al (SA and DA), for AM-350 (DA), and in some instances for PH 15-7 Mo (TH1050), which exhibited brittle and irregular fracture characteristics.

Tensile and notch strength efficiencies.- A comparison of the tensile and notch strength efficiencies of the titanium alloys and stainless steels, based on their strength-density ratios at room temperature and at -110° F (194° K) is shown in figure 6. Both the tensile and notch strength efficiencies of the titanium alloys are as high as or higher than those for the stainless steels at both temperatures, with the exception of Ti-13V-11Cr-3Al, which has the lowest notch strength efficiency. The tensile strength efficiencies of the stainless steels may vary considerably, depending upon the heat treatment and the amount of cold reduction, so that the comparisons (fig. 6) would change considerably if different heat treatments and cold reductions were used. Of course, this variation would also be the case for the heat-treatable titanium alloys, such as Ti-6Al-4V, Ti-4Al-3Mo-1V, and Ti-13V-11Cr-3Al.

Strain-Rate Sensitivity

The rapid-loading tensile tests of the standard and sharp V-notch specimens were conducted to determine the strain-rate sensitivity of the materials and the effect that long-time exposure might have on this characteristic. Only the tests of Ti-4Al-3Mo-1V have been completed, and strain rates up to about 18 per second were obtained at yield in the fastest tests. The maximum elastic or initial strain rates were about 5 per second, corresponding to a stress rate of about 80×10^6 psi (550 GN/m^2) per second. Test durations at these speeds were about 6 and 3 milliseconds, respectively, for the tests of the standard tensile and notch specimens. The test data are given in table VIII.

Representative load and strain-time records for the fastest tests of the standard tensile specimens are shown in figure 7(a), and an example of the load-time record for the notch specimen is illustrated in figure 7(b). Except for the initial loading, the load and strain-time curves are essentially linear to the point where yielding or fracture occurs.

The strain-rate sensitivity of Ti-4Al-3Mo-1V is shown in figure 8. The tensile and notch strengths increased only about 15 percent over the static strengths even for elastic strain rates up to about 5 per second, so that this alloy is only moderately strain-rate sensitive. The elongation in 2 inches (5.08 cm) decreased somewhat at high strain rates, but the notch-strength ratio remained practically the same, except for an increase at the highest strain rate. Consequently, high strain rates were not detrimental for this alloy.

EFFECT OF PROLONGED EXPOSURE AT 550° F (561° K) ON MECHANICAL PROPERTIES

Tensile and Notch Properties

The effects of long-time exposure at 550° F (561° K) on the static tensile and notch properties at room temperature and at -110° F (194° K) are illustrated in figures 9 and 10 for the titanium alloys and in figure 11 for the stainless steels. The effects of the exposure on the properties are shown by changes in the ratio of the property after exposure to the corresponding property before exposure. The ratios are based upon the average of the results for both the longitudinal and transverse directions at each exposure. The test data are given in tables III to VI.

Titanium alloys.- With the exception of Ti-13V-11Cr-3Al (SA), the ratios for the tensile, yield, and notch strengths and for elongation in 2 inches remain close to unity in the room-temperature tests. (See fig. 9(a).) As the deviations in properties are small, it appears that Ti-6Al-4V (AN) is quite stable for exposures up to 22 000 hours and that Ti-4Al-3Mo-1V (STA) and Ti-8Al-1Mo-1V (AN) are stable for exposures up to 14 000 hours. The data at -110° F (194° K) also bear out this general conclusion. (See fig. 9(b).)

A closer look at the apparent instability of Ti-13V-11Cr-3Al at room temperature for two sheet thicknesses and two heat treatments is afforded in figure 10. (Each sheet came from a separate heat, or lot, of material.) The curves for the material, 0.064 inch (0.163 cm) thick, in the SA condition are the same as in figure 9(a). The results indicate that the material in either the single-aged (SA) or double-aged (DA) condition is not entirely stable after 2000 or more hours exposure. The double-aging treatment, in which the material was deliberately overaged, resulted in some improvement in stability in some instances. The changes obtained after exposure for the same heat treatment of the sheets 0.040 and 0.064 inch (0.102 and 0.163 cm) thick were not always consistent (for example in the tensile strength), and some were erratic, as indicated by the elongation curves. In any case, this material was affected somewhat more by the exposure than were the other titanium alloys.

Stainless steels.- The stainless-steel alloy PH 15-7 Mo (TH1050) appears to be stable for exposures up to 18 000 hours, and the alloys PH 14-8 Mo (SRH950) and AM-350 (CRT and DA) appear to be stable for exposures up to 10 000 hours. The only stainless steel which showed marked signs of instability after exposure at 550° F (561° K) in the tests at room temperature was AISI 301 (CR). (See fig. 11(a).) The tensile and notch properties were affected to some extent after 2000 hours or more exposure; the largest undesirable change was the 50-percent reduction in elongation. The changes in the other materials were slight, and the exposures were not long enough to be certain of the significance of some of the changes obtained to date.

The reduction in the notch strength of AM-350 (DA) and PH 15-7 Mo (TH1050) at -110° F (194° K) shown in figure 11(b) indicates that these materials were

also affected to some extent by the elevated-temperature exposure. The only stainless steel which appeared to be relatively free of these effects, at least up to 14 000 hours, at both room and low temperatures was AM-350 (CRT).

Tensile Spot-Weld Strength

The effect of exposures up to 22 000 hours at 550° F (561° K) on the tensile spot-weld strength of the titanium-alloy and stainless-steel sheet materials at room temperature is shown in figure 12 by changes in the ratio of the average load after exposure to the average load prior to exposure. Each average is based upon the results of two to eight tests for each exposure condition. (See table IX.) The type of failure, whether in the weld or in the base material, is also noted in table IX.

Titanium alloys.- With the exception of Ti-13V-11Cr-3Al in the DA condition, the tensile spot-weld strength of the titanium alloys (fig. 12) decreases gradually after exposure at 550° F (561° K). A decrease of about 33 percent was obtained in the case of Ti-4Al-3Mo-1V (STA) in 14 000 hours, 26 percent for Ti-6Al-4V (AN) and 39 percent for Ti-13V-11Cr-3Al (SA) in 22 000 hours, and 15 percent for Ti-8Al-1Mo-1V (AN) in 14 000 hours. Failure occurred in the welds in the case of Ti-13V-11Cr-3Al, but for the other titanium alloys failure took place by shearing the weld nugget through the base material. (See table IX.)

A decrease in tensile spot-weld strength of Ti-5Al-5Zr-5Sn, Ti-7Al-12Zr, and Ti-8Al-1Mo-1V at 800° F (700° K) has also been noted in reference 8. Unpublished NASA data indicate a decline in the fatigue life of spot-weld joints loaded in shear for Ti-4Al-3Mo-1V (STA) after 8800 hours of exposure at 550° F (561° K) but not for Ti-6Al-4V (AN) and Ti-8Al-1Mo-1V (AN). The deterioration in tensile spot-weld strength of the titanium alloys is in sharp contrast to the apparent stability of these materials.

Stainless steels.- Appreciable changes in tensile spot-weld strength at room temperature were obtained after exposures of 2000 hours or more at 550° F (561° K) for some of the stainless steels. (See fig. 12.) The sequence of welding, that is, before or after heat treatment, appears to be a factor. The tensile spot-weld strength of AM-350 (DA) increased after exposure when welded before heat treatment, whereas the strength of AM-350 (DA) and PH 15-7 Mo (TH1050) decreased with exposure when welded after heat treatment. On the other hand, the strength of AM-350 increased when welded in the CRT condition. The sequence of welding for PH 14-8 Mo, however, had no apparent effect on the results for exposures up to 10 000 hours. It should be noted that the sequence of welding can also have a large effect on the initial or unexposed spot-weld strength. (See table IX.)

Failure occurred predominately in the welds in the case of AISI 301 (CR) and in the base material in PH 15-7 Mo (TH1050) and PH 14-8 Mo (SRH950). For the other materials, some of the failures were in the welds and some in the base material.

The results for the stainless steels showed more scatter than for the titanium alloys (table IX). Some of the scatter was due to the excessive bending which occurred in the tests of the stainless-steel specimens, 0.025 inch (0.063 cm) thick, but this scatter was not the case for the titanium-alloy specimens, 0.040 inch (0.102 cm) thick.

Strain-Rate Sensitivity

The effects of exposures up to 14 000 hours at 550° F (561° K) on the tensile and notch properties of Ti-4Al-3Mo-1V (STA) obtained in the rapid-loading tests at room temperature are shown in figure 13. The effect is illustrated by changes in the ratio of the property after exposure to the comparable property before exposure for elastic strain rates of approximately 5 and 0.1 per second, as well as for those at 0.00002 per second (the static tests).

Inasmuch as the ratios for the tensile strength, notch strength, and elongation in 2 inches (5.08 cm) remained nearly constant regardless of the exposure and testing speed, there are no indications in the rapid-loading tests of instability of the material, at least for exposures up to 14 000 hours. This result is in agreement with those obtained in the static tests (fig. 9) previously discussed.

METALLURGICAL INVESTIGATION

An attempt was made to determine whether any metallurgical changes had occurred in the sheet materials after exposure at 550° F (561° K). X-ray diffraction studies were made to determine the lattice parameters before and after exposure, and both light and electron microscopy were utilized to study changes in the microstructure. Microhardness measurements were obtained to detect phase changes and other exposure effects.

Titanium Alloys

The results of the metallurgical study on the titanium alloys are given in table X and are shown in figures 14 to 17. The results for the Ti-8Al-1Mo-1V, a "near-alpha" alloy, and the "alpha-beta" alloys Ti-6Al-4V and Ti-4Al-3Mo-1V are discussed first, followed by the "all-beta" alloy Ti-13V-11Cr-3Al.

Near-alpha and alpha-beta alloys.- The mechanical tests previously described indicated that the Ti-8Al-1Mo-1V (AN), Ti-6Al-4V (AN), and Ti-4Al-3Mo-1V (STA) remained quite stable, even after the longest exposures at 550° F (561° K). These results are verified by the fact that very little change was noted in the lattice parameters and microhardness, or Knoop, values (table X), or in the microstructure of these sheet materials after exposure (figs. 14, 15, and 16).

Figure 14 shows the microstructure of Ti-8Al-1Mo-1V (AN) and Ti-6Al-4V (AN) before and after exposures of 14 000 and 22 000 hours, respectively. At a magnification of 500, the beta platelets appear as small dark spots in the alpha grain boundaries. The electron micrographs (fig. 15) show clearly the distribution of beta platelets in the alpha grain boundaries of these two titanium alloys. Often classified as an "all-alpha" or near-alpha titanium alloy, Ti-8Al-1Mo-1V (AN) appears closer to an alpha-beta type, as far as structure is concerned, even though it contains fewer beta platelets than alloys such as Ti-6Al-4V (AN). Figure 16 illustrates the microstructure of Ti-4Al-3Mo-1V (STA) which consists of alpha prime plus beta and alpha phases. The micrographs (×500) show the alpha phase as light areas and the alpha prime plus beta phase as dark areas. The electron micrograph (×15 000) shows in detail the dispersion of beta stringers in the alpha-prime phase.

Beta alloy.- The mechanical tests previously discussed for the all-beta Ti-13V-11Cr-3Al in both the single- and double-aged conditions indicated that this material was not completely stable after exposure at 550° F (561° K). The lattice parameters (table X) for the single-aged material decreased slightly due to the exposure, indicating the probability of continuing beta decomposition and formation of alpha titanium and titanium chromide $TiCr_2$ precipitates. The lattice parameters for the double-aged material showed less changes; thus, it appears slightly more stable than the single-aged material after exposure. Hardness values of both the single- and double-aged Ti-13V-11Cr-3Al were little affected by the exposure.

Figure 17 shows micrographs of Ti-13V-11Cr-3Al in the single- and double-aged conditions before and after 18 000 and 22 000 hours exposure, respectively. The large beta grains could account for the relatively poor notch properties of Ti-13V-11Cr-3Al compared with the other titanium alloys. The electron micrograph shows the alpha and $TiCr_2$ precipitates in the beta grains and along the grain boundaries.

Tensile spot welds.- Noticeable losses of spot-weld tensile strength in Ti-4Al-3Mo-1V (STA), Ti-6Al-4V (AN), and Ti-8Al-1Mo-1V (AN) were observed (fig. 12) after exposure at 550° F (561° K). The metallurgical examination of the spot welds before and after exposure showed the weld nugget in these alloys to consist of a Widmanstaetten structure produced by quenching of the high-temperature beta phase. The heat-affected zone appears to be an overaged alpha-beta microstructure. The metallurgical study did not reveal any change in the structure because of exposure.

Hardness traverses of spot welds with no exposure showed the heat-affected zones and weld nugget to have about the same hardness as the base material. However, after exposure at 550° F (561° K), the heat-affected zones and weld nuggets in Ti-4Al-3Mo-1V (STA) and Ti-6Al-4V (AN) were considerably harder than the base material which maintained its original hardness. The hardness of the heat-affected zone in the Ti-4Al-3Mo-1V (STA) spot welds increased about 150 Knoop after 14 000 hours exposure, whereas the Ti-6Al-4 (AN) spot welds showed an increase of 100 Knoop after 22 000 hours exposure. There was very little change in hardness of the Ti-8Al-1Mo-1V (AN) weld zone, even after 14 000 hours exposure. The results of these hardness measurements alone cannot

explain the losses of tensile spot-weld strength, but it is of interest to note that Ti-4Al-3Mo-1V (STA) showed the greatest increases of hardness in the heat-affected zones after exposure and also displayed the greatest losses of weld strength. The loss in spot-weld strength due to long-time elevated-temperature exposure in these titanium alloys needs further investigation.

Stainless Steels

The results of the metallurgical investigation of the stainless steels are shown in table X and figures 18 to 20. Three of the stainless steels, AM-350 (CRT) and AM-350 (DA), PH 15-7 Mo (TH1050), and PH 14-8 Mo (SRH 950) are the precipitation-hardening type (figs. 18 and 19), whereas AISI 301 (fig. 20) is a work-hardening austenitic stainless steel.

Precipitation-hardening stainless steels.- The notch and tensile data for AM-350 (CRT) and AM-350 (DA), PH 15-7 Mo (TH1050), and PH 14-8 Mo (SRH 950) after exposure at 550° F (561° K) indicated that only slight changes may have taken place in these materials. The Knoop hardness values and lattice parameters (table X) and the microstructure for the three precipitation-hardening, stainless steels were also essentially unchanged by long-time exposure.

Micrographs of the three stainless steels are shown in figures 18 and 19. Figure 18 shows the microstructure of AM-350 in the CRT and DA conditions, both before and after long-time exposure at 550° F (561° K). The microstructure of AM-350 (CRT) consists of delta ferrite stringers (white areas) in a matrix of martensite and retained austenite (mixed gray and black). The microstructure of AM-350 (DA) consists of delta ferrite pools (white areas) in a matrix of martensite plus retained austenite (gray areas). A network of carbide precipitates are interspersed in the grain boundaries. It appears from these micrographs that there were no microstructural changes due to exposure in either AM-350 (CRT) or AM-350 (DA).

Figure 19 shows the microstructure of PH 15-7 MO (TH1050) and PH 14-8 Mo (SRH 950) before and after long-time exposure at 550° F (561° K). PH 15-7 Mo (TH1050) consists of delta ferrite in a martensite matrix plus retained austenite with carbide precipitates in the grain boundaries. A moderate number of inclusions was also found in this alloy. PH 14-8 Mo (SRH 950) consists of delta ferrite pools (white areas) in a matrix of a martensite plus retained austenite, but no carbide precipitates are evident in the microstructure. Moreover, PH 14-8 Mo (SRH 950) appeared to have fewer inclusions than PH 15-7 MO (TH1050). These micrographs indicate that as a result of the exposure, no microstructural changes occurred in PH 15-7 MO (TH1050) and PH 14-8Mo (SRH950).

Work-hardening austenitic stainless steel.- The results of the mechanical tests of AISI 301 (CR) presented previously showed that the strength increased and the elongation decreased after exposure at 550° F (561° K). The lack of stability of this material is also reflected by the increase in Knoop hardness with exposure and by the X-ray diffraction studies (table X). The X-ray diffraction patterns on specimens with 0, 2000, 4000, 7000, and 10 000 hours

exposure indicated that a phase transformation was gradually occurring with increased exposure, as evidenced by the gradual appearance of new peaks, which could be due to martensite. These peaks were pronounced by 7000 hours exposure. The specimens with 7000 and 10 000 hours exposure were found to be more magnetic than those with no exposure. It appears, therefore, that some of the highly cold-worked austenite has transformed to martensite because of exposure. The martensite, however, could not be distinguished from the austenitic structure with either the metallograph or electron microscope. Nevertheless, the hardness increase, the appearance of new diffraction peaks, and the addition of magnetic properties serve as sufficient evidence of the formation of another phase.

Figure 20 illustrates the microstructure of AISI 301 (CR). The only difference between the two micrographs (×500) showing the AISI 301 before and after 10 000 hours exposure is in the contrast; the exposed specimen was etched slightly longer. The electron micrograph (×15 000) illustrates the surface details of the cold-worked austenitic structure after 2000 hours exposure at 550° F (561° K) which are also representative of the structure for exposures up to 10 000 hours.

Tensile spot welds.- The effects of exposure at 550° F (561° K) on the tensile spot-weld strength for many of the stainless steels are evident from the room-temperature tests. (See fig. 12.) The exposure effects were further evidenced by corresponding changes in the weld-nugget microstructure.

AM-350 (CRT), and AM-350 (DA) welded before heat treatment, showed increases in weld strength after prolonged exposure. Examination of the weld nugget indicated that a slight aging had occurred in AM-350 (CRT), whereas no change in the initial acicular martensitic structure was noticed in AM-350 (DA).

Both the AM-350 (DA) and the PH 15-7 Mo (TH1050), when welded after heat treatment, showed a marked decrease in spot-weld strength after exposure. The micrographs for AM-350 (DA) taken after exposure, however, showed only slight indications of any change in structure, which consisted of a uniform martensite. The weld nugget of PH 15-7 MO (TH1050) welded after heat treatment showed definite signs of aging after exposure. This aging was characterized by the precipitation of carbides along preferred orientations within the grains.

CONCLUDING REMARKS

This investigation was concerned mainly with the stability of some selected titanium-alloy and stainless-steel sheet materials after prolonged exposure without stress at 550° F (561° K). The materials are representative of the various types which have been considered for application to the skin of a supersonic transport.

Inasmuch as there was no significant change in the notch or tensile properties at room temperature and at -110° F (194° K) after exposure, it appears that Ti-6Al-4V (annealed) after 22 000 hours, Ti-8Al-1Mo-1V (single, or mill, annealed) after 14 000 hours, and Ti-4Al-3Mo-1V (solution treated and aged)

after 14 000 hours are stable under these conditions. The stainless steels also appear to be stable for exposures up to 18 000 hours in the case of PH 15-7 Mo (transformation and precipitation hardened, or TH1050, condition), 10 000 hours for PH 14-8 Mo (subzero transformation and precipitation hardened, or SRH950, condition), and 10 000 hours for AM-350 (cold rolled and tempered, or CRT, condition and double aged, or DA, condition). Definite indications of instability, however, were found for Ti-13V-11Cr-3Al (single and double aged) and AISI 301 (cold rolled, or CR, condition) after 2000 hours or more exposure.

The results obtained in this investigation are generally encouraging as most of the effects of the exposure at 550° F (561° K) on the material properties have been relatively small for exposures from 10 000 to 22 000 hours. Inasmuch as the desired operational life of a supersonic transport is now considered to be at least about 30 000 hours, however, there is still the possibility that instability may develop at the longer times. The fact that some parts of the structure may also be at somewhat higher temperatures raises additional questions as to the stability of the materials under such conditions. Of concern is the appreciable deterioration in the tensile spot-weld strength of the titanium alloys and some of the stainless steels after prolonged exposure at 550° F (561° K). The need for further investigation of the weld-strength degradation of materials selected for a supersonic transport is evident.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., October 17, 1964.

APPENDIX A

CLEANING PROCEDURES FOR TITANIUM ALLOYS AND STAINLESS STEELS

The cleaning procedures for the titanium-alloy and stainless-steel sheet materials employed before and after heat treating and prior to exposure at 550° F (561° K) are outlined herein.

Titanium Alloys

Remove any markings, such as crayon, the manufacturer's stamp, and so forth, with acetone and a cloth. Alkaline cleaning, which utilized a separate tank for each solution or rinse, was as follows:

(1) Alkaline cleaner (sodium hydroxide base): 6 ounces per gallon of water at temperatures from 180° F to 200° F (355° K to 367° K); immersion time, 10 minutes

(2) Hot water rinse; immersion time, 2 to 3 minutes

(3) Nitric acid dip: 20-percent nitric acid per gallon of water, by volume; immersion time, 30 seconds

(4) Hot water rinse, agitated

(5) Cold water rinse, agitated

(6) Cold water rinse, agitated, with a continuous supply of fresh water

(7) Dry with clean cloth or paper wipers; package in clean container.

Stainless Steels

AM-350 (CRT), AM-350 (DA), and AISI 301.- The following procedure is used for cleaning the stainless steels AM-350 (CRT), AM-350 (DA), and AISI 301:

(1) Vapor degreasing with trichlorethylene vapor

(2) Hot water rinse

(3) Nitric acid dip: 20-percent nitric acid per gallon of water, by volume; immersion time, approximately 5 minutes

(4) Hot water bath, followed by cold water rinse

(5) Drying with soft clean cloth

PH 15-7 Mo and PH 14-8 Mo.- The following procedure is used for cleaning the stainless steels PH 15-7 Mo and PH 14-8 Mo:

(1) Vapor degreasing with trichloroethylene vapor

(2) Hot water rinse

(3) Hand scrubbing with fiber brush and 1 part detergent diluted with 20 parts water, by volume

(4) Warm water rinse

(5) Dry with hand hair dryer.

APPENDIX B

MECHANICAL TESTS

Static Tests

The static tests of the standard tensile specimens were conducted under controlled strain-rate conditions in a hydraulic testing machine of 100-kip (445-kN) capacity and equipped with a load-strain recorder. A strain rate of 0.005 per minute was maintained through and just beyond yield; this rate was then increased to 0.05 per minute until fracture occurred. Two linear variable differential transformer strain gages were employed in the room-temperature tests to measure strain over a gage length of 1 inch (2.54 cm). A single transformer strain gage was used in the tests at -110° F (194° K) to measure strains over a gage length of 2 inches (5.08 cm). In these tests, the specimen was submerged in a mixture of dry ice and acetone in a cryostat mounted on the testing machine. The strain gage was mounted on extensometer rods which extended above the two knife edges clamped to one face of the reduced section of the specimen. The specimen was gripped by pin-loaded plates which were bolted on each end of the specimen. The sharp V-notch tensile specimens were tested at a constant net-section stress rate corresponding to a strain rate of about 0.00125 per minute in the same hydraulic testing machine. The specimens were loaded through centered 1-inch-diameter pins and yokes so as to minimize bending in the plane of the sheet of the specimen. The tests at -110° F were run in the same cryostat as that used for the tensile tests.

Rapid-Loading Tests

The 10 000-pound-capacity high-speed pneumatic tensile testing machine at the Langley Research Center was used for the rapid-loading tests. (See ref. 9.) The total time to fracture at the fastest testing speed was about 6 milliseconds for the tensile tests and 3 milliseconds for the notch tests. Because the frequency response of the weigh bar, grips, and oscillograph systems previously used was only about 1500 cps (1.5 kHz), a new weigh bar and oscilloscope recording system was employed to verify results obtained with the former system. The weigh bar was constructed of stainless steel and instrumented with four semi-conductor strain gages made with a p-type silicon crystal. The frequency response of the new system was about 7000 cps (7.0 kHz) which was sufficient to eliminate the spurious load oscillations obtained previously (fig. 8 of ref. 9) and to make it possible to measure the mechanical properties with greater certainty.

Tensile Spot-Weld Tests

The tensile spot-weld specimens were tested at room temperature with a pin fixture which applied tension to the spot weld when the fixture was loaded in compression. The spot weld was loaded in tension at approximately 500 pounds (2.22kN) per minute.

APPENDIX C

METALLURGICAL PROCEDURES

X-Ray Diffraction

Sections were removed from exposed metallurgical coupons as well as from unexposed material. The flat faces of the sections were examined by X-ray diffraction to determine any changes in the lattice parameters due to exposure in the following manner. The sections were placed in a diffractometer and scanned at the rate of 2° per minute with a collimated copper X-ray beam employing a nickel filter and $K\alpha$ radiation. A scanning angle 2θ from 20° to 165° was used, and the diffraction pattern was recorded through this angle on a strip-chart recorder. The major diffraction peaks were identified and rescanned at 0.2° per minute. The value of 2θ for each peak was taken as the midpoint of a chord cutting the peak at one-half the peak height. The lattice parameters were calculated by using the interplanar spacing values associated with each peak.

Microstructure Examination

Sections were removed from the exposed coupon and the "as-received" material and mounted flat in bakelite. The sections were then wet ground, mechanically polished, and etched. The titanium sections were etched with a solution consisting of 97 parts water (H_2O), 2 parts concentrated nitric acid (HNO_3), and 1 part concentrated hydrofluoric acid (HF). All the stainless steels except AISI 301 were etched with a solution of 4 grams copper sulfate ($CuSo_4$), 20 milliliters ($20\ cm^3$) concentrated hydrochloric acid (HCl), and 40 milliliters ($40\ cm^3$) water. The AISI 301 sections were etched electrolytically with a solution of 10 grams oxalic acid and 100 milliliters ($100\ cm^3$) water. The etching voltage was from 4 to 6 with a current of approximately 0.5 ampere. Photomicrographs were taken at ×500 to show the microstructure. Electron micrographs of chrome-shadowed collodian surface replicas were taken to study the fine details of the microstructure.

Hardness Determinations

Hardness measurements were made on the exposed coupons, as well as on the as-received material, with a microhardness tester with a Knoop indenter and a 100-gram (0.981-N) weight.

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TABLE I.- MATERIALS AND HEAT TREATMENTS

Alloy	Condition	Nominal thickness, in. (cm)	Heat treatment (c)	
			U.S. customary units	SI units
Titanium:				
Ti-8Al-1Mo-1V[a]	AN[b]	0.040 (0.102)	Annealed 8 hours at 1450° F and FC by producer	Annealed 8 hours at 1061° K and FC by producer
Ti-6Al-4V	AN	.040 (0.102)	Annealed 1 hour at 1475° F, FC to 1300° F and AC by producer	Annealed 1 hour at 1075° K, FC to 977° K, and AC by producer
Ti-4Al-3Mo-1V[a]	STA	.040 (0.102)	Solution treated for 20 minutes at 1650° F and WQ by producer; aged 4 hours at 1050° F; AC	Solution treated for 1200 seconds at 1172° K and WQ by producer; aged 4 hours at 839° K; AC
Ti-13V-11Cr-3Al	SA	.064 (0.163) .040 (0.102)	Solution annealed by producer; aged 24 hours at 900° F; AC	Solution annealed by producer; aged 24 hours at 756° K; AC
Ti-13V-11Cr-3Al	DA	.064 (0.163) .040 (0.102)	Solution annealed by producer; aged 24 hours at 1000° F and 1 hour at 1100° F; AC	Solution annealed by producer; aged 24 hours at 811° K and 1 hour at 867° K; AC
Stainless steels:				
AM-350	CRT	0.025 (0.063)	Cold rolled 20 percent; tempered 3 to 5 minutes at 930° F; AC	Cold rolled 20 percent; tempered 180 to 300 seconds at 772° K; AC
AM-350	DA	.025 (0.063)	Annealed at 1850° F to 1975° F, AC, plus 3 hours at 1375° F, AC; aged 3 hours at 850° F; AC	Annealed at 1283° K to 1353° K, AC, plus 3 hours at 1019° K, AC; aged 3 hours at 727° K; AC
PH 15-7 Mo	TH1050	.025 (0.063)	Annealed at 1950° F and AC by producer; austenitized 90 minutes at 1400° F; quenched to 60° F; aged 90 minutes at	Annealed at 1339° K and AC by producer; austenitized 5400 seconds at 1033° K; quenched to 289° K; aged 5400 seconds at 839° K; AC
PH 14-8 Mo	SRH950	.050 (0.126)	Annealed at 1825° F and AC by producer; austenitized 1 hour at 1700° F; quenched to -100° F and held for 8 hours; aged 1 hour at 950° F; AC	Annealed at 1269° K and AC by producer; austenitized 1 hour at 1200° K; quenched to 200° K and held for 8 hours; aged 1 hour at 783° K; AC
AISI 301	CR	.025 (0.063)	Annealed at 2000° F, AC, and cold reduced 56 percent by producer	Annealed at 1367° K, AC, and cold reduced 56 percent by producer

[a]From sheet rolling program of Department of Defense.

[b]Single, or mill, annealed.

[c]AC, FC, and WQ indicate air cooled, furnace cooled, and water quenched, respectively.

TABLE II.- CHEMICAL COMPOSITION OF TITANIUM-ALLOY AND STAINLESS-STEEL SHEET MATERIALS OBTAINED FROM PRODUCERS

[Percents given on weight basis]

Titanium alloys[a]

Alloy	C	Fe	N_2	H_2	Al	V	Cr	Mo	Ti
Ti-8Al-1Mo-1V	0.034	0.09	0.013	0.005	7.8	1.1		1.1	Balance
Ti-6Al-4V	.026	.15	.013	.011	6.1	4.0			Balance
Ti-4Al-3Mo-1V	.015	.16	.011	.010	4.4	1.1		3.0	Balance
Ti-13V-11Cr-3Al, 0.064 in. (0.163 cm) thick	.026	.20	.022		2.9	14.0	11.4		Balance
Ti-13V-11Cr-3Al, 0.040 in. (0.101 cm) thick	.020	.20	.020	.017	2.8	13.4	11.3		Balance

Stainless steels

Alloy	C	Mn	P	S	Si	Cr	Ni	Co	Mo	Al	Fe
AM-350	0.080	0.76	0.019	0.012	0.30	16.80	4.15		2.80		Balance
PH 15-7 Mo	.063	.55	.020	.011	.44	14.96	7.23		2.15	1.14	Balance
PH 14-8 Mo	.040	.28	.008	.003	.67	14.38	8.14		2.00	1.22	Balance
AISI 301	.089	.15	.023	.017	.47	17.30	7.70	0.05	.16		Balance

[a]Average for different heats.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET

[U.S. customary units]

(a) Ti-8Al-1Mo-1V (AN), 0.040 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in.	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	(b)	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	155.5	159.0	145.5	146.0	18.5	16.5	14.0	10.0	0.69	127.5	110.0	0.82	0.69	69	67
0	80	157.0	159.0	146.0	148.0	17.0	16.0	14.0	9.0		126.5	114.0	.81	.72	67	79
0	-110	176.0	175.0	171.0	170.0	19.0		14.0		.74	112.0	109.8	.64	.63	71	41
0	-110	176.0	176.0	171.0	170.0						125.5	99.2	.73	.57	69	53
2 000	80	155.0	156.0	144.0	144.0	15.5	19.0	14.0	14.0	.83	114.5	110.5	.74	.72	100	80
2 000	80	153.0	153.0	142.0	142.5	18.5	17.0	16.0	14.0		126.0	114.0	.82	.74		62
2 000	-110	176.0	179.0	167.5	167.5		20.5		16.0	.83	121.0	101.0	.68	.56	64	55
2 000	-110	181.0	180.0	170.0	168.5		19.5		17.0		113.5	96.5	.64	.54	66	60
4 000	80	153.0	148.0	140.0	139.0	12.0	14.0	11.0	12.0	.86	123.0	118.0	.81	.78	71	100
4 000	80	153.0	154.0	140.0	136.0	15.0	17.0	12.0	14.0		127.0	120.0	.83	.80	67	86
4 000	-110	176.0	184.0	169.0	164.0	17.0	17.0	14.0	16.0	.85	122.0	105.0	.68	.58	70	71
4 000	-110	186.0	178.0	173.0	168.0		18.0	14.0	15.0		118.0	103.0	.65	.57	86	71
7 000	80	149.0	156.0	137.0	144.5	15.5	17.5	12.5	15.5	.84	126.0	117.7	.83	.75	71	79
7 000	80	154.0	157.0	143.0	143.0	15.5	15.0	12.5	12.5		121.0	122.0	.70	.78	71	71
7 000	-110	179.0	181.2	165.5				12.0			122.0	96.2	.69	.54	80	74
7 000	-110	176.0	176.0	163.8	162.0	12.0		9.0		.75	112.4	101.2	.63	.57	77	77
10 000	80	155.5	154.0	147.5	144.0	16.5	15.0	11.0	13.0	.77	123.5	108.0	.80	.70	0	100
10 000	80	152.5	156.5	143.8	147.0	14.5	16.5	11.0	13.0		122.5	123.6	.80	.80	0	100
10 000	-110	180.0	180.0	170.0	167.0			11.0	13.0		106.9	104.8	.60	.58	60	75
10 000	-110	178.5	180.5	168.4	167.0			11.0	12.0		121.0	109.2	.68	.61	40	75
14 000	80	158.7	159.5	147.0	147.0	15.0	16.0	9.0	10.0	.60	128.0	125.8	.81	.79	100	97
14 000	80	159.0	159.5	145.5	145.7	15.0	17.0	9.0	10.0		124.0	121.8	.78	.76	75	95
14 000	-110	177.0	178.5	169.0	164.0		15.0		13.0	.88	119.2	108.8	.66	.60	75	60
14 000	-110	184.0	183.5	169.9	172.2	15.0	13.0	12.0	13.0		113.2	110.8	.63	.61	75	60

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(b) Ti-6Al-4V (AN), 0.040 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	145.0	145.5	138.5	141.0	12.5	13.0	7.0	9.0	0.60	144.5	152.5	1.00	1.10	84	57
0	80	145.5	146.7	136.9	139.0	13.0	13.5	7.0	8.0		135.0	141.8	.93	.97	82	72
0	-110	172.0	171.0	162.5	167.0	14.0	18.0	11.0	13.0	.76	138.5	139.3	.81	.82	85	57
0	-110	169.0	171.0	159.0	164.0		14.5	14.0	9.0		124.8	139.0	.73	.81	100	66
2 000	80	143.8	145.0	138.4	140.7	13.0	13.5	5.0	9.0	.51	130.5	150.1	.91	1.04	83	72
2 000	80	144.2	145.8	137.4	142.8	14.0	14.0	7.0			131.5	150.6	.91	1.04	84	67
2 000	-110	171.0	172.0	164.0	166.0		9.0	7.0	7.0	.64	131.8	139.5	.78	.81	100	60
2 000	-110	168.2	171.0	161.5	166.0	14.5	14.0	8.0	10.0		134.2	131.5	.79	.77	77	89
4 000	80	144.9	147.5	140.5	141.0	12.0	15.0	4.0	7.5	.39	141.9	151.0	.98	1.03	88	60
4 000	80	144.6	147.1	138.0	142.0	12.5	15.0	4.0	5.5		143.5	145.2	.99	.99	100	62
4 000	-110	171.0	171.5	163.0	164.0	14.5	14.0	7.0	9.0	.56	144.0	142.5	.85	.83	79	70
4 000	-110	170.0	172.0	162.5	167.0	14.0	13.0	8.0	7.0		143.5	134.0	.84	.78	82	50
7 000	80	144.5	145.0	134.0	138.0	14.0	14.0	8.0	10.0	.67	146.5	150.5	1.02	1.04	75	86
7 000	80	142.0	145.5	135.5	138.5	15.0	13.5	10.0	10.0		142.5	153.0	.99	1.05	43	60
7 000	-110	169.0	169.0	161.5	162.5	11.0		6.0	7.0	.59	127.6	139.0	.75	.82	87	65
7 000	-110	169.5	169.0	161.0	161.5		13.5	8.0	8.0		121.0	137.7	.72	.81	90	76
10 000	80	141.0	142.0	134.5	138.0	12.0	15.0	9.0	11.0	.73	140.0	147.0	.99	1.03	83	87
10 000	80	142.0	143.5	137.0	138.0	13.0	15.0	10.0	10.0		129.0	145.0	.91	1.02	100	71
10 000	-110	166.5	169.0	161.5	166.0	15.0	8.0	12.0	8.0	.87	129.0	134.0	.77	.79	64	79
10 000	-110	168.0	170.0	164.0	167.0	14.0	15.0	10.0	15.0		129.5	143.0	.78	.84	84	62
14 000	80	144.5	151.0	136.0	144.0	14.0	15.6	6.0	10.0	.54	137.2	151.5	.95	1.01	100	50
14 000	80	144.6	150.0	135.5	139.0	14.6	15.6	6.0	10.0		134.3	148.2	.93	.99	80	40
14 000	-110	170.0	169.2	169.0	162.5	15.0	15.5	6.0	10.0	.52	135.5	134.8	.80	.80	99	70
14 000	-110	169.5	168.0	162.0	164.0	15.0	15.6	6.0	10.0		131.0	142.4	.77	.85	100	70
18 000	80	145.0	149.0	139.0	142.0	12.0	14.0	7.0	9.0	.61	142.5	150.5	.98	1.00	100	75
18 000	80	145.0	152.0	138.0	144.0	13.0	12.0	7.0	8.0		131.0	147.5	.90	.98	100	100
18 000	-110	169.0	173.0	162.0	168.0	12.5	13.0	6.5	7.0	.56	131.0	127.5	.78	.74	100	60
18 000	-110	168.0	172.0	165.0	167.0		13.0	8.0	7.0		128.0	143.0	.76	.83	99	100
22 000	80	146.5	145.4	139.0	138.5	12.5	12.5	6.0	8.0	.57	138.5	150.5	.95	1.03	100	100
22 000	80	146.0	147.2	138.5	142.0	13.0	14.5	8.0	8.0		136.3	148.5	.93	1.01	100	100
22 000	-110	174.3	175.4	167.5	169.0	15.0	13.5	7.0	10.0	.59	132.2	143.0	.76	.82	100	96
22 000	-110	173.5	175.4	162.0	168.5	14.0	13.0	8.0	8.0		132.8	135.7	.76	.77	93	100

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(c) Ti-4Al-3Mo-1V (STA), 0.040 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	138.0	159.0	121.0	149.0	11.0	8.0	11.0	5.0	0.76	133.0	153.0	0.97	0.96	(d)	52
0	80	135.5	159.0	118.0	148.0			7.0	6.0		128.0	153.0	.94	.96	100	65
0	-110	163.0	188.0	144.0	175.0		10.0	7.0	7.0	.68	151.0	133.0	.92	.71	83	70
0	-110	164.0	188.0	142.0	175.0			7.0	6.0		149.0	149.0	.91	.79	80	62
2 000	80	135.0	157.0	119.0	146.0	11.0	10.0	10.0	8.0	.86	122.0	154.0	.90	.98	17	55
2 000	80	135.0	158.5	120.0	148.0	11.0	10.0	9.0	9.0		131.0	145.0	.97	.92	30	78
2 000	80										121.0	154.0	.90	.98	86	49
2 000	-110	157.5	182.0				10.0	6.0	8.0		146.0	125.0	.93	.68	67	57
2 000	-110	155.5	182.0	132.0	175.0		11.0	5.0	8.0	.65	138.0	150.0	.88	.82	30	57
2 000	-110	157.0	183.0	135.0	172.0		9.0	6.0	6.0		138.0	145.0	.88	.80	46	57
4 000	80	136.0	158.0	119.0	146.0	12.0	10.0	10.0	7.0	.77	131.0	156.0	.97	.98	77	71
4 000	80	135.0	160.0	119.0	147.0	11.0	10.0	9.0	7.0		131.5	154.0	.97	.97	86	100
4 000	80										129.0	150.0	.95	.94	100	100
4 000	-110	153.5	182.0	136.0	171.5		8.2	6.0	7.0	.79	137.0	158.5	.84	.86	0	0
4 000	-110	165.0	188.0	142.2	175.5		16.5	6.0	7.0		134.0	140.4	.81	.76	35	75
4 000	-110										137.5	157.0	.84	.85	0	55
7 000	80	138.5	162.0	119.5	147.0	11.5	11.0	9.8	8.0	.78	128.0	156.0	.93	.97	100	100
7 000	80	137.8	161.0	122.8	148.0	11.0	11.0	9.0	8.0		131.7	152.5	.95	.94	100	100
7 000	80										128.0	152.5	.93	.94	100	100
7 000	-110	161.5	186.5	140.0	175.0			9.9	6.0	.69	140.0	158.5	.87	.85	70	100
7 000	-110	160.0	186.0	133.0	172.0	11.6		9.9	6.0		142.0	155.0	.89	.84	100	85
7 000	-110										136.0	158.0	.85	.85	99	80
10 000	80	140.0	163.5	118.0	150.0	7.0	10.0	5.0	8.0	.81	131.5	157.5	.94	.97	100	100
10 000	80	141.0	163.0	121.0	151.5	9.0	10.0	8.0	8.0		118.8	152.5	.85	.94	100	95
10 000	-110	163.0	186.0	140.0	176.0	13.5	10.0	11.0	7.0	.75	144.5	153.0	.89	.83	75	80
10 000	-110	161.0	182.0	140.0	176.0	13.0	10.0	10.0	7.0		126.0	150.5	.77	.82	70	80
14 000	80	144.0	164.0	124.0	148.0	10.0	10.0	9.0	8.0	.83	125.7	154.3	.87	.94	100	95
14 000	80		164.5		150.0		9.0		7.0		126.6	156.5	.88	.95	100	95
14 000	-110	163.0	189.0	151.5	183.0						131.8	154.8	.80	.83	95	83
14 000	-110	167.0	186.0	148.0	176.0		10.5		7.5	.71	142.8	153.0	.87	.82	100	85

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

[d]Fracture out of plane of notch.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(d) Ti-13V-11Cr-3Al (SA), 0.064 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	176.5	183.5	159.5	163.0	9.0	7.0	8.0		0.86	97.7	87.3	0.56	0.48	71	44
0	80	175.5	181.5	159.9	164.5	8.0	7.0	7.0	5.0		97.2	90.2	.55	.49	66	48
2 000	80	177.6	183.7	161.3	164.2	8.0	7.0	6.0	5.0	.67	90.4	77.6	.51	.43	60	69
2 000	80	177.1	181.7	159.7	163.5	6.0	7.5	4.0	4.0		86.7	78.2	.49	.43	57	54
4 000	80	179.1	185.2	159.5	164.9	7.5	7.0	5.0	4.0	.69	91.3	84.3	.51	.46	60	54
4 000	80	179.2	180.5	159.6	160.9	8.0	8.0	6.0	6.0		91.8	88.0	.51	.48	68	43
7 000	80	179.0	184.1	158.0	168.0	7.0	4.5	6.0	4.0	.88	82.3	71.8	.46	.39	67	48
7 000	80	177.5	181.2	159.5	161.0	7.0	5.5	6.0	5.0		82.1	81.2	.46	.44	61	67
10 000	80	168.0	174.5	155.5	164.0	3.5		3.0		.85	78.2	67.8	.46	.39	72	58
10 000	80	175.0	178.0	157.0	162.5	6.0	3.5	5.0	3.0		81.4	71.1	.48	.41	62	86
14 000	80	181.0	184.0	159.0	165.0	5.0	5.0	5.0	5.0	.74	81.8	72.3	.45	.40	90	90
14 000	80	180.0	183.5	160.0	162.0	9.0	6.0	3.0	5.5		79.0	74.2	.44	.41	95	90
18 000	80	173.5	186.0	159.0	166.7		5.0	1.0	5.0	.80	82.7	68.0	.45	.36	60	85
18 000	80	182.0	188.5	157.8	169.2			6.0	4.0		82.3	79.3	.45	.42	100	90
22 000	80	190.0	191.5			7.0	6.0	6.0	4.0	.73	79.3	65.3	.41	.34	85	90
22 000	80	194.0	193.5			6.0	7.0	4.0	5.0		78.5	71.2	.41	.37	100	100
22 000	-110	223.8	226.0	202.0	221.0	4.0	2.0	3.0	1.0	.64	48.3	46.5	.22	.21	0	0
22 000	-110	214.0	220.0	204.0	218.0	4.0	2.5	2.5	1.5		47.8	51.8	.22	.23	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(e) Ti-13V-11Cr-3Al (DA), 0.064 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties										Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)		Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse			Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	163.7	163.9	144.6	150.5	11.5	9.5	4.0	4.0	}	0.42	104.1	88.6	0.64	0.54	59	20
0	80	164.2	164.7	146.2	150.0	11.5	10.0	5.0	5.0			109.6	84.2	.67	.51	69	10
2 000	80	150.9	160.2	143.8	149.1	3.0	4.0	2.0	2.0	}	.75	115.0	89.8	.74	.56	61	49
2 000	80	159.2	159.5	146.0	150.5		4.0	4.0	3.0			105.5	95.1	.69	.60	34	53
4 000	80	141.8	146.5	141.0	146.0		1.5		1.0	}	.80	102.0	91.8	.72	.63	0	0
4 000	80	141.8	148.0	141.8	145.0		1.0					106.5	93.7	.75	.65	0	0
7 000	80	147.0	157.0	144.5	148.0		3.0	1.0	3.0	}	1.00	97.5	90.5	.64	.59	0	0
7 000	80	157.0	150.5	143.0				3.0	5.0			105.0	93.1	.69	.61	23	0
10 000	80	149.0	161.0	147.0	153.0		10.0	3.0	5.0	}	.45	93.5	96.8	.61	.61	0	0
10 000	80	158.0	157.0	145.0	152.0	10.0		4.0	6.0			96.2	81.2	.63	.51	0	0
14 000	80	160.0	157.5	146.0	150.0		2.0	5.0	1.0			93.2	83.0	.59	.53	0	0
14 000	80	155.8	159.0	145.5	149.8			2.0	1.0			99.8	89.2	.63	.57	5	0
18 000	80	168.0	169.0	148.0	156.5	12.0	6.0	9.0	4.0	}	.64	102.5	95.8	.61	.57	95	0
18 000	-110	200.0	202.0	185.0	198.0	5.0	5.0	3.0	2.0			68.0	63.8	.34	.32	20	0
22 000	80	157.0	164.0	149.2	154.0		4.5	3.0	3.0		.67	101.0	94.0	.64	.58	0	0
22 000	80		159.5	147.6	153.2							99.6	92.7	.64	.57	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(f) Ti-13V-11Cr-3Al (SA), 0.040 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	146.0	177.0		172.0		1.0	2.0	0.5		103.5	80.5		0.45	77	100
0	80	159.0	190.0		175.0	1.5	2.0		2.5	1.00	95.5	92.6		.52	100	100
0	80		171.0		170.5		1.0		.5							
0	-110	216.0	221.0	202.0	211.0	5.0	2.0	5.0	2.0	.80	91.0	76.2	0.42	.35	0	0
0	-110	213.0		206.0		5.5		3.0			85.5	80.6	.40	.37	0	0
2 000	80	189.5	189.0	168.5	172.5	8.5	5.5	8.0	4.0	.83	91.0	77.8	.48	.41	72	50
2 000	80	187.0	192.0	167.5	176.5	5.5	4.5	5.0	3.0		109.0	84.5	.58	.44	72	79
2 000	-110		223.0		214.0		3.0		2.0	.60		62.0		.28		0
2 000	-110		220.0		212.0		2.0		1.0			67.5		.31		0
4 000	80	190.0	190.0	170.0	173.0	8.0	5.0	7.0	5.0	.89	74.0	78.5	.39	.41	21	86
4 000	80	191.0	191.0	169.0	172.0	8.0	7.0	7.0	6.0		86.6	78.0	.45	.41	57	66
4 000	-110		222.0		212.0		2.0		2.0	1.00		60.8		.27		0
4 000	-110		225.0		213.0		2.0		2.0			66.5		.30		0
7 000	80	191.0	194.5	171.0	179.0	9.0		6.0	6.0	.69	89.8	86.3	.45	.44	0	0
7 000	80	210.5	199.5	175.0	183.0	8.0	9.0	6.0	6.0		97.3	75.8	.49	.39	0	0
7 000	-110		214.5		199.5				3.5	.57		63.0		.28		0
7 000	-110		227.0		210.0		6.0		3.3			60.8		.27		0
10 000	80		200.5		182.5		2.5		1.5	.60		85.8		.43		0
10 000	80		201.0		185.0		5.0		3.0			85.8		.43		0
10 000	-110		228.0		213.0		2.0		1.0	.57		66.2		.29		0
10 000	-110		234.0		221.0		1.5		1.0			59.3		.26		0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.

TABLE III.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Concluded

(g) Ti-13V-11Cr-3Al (DA), 0.040 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	144.0	143.5	138.0	141.0	3.0	2.0	2.5	1.5	0.85	123.0	100.0	0.84	0.68	21	43
0	80	150.5	150.5	136.5	142.5	7.0	4.5	6.0	4.0		126.0	103.0	.86	.70	60	51
0	-110	184.0	185.0	182.0	183.0	7.0		6.0	3.0	.67	90.0	64.5	.49	.35	0	0
0	-110	182.0	183.0	179.0	178.0	7.0	4.0	5.0	2.0		89.2	62.6	.49	.34	0	0
2 000	80		146.5		141.5		3.5		3.0	.77	121.0	100.5	[d].83	.69	50	15
2 000	80		146.0		141.5		3.0		2.0		127.0	90.0	[d].87	.62	46	0
2 000	-110		188.0		184.0		4.0		3.0	.71		72.0		.38		0
2 000	-110		188.0		184.0		3.0		2.0			66.7		.36		0
4 000	80		155.0		145.0		10.0		9.0	.89	118.0	106.2	[d].76	.69	30	0
4 000	80		156.0		144.5		9.0		8.0		126.0	97.7	[d].81	.63	31	0
4 000	-110		189.0		185.0		2.5		1.0	.55		72.0		.38		0
4 000	-110		186.0		183.0		3.0		2.0			68.4		.37		0
7 000	80		155.5		147.0		6.5		6.0	.72	114.7	106.8	[d].74	.69	40	90
7 000	80		154.5		147.0		6.0		3.0		110.8	103.6	[d].72	.67	70	90
7 000	-110		193.0		182.0		6.6		3.3	.50		68.1		.35		0
7 000	-110		194.0		184.0				3.3			64.0		.33		0
10 000	80		162.5		151.0		6.5		5.0	.80	118.8	98.6	[d].73	.61	90	95
10 000	80		162.0		151.0		6.0		5.0			110.5		.68		90
10 000	-110		198.5		190.0						89.1	70.3	[d].45	.35	0	0
10 000	-110		198.5		189.0							65.9		.33		0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

[d]Based on transverse properties.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET

[SI units]

(a) Ti-8Al-1Mo-1V (AN), 0.102 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1072.1	1096.3	1003.2	1006.6	18.5	16.5	14.0	10.0	0.69	879.1	758.4	0.82	0.69	69	67
0	300	1082.5	1096.3	1006.6	1020.4	17.0	16.0	14.0	9.0		872.2	786.0	.81	.72	67	79
0	194	1213.5	1206.6	1179.0	1172.1	19.0		14.0		.74	772.2	757.0	.64	.63	71	41
0	194	1213.5	1213.5	1179.0	1172.1						865.3	684.0	.73	.57	69	53
2 000	300	1068.7	1075.6	992.8	992.8	15.5	19.0	14.0	14.0	.83	789.4	761.9	.74	.72	100	80
2 000	300	1054.9	1054.9	979.1	982.5	18.5	17.0	16.0	14.0		868.7	786.0	.82	.74		62
2 000	194	1213.5	1234.2	1154.9	1154.9		20.5		16.0	.83	834.3	696.4	.68	.56	64	55
2 000	194	1248.0	1241.1	1172.1	1161.8		19.5		17.0		782.6	665.3	.64	.54	66	60
4 000	300	1054.9	1020.4	965.3	958.4	12.0	14.0	11.0	12.0	.86	848.1	813.6	.81	.78	71	100
4 000	300	1054.9	1061.8	965.3	937.7	15.0	17.0	12.0	14.0		875.6	827.4	.83	.80	67	86
4 000	194	1213.5	1268.6	1165.2	1130.7	17.0	17.0	14.0	16.0	.85	841.2	723.9	.68	.58	70	71
4 000	194	1282.4	1227.3	1192.8	1158.3		18.0	14.0	15.0		813.6	710.2	.65	.57	86	71
7 000	300	1027.3	1075.6	944.6	996.3	15.5	17.5	12.5	15.5	.84	868.7	811.5	.83	.75	71	79
7 000	300	1061.8	1082.5	986.0	986.0	15.5	15.0	12.5	12.5		834.3	841.2	.70	.78	71	71
7 000	194	1234.2	1249.3	1141.1				12.0			841.2	663.3	.69	.54	80	74
7 000	194	1213.5	1213.5	1129.4	1117.0	12.0		9.0		.75	775.0	697.7	.63	.57	77	77
10 000	300	1072.1	1061.8	1017.0	992.8	16.5	15.0	11.0	13.0	.77	851.5	744.6	.80	.70	0	100
10 000	300	1051.5	1079.0	991.5	1013.5	14.5	16.5	11.0	13.0		844.6	852.2	.80	.80	0	100
10 000	194	1241.1	1241.1	1172.1	1151.4			11.0	13.0		737.0	722.6	.60	.58	60	75
10 000	194	1230.7	1244.5	1161.1	1151.4			11.0	12.0		834.3	752.9	.68	.61	40	75
14 000	300	1094.2	1099.7	1013.5	1013.5	15.0	16.0	9.0	10.0	.60	882.5	867.4	.81	.79	100	97
14 000	300	1096.3	1099.7	1003.2	1003.2	15.0	17.0	9.0	10.0		854.9	839.8	.78	.76	75	95
14 000	194	1220.4	1230.7	1165.2	1130.7		15.0		13.0	.88	821.9	750.1	.66	.60	75	60
14 000	194	1268.6	1265.2	1171.4	1187.3	15.0	13.0	12.0	13.0		780.5	763.9	.63	.61	75	60

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(b) Ti-6Al-4V (AN), 0.102 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm	Notch strength, MN/m²		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	(b)	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	999.7	1003.2	954.9	972.2	12.5	13.0	7.0	9.0	0.60	996.3	1051.5	1.00	1.10	84	57
0	300	1003.2	1011.5	943.9	958.4	13.0	13.5	7.0	8.0		930.8	977.7	.93	.97	82	72
0	194	1185.9	1179.0	1120.4	1151.4	14.0	18.0	11.0	13.0	.76	954.9	960.4	.81	.82	85	57
0	194	1165.2	1179.0	1096.3	1130.7		14.5	14.0	9.0		860.5	958.4	.73	.81	100	66
2 000	300	991.5	999.7	954.2	970.1	13.0	13.5	5.0	9.0	.51	899.8	1034.9	.91	1.04	83	72
2 000	300	994.2	1005.3	947.3	984.6	14.0	14.0	7.0			906.7	1038.4	.91	1.04	84	67
2 000	194	1179.0	1186.0	1130.7	1144.5		9.0	7.0	7.0	.64	908.7	961.8	.78	.81	100	60
2 000	194	1159.7	1179.0	1113.5	1144.5	14.5	14.0	8.0	10.0		925.3	906.7	.79	.77	77	89
4 000	300	999.1	1017.0	968.7	972.2	12.0	15.0	4.0	7.5	.39	978.4	1041.1	.98	1.03	88	60
4 000	300	997.0	1014.2	951.5	979.1	12.5	15.0	4.0	5.5		989.4	1001.1	.99	.99	100	62
4 000	194	1179.0	1182.5	1123.8	1130.7	14.5	14.0	7.0	9.0	.56	992.8	982.5	.85	.83	79	70
4 000	194	1172.1	1185.9	1120.4	1151.4	14.0	13.0	8.0	7.0		989.4	923.9	.84	.78	82	50
7 000	300	996.3	999.7	923.9	951.5	14.0	14.0	8.0	10.0	.67	1010.1	1037.7	1.02	1.04	75	86
7 000	300	979.1	1003.2	934.2	954.9	15.0	13.5	10.0	10.0		982.5	1054.9	.99	1.05	43	60
7 000	194	1165.2	1165.2	1113.5	1120.4	11.0		6.0	7.0	.59	879.8	958.4	.75	.82	87	65
7 000	194	1168.7	1165.2	1110.1	1113.5		13.5	8.0	8.0		834.3	949.4	.72	.81	90	76
10 000	300	972.2	979.1	927.3	951.5	12.0	15.0	9.0	11.0	.73	965.3	1013.5	.99	1.03	83	87
10 000	300	979.1	989.4	944.6	951.5	13.0	15.0	10.0	10.0		889.4	999.7	.91	1.02	100	71
10 000	194	1148.0	1165.2	1113.5	1144.5	15.0	8.0	12.0	8.0	.87	889.4	923.9	.77	.79	64	79
10 000	194	1158.3	1172.1	1130.7	1151.4	14.0	15.0	10.0	15.0		892.9	986.0	.78	.84	84	62
14 000	300	996.3	1041.1	937.7	992.8	14.0	15.6	6.0	10.0	.54	946.0	1044.6	.95	1.01	100	50
14 000	300	997.0	1034.2	934.2	958.4	14.6	15.6	6.0	10.0		926.0	1021.8	.93	.99	80	40
14 000	194	1172.1	1166.6	1165.2	1120.4	15.0	15.5	6.0	10.0	.52	934.2	929.4	.80	.80	99	70
14 000	194	1168.7	1158.3	1117.0	1130.7	15.0	15.6	6.0	10.0		903.2	981.8	.77	.85	100	70
18 000	300	999.7	1027.3	958.4	979.1	12.0	14.0	7.0	9.0	.61	982.5	1037.7	.98	1.00	100	75
18 000	300	999.7	1048.0	951.5	992.8	13.0	12.0	7.0	8.0		903.2	1017.0	.90	.98	100	100
18 000	194	1165.2	1192.8	1117.0	1158.3	12.5	13.0	6.5	7.0	.56	903.2	879.1	.78	.74	100	60
18 000	194	1158.3	1185.9	1137.6	1151.4		13.0	8.0	7.0		882.5	986.0	.76	.83	99	100
22 000	300	1010.0	1002.4	958.3	954.8	12.5	12.5	6.0	8.0	.57	954.8	1037.5	.95	1.03	100	100
22 000	300	1006.5	1014.8	954.8	978.9	13.0	14.5	8.0	8.0		939.7	1023.8	.93	1.01	100	100
22 000	194	1201.6	1209.2	1154.7	1165.1	15.0	13.5	7.0	10.0	.59	911.4	985.8	.76	.82	100	96
22 000	194	1196.1	1209.2	1116.8	1161.6	14.0	13.0	8.0	8.0		915.5	935.5	.76	.77	93	100

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(c) Ti-4Al-3Mo-1V (STA), 0.102 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	951.5	1096.3	834.3	1027.3	11.0	8.0	11.0	5.0	0.76	917.0	1054.9	0.97	0.96	(d)	52
0	300	934.2	1096.3	813.6	1020.4			7.0	6.0		882.5	1054.9	.94	.96	100	65
0	194	1123.8	1296.2	992.8	1206.6		10.0	7.0	7.0	.68	1041.1	917.0	.92	.71	83	70
0	194	1130.7	1296.2	979.1	1206.6			7.0	6.0		1027.3	1027.3	.91	.79	80	62
2 000	300	930.8	1082.5	820.5	1006.6	11.0	10.0	10.0	8.0	.86	841.2	1061.8	.90	.98	17	55
2 000	300	930.8	1092.8	827.4	1020.4	11.0	10.0	9.0	9.0		903.2	999.7	.97	.92	30	78
2 000	300										834.3	1061.8	.90	.98	86	49
2 000	194	1085.9	1254.8				10.0	6.0	8.0	.65	1006.6	861.8	.93	.68	67	57
2 000	194	1072.1	1254.8	910.1	1206.6		11.0	5.0	8.0		951.5	1034.2	.88	.82	30	57
2 000	194	1082.5	1261.7	930.8	1185.9		9.0	6.0	6.0		951.5	999.7	.88	.80	46	57
4 000	300	937.7	1089.4	820.5	1006.6	12.0	10.0	10.0	7.0	.77	903.2	1075.6	.97	.98	77	71
4 000	300	930.8	1103.2	820.5	1013.5	11.0	10.0	9.0	7.0		906.7	1061.8	.97	.97	86	100
4 000	300										889.4	1034.2	.95	.94	100	100
4 000	194	1058.3	1254.8	937.7	1182.5		8.2	6.0	7.0	.79	944.6	1092.8	.84	.86	0	0
4 000	194	1137.6	1296.2	980.4	1210.0		16.5	6.0	7.0		923.9	968.0	.81	.76	35	75
4 000	194										948.0	1082.5	.84	.85	0	55
7 000	300	954.9	1117.0	823.9	1013.5	11.5	11.0	9.8	8.0	.78	882.5	1075.6	.93	.97	100	100
7 000	300	950.1	1110.1	846.7	1020.4	11.0	11.0	9.0	8.0		908.0	1051.5	.95	.94	100	100
7 000	300										882.5	1051.5	.93	.94	100	100
7 000	194	1113.5	1285.9	965.3	1206.6			9.9	6.0	.69	965.3	1092.8	.87	.85	70	100
7 000	194	1103.2	1282.4	917.0	1185.9	11.6		9.9	6.0		979.1	1068.7	.89	.84	100	85
7 000	194										937.7	1089.4	.85	.85	99	80
10 000	300	965.3	1127.3	813.6	1034.2	7.0	10.0	5.0	8.0	.81	906.7	1085.9	.94	.97	100	100
10 000	300	972.2	1123.8	834.3	1044.6	9.0	10.0	8.0	8.0		819.1	1051.5	.85	.94	100	95
10 000	194	1123.8	1282.4	965.3	1213.5	13.5	10.0	11.0	7.0	.75	996.3	1054.9	.89	.83	75	80
10 000	194	1110.1	1254.8	965.3	1213.5	13.0	10.0	10.0	7.0		868.7	1037.7	.77	.82	70	80
14 000	300	992.8	1130.7	854.9	1020.4	10.0	10.0	9.0	8.0	.83	866.7	1063.9	.87	.94	100	95
14 000	300		1134.2		1034.2		9.0		7.0		872.9	1079.0	.88	.95	100	95
14 000	194	1123.8	1303.1	1044.6	1261.7						908.7	1067.3	.80	.83	95	83
14 000	194	1151.4	1282.4	1020.4	1213.5		10.5		7.5	.71	984.6	1054.9	.87	.82	100	85

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

[d]Fracture out of plane of notch.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(d) Ti-13V-11Cr-3Al (SA), 0.163 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1216.9	1265.2	1099.7	1123.8	9.0	7.0	8.0		0.86	604.7	601.9	0.56	0.48	71	44
0	300	1210.0	1251.4	1102.5	1134.2	8.0	7.0	7.0	5.0		670.2	621.9	.55	.49	66	48
2 000	300	1224.5	1266.6	1112.1	1132.1	8.0	7.0	6.0	5.0	.67	623.3	535.0	.51	.43	60	69
2 000	300	1221.1	1252.8	1101.1	1127.3	6.0	7.5	4.0	4.0		666.7	539.2	.49	.43	57	54
4 000	300	1234.9	1276.9	1099.7	1136.9	7.5	7.0	5.0	4.0	.69	629.5	581.2	.51	.46	60	54
4 000	300	1235.5	1244.5	1100.4	1109.4	8.0	8.0	6.0	6.0		632.9	606.7	.51	.48	68	43
7 000	300	1234.2	1269.3	1089.4	1158.3	7.0	4.5	6.0	4.0	.88	567.4	495.0	.46	.39	67	48
7 000	300	1223.8	1249.3	1099.7	1110.1	7.0	5.5	6.0	5.0		566.1	559.9	.46	.44	61	67
10 000	300	1158.3	1203.1	1072.1	1130.7	3.5		3.0		.85	539.2	467.5	.46	.39	72	58
10 000	300	1206.6	1227.3	1082.5	1120.4	6.0	3.5	5.0	3.0		561.2	490.2	.48	.41	62	86
14 000	300	1248.0	1268.6	1096.3	1137.6	5.0	5.0	5.0	5.0	.74	564.0	498.5	.45	.40	90	90
14 000	300	1241.1	1265.2	1103.2	1117.0	9.0	6.0	3.0	5.5		544.7	511.6	.44	.41	95	90
18 000	300	1196.2	1282.4	1096.3	1149.4		5.0	1.0	5.0	.80	570.2	468.8	.45	.36	60	85
18 000	300	1254.8	1299.7	1088.0	1166.6			6.0	4.0		567.4	546.8	.45	.42	100	90
22 000	300	1310.0	1320.3			7.0	6.0	6.0	4.0	.73	546.8	450.2	.41	.34	85	90
22 000	300	1337.6	1334.1			6.0	7.0	4.0	5.0		541.2	490.9	.41	.37	100	100
22 000	194	1543.0	1558.2	1392.7	1523.7	4.0	2.0	3.0	1.0	.64	333.0	320.6	.22	.21	0	0
22 000	194	1475.5	1516.8	1406.5	1503.1	4.0	2.5	2.5	1.5		329.6	357.1	.22	.23	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(e) Ti-13V-11Cr-3Al (DA), 0.163 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1128.7	1130.1	997.0	1037.7	11.5	9.5	4.0	4.0	0.42	717.7	610.9	0.64	0.54	59	20
0	300	1132.1	1135.6	1008.0	1034.2	11.5	10.0	5.0	5.0		755.7	580.5	.67	.51	69	10
2 000	300	1040.4	1104.5	991.5	1028.0	3.0	4.0	2.0	2.0	.75	792.9	619.1	.74	.56	61	49
2 000	300	1097.6	1099.7	1006.6	1037.7		4.0	4.0	3.0		727.4	655.7	.69	.60	34	53
4 000	300	977.7	1010.1	972.2	1006.6	0	1.5	0	1.0	.80	704.6	632.9	.72	.63	0	0
4 000	300	977.7	1020.4	977.7	999.7	0	1.0	0	0		734.3	646.0	.75	.65	0	0
7 000	300	1013.5	1082.5	996.3	1020.4		3.0	1.0	3.0	1.00	672.2	624.0	.64	.59	0	0
7 000	300	1082.5	1037.7	986.0				3.0	5.0		723.9	641.9	.69	.61	23	0
10 000	300	1027.3	1110.1	1013.5	1054.9		10.0	3.0	5.0	.45	644.7	667.4	.61	.61	0	0
10 000	300	1089.4	1082.5	999.7	1048.0	10.0		4.0	6.0		663.3	559.9	.63	.51	0	0
14 000	300	1103.2	1085.9	1006.6	1034.2		2.0	5.0	1.0		642.6	572.3	.59	.53	0	0
14 000	300	1074.2	1096.3	1003.2	1032.8			2.0	1.0		688.1	615.0	.63	.57	5	0
18 000	300	1158.3	1165.2	1020.4	1079.0	12.0	6.0	9.0	4.0	.64	706.7	660.5	.61	.57	95	0
18 000	194	1379.0	1392.7	1275.5	1365.2	5.0	5.0	3.0	2.0		468.8	439.9	.34	.32	20	0
22 000	300	1082.4	1130.6	1028.6	1061.7		4.5	3.0	3.0	.67	696.3	648.0	.64	.58	0	0
22 000	300		1099.6	1017.6	1056.2						686.6	639.1	.64	.57	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Continued

(f) Ti-13V-11Cr-3Al (SA), 0.102 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	(b)	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1006.6	1220.4		1185.9		1.0	2.0	0.5	1.00	713.6	555.0		0.45	77	100
0	300	1096.3	1310.0		1206.6	1.5	2.0		2.5		658.4	638.5		.52	100	100
0	300		1179.0		1175.6		1.0		.5							
0	194	1489.3	1523.7	1392.7	1454.8	5.0	2.0	5.0	2.0	.80	627.4	525.4	0.42	.35	0	0
0	194	1468.6		1420.3		5.5		3.0			589.5	555.7	.40	.37	0	0
2 000	300	1306.6	1303.1	1161.8	1189.3	8.5	5.5	8.0	4.0	.83	627.4	536.4	.48	.41	72	50
2 000	300	1289.3	1323.8	1154.9	1216.9	5.5	4.5	5.0	3.0		751.5	582.6	.58	.44	72	79
2 000	194		1537.5		1475.5		3.0		2.0	.60		427.5		.28		0
2 000	194		1516.8		1461.7		2.0		1.0			465.4		.31		0
4 000	300	1310.0	1310.0	1172.1	1192.8	8.0	5.0	7.0	5.0	.89	510.2	541.2	.39	.41	21	86
4 000	300	1316.9	1316.9	1165.2	1185.9	8.0	7.0	7.0	6.0		597.1	537.8	.45	.41	57	66
4 000	194		1530.6		1461.7		2.0		2.0	1.00		419.2		.27		0
4 000	194		1551.3		1468.6		2.0		2.0			458.5		.30		0
7 000	300	1316.9	1341.0	1179.0	1234.2	9.0		6.0	6.0	.69	619.1	595.0	.45	.44	0	0
7 000	300	1451.3	1375.5	1206.6	1261.7	8.0	9.0	6.0	6.0		670.9	522.6	.49	.39	0	0
7 000	194		1478.9		1375.5				3.5	.57		434.4		.28		0
7 000	194		1565.1		1447.9		6.0		3.3			419.2		.27		0
10 000	300		1382.4		1258.3		2.5		1.5	.60		591.6		.43		0
10 000	300		1385.8		1275.5		5.0		3.0			591.6		.43		0
10 000	194		1572.0		1468.6		2.0		1.0	.57		456.4		.29		0
10 000	194		1613.4		1523.7		1.5		1.0			408.9		.26		0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE IV.- TENSILE AND NOTCH PROPERTIES FOR TITANIUM-ALLOY SHEET - Concluded

(g) Ti-13V-11Cr-3Al (DA), 0.102 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	992.8	989.4	951.5	972.2	3.0	2.0	2.5	1.5	0.85	848.1	689.5	0.84	0.68	21	43
0	300	1037.7	1037.7	941.1	982.5	7.0	4.5	6.0	4.0		868.7	710.2	.86	.70	60	51
0	194	1268.6	1275.5	1254.8	1261.7	7.0		6.0	3.0	.67	620.5	444.7	.49	.35	0	0
0	194	1254.8	1261.7	1234.2	1227.3	7.0	4.0	5.0	2.0		619.1	431.6	.49	.34	0	0
2 000	300		1010.1		975.6		3.5		3.0	.77	834.3	692.9	[d].83	.69	50	15
2 000	300		1006.6		975.6		3.0		2.0		875.6	620.5	[d].87	.62	46	0
2 000	194		1296.2		1268.6		4.0		3.0	.71		496.4		.38		0
2 000	194		1296.2		1268.6		3.0		2.0			459.9		.36		0
4 000	300		1068.7		999.7		10.0		9.0	.89	813.6	732.2	[d].76	.69	30	0
4 000	300		1075.6		996.3		9.0		8.0		868.7	673.6	[d].81	.63	31	0
4 000	194		1303.1		1275.5		2.5		1.0	.55		496.4		.38		0
4 000	194		1282.4		1261.7		3.0		2.0			471.6		.37		0
7 000	300		1072.1		1013.5		6.5		6.0	.72	790.8	736.4	[d].74	.69	40	90
7 000	300		1065.2		1013.5		6.0		3.0		763.9	714.3	[d].72	.67	70	90
7 000	194		1330.7		1254.8		6.6		3.3	.50		469.5		.35		0
7 000	194		1337.6		1268.6				3.3			441.3		.33		0
10 000	300		1120.4		1041.1		6.5		5.0	.80	819.1	679.8	[d].73	.61	90	95
10 000	300		1117.0		1041.1		6.0		5.0			761.9		.68		90
10 000	194		1368.6		1310.0						614.3	484.7	[d].45	.35	0	0
10 000	194		1368.6		1303.1							454.4		.33		0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

[d]Based on transverse properties.

TABLE V.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET

[U.S. customary units]

(a) AM-350 (CRT), 0.025 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in.	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	(b)	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	199.5	208.5	180.7	167.5	18.0	18.5	15.0	16.5	0.86	197.0	193.5	0.96	0.93	57	74
0	80	210.0	208.0	182.0	168.5	19.0	16.8	17.0	14.0		198.5	188.0	.97	.90	55	83
0	-110	252.0	248.0	179.0	164.5	18.5	14.0	16.0	12.0	.83	205.0	193.0	.82	.79	93	100
0	-110	248.0	244.0	175.0	163.0	17.5	14.8	14.0	12.0		206.0	194.0	.83	.79	65	62
2 000	80	204.0	212.0	186.0	165.0	20.0	19.0	20.0	16.0	.90	200.0	190.0	.97	.90	67	86
2 000	80	210.0	211.0	186.0	173.0	20.0	19.0	18.0	16.0		201.0	191.0	.97	.90	91	100
2 000	-110	246.0	250.0	176.0	177.0		17.0	12.0	14.0	.77	205.0	197.0	.82	.79	67	80
2 000	-110	254.0	250.0	178.0	174.0	18.0		16.0	12.0		208.0	193.0	.83	.77	77	91
4 000	80	197.0	207.0	188.0	170.0	17.0	17.0	13.0	15.0	.81	201.0	193.0	1.02	.94	100	100
4 000	80	197.0	205.0	187.0	173.0	18.0	17.0	14.0	14.0		201.0	193.5	1.02	.94	100	100
4 000	-110	249.0	245.0	189.0	178.5		17.0	18.0	15.0	.86	207.0	192.0	.84	.78	95	100
4 000	-110	244.0	250.0	188.5	176.0		20.0	14.0	17.0		206.0	195.5	.84	.79	99	100
7 000	80	198.0	204.0	189.0	173.0	17.0	17.0	11.0	12.0	.69	201.5	194.0	1.02	.95	80	100
7 000	80	199.0	207.0	189.0	178.0	18.0	16.0	12.0	12.0		202.0	193.5	1.02	.94	80	80
7 000	-110	249.0	249.0	190.5	178.5	17.0	18.0	15.0	15.0	.87	211.0	191.0	.85	.77	85	80
7 000	-110	249.0	250.0	190.0	182.0	18.0	17.0	16.0	15.0		207.0	192.0	.83	.77	80	100
10 000	80	202.0	219.0	183.0	175.0		16.0		15.0	.85	202.0	203.0	1.01	.94	100	100
10 000	80	197.0	215.0	194.0	175.0	16.0	16.0	12.0	14.0		204.0	199.0	1.02	.92	100	100
10 000	-110	255.0	257.0	176.5	181.0	18.0	15.0	15.0	12.0	.84	208.5	201.0	.82	.79	100	100
10 000	-110	256.0	255.0	178.0	184.0	14.0	17.0	12.0	15.0		208.0	200.0	.81	.78	100	100
14 000	80	207.5	209.0	196.0	175.5	20.5	15.5	17.0	14.0	.81	205.0	198.0	1.00	.94	100	98
14 000	80	203.0	214.5	191.0	178.5	20.0	17.5	14.0	14.0		208.0	201.0	1.01	.95	90	95
14 000	-110	257.0	259.5	180.0	178.0	17.5	16.5	16.0	14.0	.90	211.0	204.0	.82	.79	80	100
14 000	-110	260.0	258.5	179.5	178.0	18.0	17.0	16.0	16.0		206.0	200.0	.80	.72	100	100

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.

TABLE V.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Continued

(b) AM-350 (DA), 0.025 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80										168.5	157.5	0.91	0.84	100	100
0	80	184.5	187.0	152.0	158.5	13.0	12.5	8.0	10.0		173.5	164.5	.94	.91	17	100
0	80	187.0	189.0	153.0	157.0	16.0	13.0	13.0	10.0	0.75	175.0	156.0	.94	.83	64	77
0	-110	211.0	210.0	177.0	177.5		14.0	16.0	12.0		128.0	132.0	.61	.63	0	0
0	-110	211.0	210.5	179.0	179.0	17.0		15.0	10.0	.85	114.3	132.0	.54	.63	0	0
0	-110										114.5	135.5	.54	.64	0	0
2 000	80	186.0	188.5	153.5	153.0	12.0	11.0	9.0	7.0	.74	164.8	166.7	.89	.88	84	100
2 000	80	183.0	189.5	152.0	158.5	12.0	12.0	10.0	8.0		173.2	167.5	.94	.89	(d)	100
2 000	80	186.5		151.5		14.0		11.0			172.5	145.8	.93	.77	(d)	100
2 000	-110	211.0	213.9	173.0	183.8	15.0	14.0	12.0	8.0		113.2	123.5	.54	.58	0	0
2 000	-110	210.0	215.0	177.0	180.2	19.0	14.0	17.0	9.0	.77	112.5	121.4	.53	.57	0	0
2 000	-110	212.0	215.3	179.0	183.0	18.0	16.0	15.0	13.0		107.8	124.9	.51	.58	0	0
4 000	80	187.5	192.0	157.0	161.0	14.0	13.0	10.0	11.0		168.7	161.2	.90	.84	100	100
4 000	80	188.8	192.0	158.0	161.5	12.0	12.5	9.0	10.0	.81	173.0	154.0	.91	.80	100	100
4 000	80	188.8		156.2		14.0		10.0			170.5	167.0	.91	.87	100	100
4 000	-110	214.0	214.0	178.5	179.5	16.0	17.0	12.0	15.0		124.8	125.8	.58	.59	0	0
4 000	-110	215.0	216.0	180.0	182.0	17.0	18.0	14.0	15.0	.84	127.2	138.7	.59	.65	0	0
4 000	-110	215.0		182.0		19.0		17.0			117.2	129.0	.55	.60	0	0
7 000	80	193.0	193.0	154.0	157.0	14.0	13.0	10.0	10.0	.75	178.2	164.0	.93	.85	100	100
7 000	80	191.0	194.0	156.0	157.0	12.0	14.0	9.0	11.0		181.5	168.2	.95	.87	100	100
7 000	-110	217.0	217.0	190.0	186.0	15.0		13.0		.87	120.6	111.8	.55	.52	0	0
7 000	-110	215.0	217.0	187.5	189.0						123.1	114.8	.57	.53	0	0
10 000	80	193.0	193.0	161.0	159.0	13.0	13.0	10.0	10.0	.71	161.3	157.0	.84	.81	100	100
10 000	80	191.0	193.0	163.0	159.0	14.0	12.0	9.0	8.0		177.2	153.0	.92	.79	100	100
10 000	-110	217.0	218.0	184.5	185.5	11.0	14.0	10.0	10.0	.74	105.5	130.9	.49	.60	0	0
10 000	-110	216.0	219.0	189.0	188.5	15.0	14.0	12.0	8.0		110.5	120.2	.51	.55	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.
[d]Fracture out of plane of notch.

TABLE V.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Continued

(c) PH 15-7 Mo (TH1050), 0.025 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	215.8	222.4	212.0	218.9	5.5	4.5	4.0	2.0		187.5	166.1	0.87	0.75	100	100
0	80	214.3	220.0	210.8	214.2		5.0	1.0	1.0	0.41	192.0	155.7	.89	.70	100	100
0	80	215.4	221.7	212.8	215.0	5.0	6.5	2.0	3.0							
0	-110	239.0	243.0	220.0	231.0			5.0	4.5	.70	165.0	174.0	.70	.72	(d)	57
0	-110	236.0	242.0	219.0	226.0	8.0	8.0	6.0	7.0		186.0	184.0	.78	.76	80	(d)
2 000	80	217.0	223.0	215.0	219.0	6.5	4.5	5.0	2.0	.59	176.0	164.0	.81	.74	100	86
2 000	80	216.0	223.0	213.0	220.0	6.0	2.5	3.0	1.5		196.5	158.0	.91	.71	77	86
2 000	-110	242.0	249.0	227.0	235.0	9.5		7.0	3.0	.67	171.5	155.0	.71	.63	(d)	(d)
2 000	-110	243.0	247.0	229.0	232.0	9.0	6.0	8.0	4.0		187.5	160.0	.77	.65	(d)	(d)
4 000	80	215.0	221.0	211.0	212.0	6.0	7.0	4.0	5.0	.64	182.0	172.0	.85	.78	80	100
4 000	80	214.5	222.0	211.0	210.0	7.5	6.0	4.0	4.0		195.0	167.0	.91	.75	83	87
4 000	-110	243.0	248.0	229.0	238.0	7.5	3.0	4.0	2.0	.59	163.0	162.0	.67	.65	(d)	(d)
4 000	-110	242.0	250.0	230.0	239.5	9.0	6.0	6.0	3.0		151.0	142.0	.62	.57	(d)	(d)
7 000	80	216.0	222.0	215.0	216.5	8.0	6.0	6.0	4.0		196.0	174.0	.91	.77	80	83
7 000	80	216.0	222.0	214.0	216.0	6.0	5.0	4.0	3.0	.65	200.0	166.0	.93	.73	100	77
7 000	80	215.0	224.0	212.0	218.0	6.0	6.0	4.0	3.0							
7 000	-110	237.0	250.0	227.3	239.0	7.0		3.0	3.0		173.0	157.0	.72	.63	0	0
7 000	-110	242.0	248.0	230.0	237.0	9.0		7.0	3.0	.52	164.0	162.0	.68	.65	0	0
7 000	-110	245.0	248.0	228.0	240.0	9.0		7.0	3.0							
10 000	80	225.0	227.0	220.0	220.0	8.0	9.0	5.0	3.0		194.5	177.5	.87	.77	85	95
10 000	80	225.0	231.0	219.0	224.0	5.0	6.0	2.0	2.0	.42	201.0	178.5	.89	.78	90	100
10 000	80	224.0	233.0	219.4	224.4	6.0	6.0	2.0	3.0							
10 000	-110	239.0	251.3	231.0	242.0	6.5	9.0	4.0	7.5		175.5	167.5	.73	.51	0	0
10 000	-110	243.0	251.0	230.0	239.0	8.5		6.0	3.0	.59	183.5		.76	.67	0	
10 000	-110	241.0	253.0	228.6	244.0	6.0		4.0	2.0							
14 000	80	230.0	235.0	219.0	225.0	7.0	4.5	4.0	3.0	.62	188.9	180.0	.82	.77	100	100
14 000	80	231.0	235.0	220.0	227.0	10.0	6.0	6.0	4.0		191.0	166.2	.83	.71	100	100
14 000	-110	249.5	252.0	229.0	239.0	7.5	7.0	4.0	5.0	.64	177.0	171.0	.72	.67	0	0
14 000	-110	244.0	258.0	232.0	230.0	9.0		6.0			156.9	158.0	.64	.62	0	0
14 000	-110		253.0		242.0											
18 000	80	225.5	234.0	220.0	230.0	8.0	5.0	6.0	3.0	.63	196.0	164.5	.87	.70	100	100
18 000	80	226.0	235.5	222.0	229.5	5.0	6.0	3.0	3.0		194.5	165.0	.86	.71	65	100
18 000	-110	250.5	254.5	237.0	247.0	9.5	6.5	6.0	5.0	.71	169.5	139.5	.68	.55	0	0
18 000	-110	249.0	257.5	237.0	245.0	8.0	7.0	5.0	6.0		177.0	142.0	.71	.56	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.
[d]Irregular fracture out of notch plane.

TABLE V.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Continued

(d) PH 14-8 Mo (SRH950), 0.050 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	223.0	228.0	178.0	182.0	11.5	10.0	8.0	5.0	0.62	217.0	187.0	0.97	0.82	85	100
0	80	227.0	226.0	188.0	185.0	13.0	9.0	9.0	5.0		205.0	191.0	.91	.84	100	100
0	-110	265.0	258.3	216.0	207.0	14.0		10.0	5.0	.52	225.0	188.0	.86	.74	60	100
0	-110	257.0	254.0	204.0	205.0	14.0		10.0	4.0		228.0	182.5	.87	.71	100	100
2 400	80	225.0	231.0	178.9	184.0	14.5	7.0	11.0	2.0	.61	211.0		.93		95	
2 400	80	229.0	238.0	195.0	188.0	11.0	8.5	7.0	5.0		196.0		.86		100	
2 400	-110	267.4	268.0	203.0	193.5	13.0	11.0	8.0	7.0	.62	228.0		.86		100	
2 400	-110	264.0	266.0	202.0	200.0	8.0	10.0	4.0	7.0		235.0		.89		100	
7 000	80	237.0	230.5	200.5	199.0	13.0	9.0	9.0	4.0	.55	199.5	190.0	.86	.82	100	100
7 000	80	224.0	236.0	183.0	203.5	11.0	5.0	5.0	3.0		214.0	179.0	.93	.77	100	100
7 000	-110	270.0	287.0	211.0	221.0	13.0	12.0	9.0	8.0	.71	230.0	197.5	.85	.71	100	100
7 000	-110	269.0	272.5	216.0	223.5	14.0	10.5	11.0	7.0		227.5	198.5	.85	.71	100	98
10 000	80	228.5	221.0	192.5	180.0	10.5	8.5	6.0	5.0	.63	220.0	167.0	.96	.74	100	100
10 000	80		230.7		197.0		11.0		8.0		206.0	174.5	.90	.77	100	100
10 000	-110	264.5	269.8	197.5	217.0	14.5		10.0	8.0	.65	218.0	189.5	.82	.70	90	100
10 000	-110	271.0	271.8	223.0	224.5	14.5		11.0	8.5		221.0	192.5	.83	.71	100	100

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.

TABLE V.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Concluded

(e) AISI 301 (CR), 0.025 inch thick

Exposure at 550° F, hr	Test temperature, °F	Tensile properties									Notch properties					
		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 2 in. (b)	Notch strength, ksi		Notch strength ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	80	209.0	216.0	189.0	183.5	6.0	5.0	4.0	2.0	0.52	208.0	190.0	0.99	0.87	60	90
0	80	209.0	216.0	190.0	180.0	5.0	7.0	3.0	3.0		209.5	193.0	.99	.88	49	83
0	-110	228.0	230.0	199.0	188.0	29.0		22.0	20.0	.83	224.0	202.0	.98	.88	77	72
0	-110	231.0	232.0	206.0	188.0	30.0	31.0	28.0	30.0		226.0	198.0	.99	.86	94	86
2 000	80	234.0	243.0	197.0	206.0	6.0	6.0	3.0	2.0	.40	222.0	200.0	.96	.83	95	85
2 000	80	232.0	241.0	207.0			3.0	2.0	3.0		222.0	204.0	.96	.84	90	100
2 000	80										228.0	195.0	.98	.81	85	90
2 000	-110	243.0	252.0	218.0	205.0		25.0	25.0	22.0	.94	232.0	209.0	.96	.83	95	90
2 000	-110	243.0	252.0	213.0	211.0		29.0	25.0	30.0		239.0	198.5	.99	.79	60	90
2 000	-110										241.0	222.0	.99	.88	95	80
4 000	80	237.0	247.0	206.0	214.0	3.0	3.0	1.0	1.0	.33	218.0	204.0	.93	.83	60	99
4 000	80	234.0	247.0	212.0	208.0	3.0	3.0	1.0	1.0		226.0	201.0	.96	.82	80	95
4 000	-110	249.0	249.0	217.0	216.0	30.0	30.0	29.0	28.0	.95	238.0	220.0	.96	.88	75	80
4 000	-110	246.0	252.0	208.0	222.0	30.0	29.0	29.0	27.0		236.0	221.0	.95	.88	95	80
7 000	80	235.0	246.0	202.0	208.0	2.5	3.0	0	0	.36	222.0	208.0	.94	.84	50	100
7 000	80	237.0	247.0	208.0	208.0	2.5	3.0	1.0	0		228.0	209.0	.97	.85	85	100
7 000	-110	250.0	253.0	211.0	208.0	31.5	26.5	30.0	21.0	.90	240.0	214.0	.97	.84	99	85
7 000	-110	248.0	257.0	222.0	218.0	31.5	31.0	31.0	26.0		236.0	202.0	.95	.79	100	80
10 000	80	237.0	245.0	207.0	231.0						223.0	211.0	.94	.86	100	100
10 000	80	238.0	246.0	212.0	213.0	3.0		1.0		.33	224.0	202.0	.94	.83	100	100
10 000	-110	251.0	254.4						22.0	.86	231.0	211.0	.92	.83	95	90
10 000	-110	251.0	253.0	221.0	251.0	25.0		21.0			234.0	206.0	.94	.81	90	85
14 000	80	239.0	246.0	210.0	214.5		2.0		1.0	.50	232.0	212.0	.98	.86	100	100
14 000	80	236.0	247.0	214.0	215.5						232.0	198.0	.98	.80	95	93
14 000	-110	251.0	255.0	211.8	219.8	29.0	21.5	28.0	20.0	.95	244.0	215.0	.97	.85	100	83
14 000	-110	251.0	253.5	227.5	222.0	28.0	23.5	27.0	22.0		248.0	212.0	.99	.83	93	87

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.

TABLE VI.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET

[SI units]

(a) AM-350 (CRT), 0.063 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1375.5	1437.6	1245.9	1154.9	18.0	18.5	15.0	16.5	0.86	1358.3	1334.1	0.96	0.93	57	74
0	300	1447.9	1434.1	1254.8	1161.8	19.0	16.8	17.0	14.0		1368.6	1296.2	.97	.90	55	83
0	194	1737.5	1709.9	1234.2	1134.2	18.5	14.0	16.0	12.0	.83	1413.4	1330.7	.82	.79	93	100
0	194	1709.9	1682.3	1206.6	1123.8	17.5	14.8	14.0	12.0		1420.3	1337.6	.83	.79	65	62
2 000	300	1406.5	1461.7	1282.4	1137.6	20.0	19.0	20.0	16.0	.90	1379.0	1310.0	.97	.90	67	86
2 000	300	1447.9	1454.8	1282.4	1193.8	20.0	19.0	18.0	16.0		1385.8	1316.9	.97	.90	91	100
2 000	194	1696.1	1723.7	1213.5	1220.4		17.0	12.0	14.0	.77	1413.4	1358.3	.82	.79	67	80
2 000	194	1751.3	1723.7	1227.3	1199.7	18.0		16.0	12.0		1434.1	1330.7	.83	.77	77	91
4 000	300	1358.3	1427.2	1296.2	1172.1	17.0	17.0	13.0	15.0	.81	1385.8	1330.7	1.02	.94	100	100
4 000	300	1358.3	1413.4	1289.3	1192.8	18.0	17.0	14.0	14.0		1385.8	1334.1	1.02	.94	100	100
4 000	194	1716.8	1689.2	1303.1	1230.7		17.0	18.0	15.0	.86	1427.2	1323.8	.84	.78	95	100
4 000	194	1682.3	1723.7	1299.7	1213.5		20.0	14.0	17.0		1420.3	1347.9	.84	.79	99	100
7 000	300	1365.2	1406.5	1303.1	1192.8	17.0	17.0	11.0	12.0	.69	1389.3	1337.6	1.02	.95	80	100
7 000	300	1372.1	1427.2	1303.1	1227.3	18.0	16.0	12.0	12.0		1392.7	1334.1	1.02	.94	80	80
7 000	194	1716.8	1716.8	1313.5	1230.7	17.0	18.0	15.0	15.0	.87	1454.8	1316.9	.85	.77	85	80
7 000	194	1716.8	1723.7	1310.0	1254.8	18.0	17.0	16.0	15.0		1427.2	1323.8	.83	.77	80	100
10 000	300	1392.7	1510.0	1261.7	1206.6		16.0		15.0	.85	1392.7	1399.6	1.01	.94	100	100
10 000	300	1358.2	1482.4	1337.6	1206.6	16.0	16.0	12.0	14.0		1406.5	1372.1	1.02	.92	100	100
10 000	194	1758.2	1772.0	1216.9	1248.0	18.0	15.0	15.0	12.0	.84	1437.6	1385.8	.82	.79	100	100
10 000	194	1765.1	1758.2	1227.3	1268.6	14.0	17.0	12.0	15.0		1434.1	1379.0	.81	.78	100	100
14 000	300	1430.5	1440.8	1351.2	1209.9	20.5	15.5	17.0	14.0	.81	1413.3	1365.0	1.00	.94	100	98
14 000	300	1399.5	1478.8	1316.8	1230.6	20.0	17.5	14.0	14.0		1434.0	1385.7	1.01	.95	90	95
14 000	194	1771.8	1789.0	1240.9	1227.1	17.5	16.5	16.0	14.0	.90	1454.6	1406.4	.82	.79	80	100
14 000	194	1792.4	1782.1	1237.5	1227.1	18.0	17.0	16.0	16.0		1420.2	1378.8	.80	.72	100	100

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE VI.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Continued

(b) AM-350 (DA), 0.063 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	(b)	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300										1161.8	1085.9	0.91	0.84	100	100
0	300	1272.1	1289.3	1048.0	1092.8	13.0	12.5	8.0	10.0		1196.2	1168.7	.94	.91	17	100
0	300	1289.3	1303.1	1054.9	1082.5	16.0	13.0	13.0	10.0	0.75	1206.6	1075.6	.94	.83	64	77
0	194	1454.8	1447.9	1220.4	1223.8		14.0	16.0	12.0	.85	882.5	910.1	.61	.63	0	0
0	194	1454.8	1451.3	1234.2	1234.2	17.0		15.0	10.0		778.0	910.1	.54	.63	0	0
0	194										789.4	934.2	.54	.64	0	0
2 000	300	1282.4	1300.0	1058.3	1054.9	12.0	11.0	9.0	7.0	.74	1136.3	1149.4	.89	.88	84	100
2 000	300	1261.7	1306.6	1048.0	1092.8	12.0	12.0	10.0	8.0		1194.2	1154.9	.94	.89	(d)	100
2 000	300	1285.9		1044.6		14.0		11.0			1189.3	1005.3	.93	.77	(d)	100
2 000	194	1454.8	1474.8	1192.8	1267.3	15.0	14.0	12.0	8.0		780.5	851.5	.54	.58	0	0
2 000	194	1447.9	1482.2	1220.4	1242.4	19.0	14.0	17.0	9.0	.77	775.7	837.0	.53	.57	0	0
2 000	194	1461.7	1484.4	1234.2	1261.7	18.0	16.0	15.0	13.0		743.3	861.2	.51	.58	0	0
4 000	300	1292.8	1323.8	1082.5	1110.1	14.0	13.0	10.0	11.0		1163.1	1111.4	.90	.84	100	100
4 000	300	1301.7	1323.8	1089.4	1113.5	12.0	12.5	9.0	10.0	.81	1192.8	1061.8	.91	.80	100	100
4 000	300	1301.7		1077.0		14.0		10.0			1175.6	1151.4	.91	.87	100	100
4 000	194	1475.5	1475.5	1230.7	1237.6	16.0	17.0	12.0	15.0		860.5	867.4	.58	.59	0	0
4 000	194	1482.4	1489.3	1241.1	1254.8	17.0	18.0	14.0	15.0	.84	877.0	956.3	.59	.65	0	0
4 000	194	1482.4		1254.8		19.0		17.0			808.1	889.4	.55	.60	0	0
7 000	300	1330.7	1330.7	1061.8	1082.5	14.0	13.0	10.0	10.0	.75	1228.6	1130.7	.93	.85	100	100
7 000	300	1316.9	1337.6	1075.6	1082.5	12.0	14.0	9.0	11.0		1251.4	1159.7	.95	.87	100	100
7 000	194	1496.2	1496.2	1310.0	1282.4	15.0		13.0		.87	831.5	770.8	.55	.52	0	0
7 000	194	1482.4	1496.2	1292.8	1303.1						848.7	791.5	.57	.53	0	0
10 000	300	1330.7	1330.7	1110.1	1096.3	13.0	13.0	10.0	10.0	.71	1112.1	1082.5	.84	.81	100	100
10 000	300	1316.9	1330.7	1123.8	1096.3	14.0	12.0	9.0	8.0		1221.8	1054.9	.92	.79	100	100
10 000	194	1496.2	1503.1	1272.1	1279.0	11.0	14.0	10.0	10.0	.74	727.4	902.5	.49	.60	0	0
10 000	194	1489.3	1510.0	1303.1	1300.0	15.0	14.0	12.0	8.0		761.9	828.7	.51	.55	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

[d]Fracture out of plane of notch.

TABLE VI.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Continued

(c) PH 15-7Mo (TH1050), 0.063 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1487.9	1533.4	1461.7	1509.3	5.5	4.5	4.0	2.0		1292.8	1145.2	0.87	0.75	100	100
0	300	1477.5	1516.8	1453.4	1476.9		5.0	1.0	1.0	0.41	1323.8	1073.5	.89	.70	100	100
0	300	1485.1	1528.6	1467.2	1482.4	5.0	6.5	2.0	3.0							
0	194	1647.8	1675.4	1516.8	1592.7			5.0	4.5	.70	1137.6	1199.7	.70	.72		57
0	194	1627.2	1668.5	1510.0	1558.2	8.0	8.0	6.0	7.0		1282.4	1268.6	.78	.76	80	
2 000	300	1496.2	1537.5	1482.4	1510.0	6.5	4.5	5.0	2.0	.59	1213.5	1130.7	.81	.74	100	86
2 000	300	1489.3	1537.5	1468.6	1516.8	6.0	2.5	3.0	1.5		1354.8	1089.4	.91	.71	77	86
2 000	194	1668.5	1716.8	1565.1	1620.3	9.5		7.0	3.0	.67	1182.5	1068.7	.71	.63		
2 000	194	1675.4	1703.0	1578.9	1599.6	9.0	6.0	8.0	4.0		1292.8	1103.2	.77	.65		
4 000	300	1482.4	1523.7	1454.8	1461.7	6.0	7.0	4.0	5.0	.64	1254.8	1185.9	.85	.78	80	100
4 000	300	1478.9	1530.6	1454.8	1447.9	7.5	6.0	4.0	4.0		1344.5	1151.4	.91	.75	83	87
4 000	194	1675.4	1709.9	1578.9	1641.0	7.5	3.0	4.0	2.0	.59	1123.8	1117.0	.67	.65		
4 000	194	1668.5	1723.7	1585.8	1651.3	9.0	6.0	6.0	3.0		1041.1	979.1	.62	.57		
7 000	300	1489.3	1530.6	1482.4	1492.7	8.0	6.0	6.0	4.0		1351.4	1200.0	.91	.77	80	83
7 000	300	1489.3	1530.6	1475.5	1489.3	6.0	5.0	4.0	3.0	.65	1379.0	1144.5	.93	.73	100	77
7 000	300	1482.4	1544.4	1461.7	1503.1	6.0	6.0	4.0	3.0							
7 000	194	1634.1	1723.7	1567.2	1647.8	7.0		3.0	3.0		1192.8	1082.5	.72	.63	0	0
7 000	194	1668.5	1709.9	1585.8	1634.1	9.0		7.0	3.0	.52	1130.7	1117.0	.68	.65	0	0
7 000	194	1689.2	1709.9	1572.0	1654.7	9.0		7.0	3.0							
10 000	300	1551.3	1565.1	1516.8	1516.8	8.0	9.0	5.0	3.0		1341.0	1223.8	.87	.77	85	95
10 000	300	1551.3	1592.7	1510.0	1544.4	5.0	6.0	2.0	2.0	.42	1385.8	1230.7	.89	.78	90	100
10 000	300	1544.4	1606.5	1512.7	1547.2	6.0	6.0	2.0	3.0							
10 000	194	1647.8	1745.1	1592.7	1668.3	6.5	9.0	4.0	7.5		1210.0	1154.9	.73	.51	0	0
10 000	194	1675.4	1730.6	1585.8	1647.7	8.5		6.0	3.0	.59	1265.2		.76	.67	0	
10 000	194	1661.6	1744.4	1576.1	1682.1	6.0		4.0	2.0							
14 000	300	1585.8	1620.3	1510.0	1565.1	7.0	4.5	4.0	3.0	.62	1302.4	1241.1	.82	.77	100	100
14 000	300	1592.7	1620.3	1516.8	1647.8	10.0	6.0	6.0	4.0		1316.9	1145.9	.83	.71	100	100
14 000	194	1720.2	1737.5	1578.9	1585.8	7.5	7.0	4.0	5.0	.64	1220.4	1179.0	.72	.67	0	0
14 000	194	1682.3	1778.8	1599.6	1668.5	9.0		6.0			1081.8	1089.4	.64	.62	0	0
14 000	194		1744.4													
18 000	300	1554.8	1613.4	1516.8	1585.8	8.0	5.0	6.0	3.0	.63	1351.4	1134.2	.87	.70	100	100
18 000	300	1558.2	1623.7	1530.6	1582.3	5.0	6.0	3.0	3.0		1341.0	1137.6	.86	.71	65	100
18 000	194	1727.1	1754.7	1634.1	1703.0	9.5	6.5	6.0	5.0	.71	1168.7	961.8	.68	.55	0	0
18 000	194	1716.8	1775.4	1634.1	1689.2	8.0	7.0	5.0	6.0		1220.4	979.1	.71	.56	0	0

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.
[b]Average of longitudinal and transverse values for each temperature and exposure.
[c]Percent of net section exhibiting shear-type failure.

TABLE VI.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Continued

(d) PH 14-8Mo (SRH950), 0.127 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1537.5	1572.0	1227.3	1254.8	11.5	10.0	8.0	5.0	0.62	1496.2	1289.3	0.97	0.82	85	100
0	300	1565.1	1558.2	1296.2	1275.5	13.0	9.0	9.0	5.0		1413.4	1316.9	.91	.84	100	100
0	194	1827.1	1780.9	1489.3	1427.2	14.0		10.0	5.0	.52	1551.3	1296.2	.86	.74	60	100
0	194	1772.0	1751.3	1406.5	1413.4	14.0		10.0	4.0		1572.0	1258.3	.87	.71	100	100
2 400	300	1551.3	1592.7	1233.5	1268.6	14.5	7.0	11.0	2.0	.61	1454.8		.93		95	
2 400	300	1578.9	1641.0	1344.5	1296.2	11.0	8.5	7.0	5.0		1351.4		.86		100	
2 400	194	1843.7	1847.8	1399.6	1334.1	13.0	11.0	8.0	7.0	.62	1572.0		.86		100	
2 400	194	1820.2	1834.0	1392.7	1379.0	8.0	10.0	4.0	7.0		1620.3		.89		100	
7 000	300	1634.1	1589.2	1382.4	1410.0	13.0	9.0	9.0	4.0	.55	1375.5	1310.0	.86	.82	100	100
7 000	300	1544.4	1627.2	1261.7	1444.5	11.0	5.0	5.0	3.0		1475.5	1234.2	.93	.77	100	100
7 000	194	1861.6	1978.8	1437.6	1523.7	13.0	12.0	9.0	8.0	.71	1585.8	1361.7	.85	.71	100	100
7 000	194	1854.7	1878.8	1489.3	1541.0	14.0	10.5	11.0	7.0		1568.6	1368.6	.85	.71	100	98
10 000	300	1575.3	1523.6	1327.1	1240.9	10.5	8.5	6.0	5.0	.63	1516.7	1151.3	.96	.74	100	100
10 000	300		1590.4		1358.1		11.0		8.0		1420.2	1203.0	.90	.77	100	100
10 000	194	1823.5	1860.0	1361.6	1496.0	14.5		10.0	8.0	.65	1502.9	1306.4	.82	.70	90	100
10 000	194	1868.3	1873.8	1537.4	1547.7	14.5		11.0	8.5		1523.6	1327.1	.83	.71	100	100

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE VI.- TENSILE AND NOTCH PROPERTIES FOR STAINLESS-STEEL SHEET - Concluded

(e) AISI 301 (CR), 0.063 cm thick

Exposure at 561° K, hr	Test temperature, °K	Tensile properties									Notch properties					
		Tensile strength, MN/m²		Yield strength, MN/m²		Elongation in 5.08 cm, percent (a)		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm (b)	Notch strength, MN/m²		Notch strength, ratio		Shear lip, percent (c)	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
0	300	1441.0	1489.3	1303.1	1265.2	6.0	5.0	4.0	2.0	0.52	1434.1	1310.0	0.99	0.87	60	90
0	300	1441.0	1489.3	1310.0	1241.1	5.0	7.0	3.0	3.0		1444.5	1330.7	.99	.88	49	83
0	194	1572.0	1585.8	1372.1	1296.2	29.0		22.0	20.0	.83	1544.4	1392.7	.98	.88	77	72
0	194	1592.7	1599.6	1420.3	1296.2	30.0	31.0	28.0	30.0		1558.2	1365.2	.99	.86	94	86
2 000	300	1613.4	1675.4	1358.3	1420.3	6.0	6.0	3.0	2.0	.40	1530.6	1379.0	.96	.83	95	85
2 000	300	1599.6	1661.6	1427.2			3.0	2.0	3.0		1530.6	1406.5	.96	.84	90	100
2 000	300										1572.0	1344.5	.98	.81	85	90
2 000	194	1675.4	1737.5	1503.1	1413.4		25.0	25.0	22.0	.94	1599.6	1441.0	.96	.83	95	90
2 000	194	1675.4	1737.5	1468.6	1454.8		29.0	25.0	30.0		1647.8	1368.6	.99	.79	60	90
2 000	194										1661.6	1530.6	.99	.88	95	80
4 000	300	1634.1	1703.0	1420.3	1475.5	3.0	3.0	1.0	1.0	.33	1503.1	1406.5	.93	.83	60	99
4 000	300	1613.4	1703.0	1461.7	1434.1	3.0	3.0	1.0	1.0		1558.2	1385.8	.96	.82	80	95
4 000	194	1716.8	1716.8	1496.2	1489.3	30.0	30.0	29.0	28.0	.95	1641.0	1516.8	.96	.88	75	80
4 000	194	1696.1	1737.5	1434.1	1530.6	30.0	29.0	29.0	27.0		1627.2	1523.7	.95	.88	95	80
7 000	300	1620.3	1696.1	1392.7	1434.1	2.5	3.0	0	0	.36	1530.6	1434.1	.94	.84	50	100
7 000	300	1634.1	1703.0	1434.1	1434.1	2.5	3.0	1.0	0		1572.0	1441.0	.97	.85	85	100
7 000	194	1723.7	1744.4	1454.8	1434.1	31.5	26.5	30.0	21.0	.90	1654.7	1475.5	.97	.84	99	85
7 000	194	1709.9	1772.0	1530.6	1503.1	31.5	31.0	31.0	26.0		1627.2	1392.7	.95	.79	100	80
10 000	300	1634.1	1689.2	1427.2	1592.7						1537.5	1454.8	.94	.86	100	100
10 000	300	1641.0	1696.1	1461.7	1468.6	3.0		1.0		.33	1544.4	1392.7	.94	.83	100	100
10 000	194	1730.6	1754.0						22.0	.86	1592.7	1454.8	.92	.83	95	90
10 000	194	1730.6	1744.4	1523.7	1730.6	25.0		21.0			1613.4	1420.3	.94	.81	90	85
14 000	300	1647.7	1695.9	1447.7	1478.8		2.0		1.0	.50	1599.4	1461.5	.98	.86	100	100
14 000	300	1627.0	1702.8	1475.3	1485.7						1599.4	1365.0	.98	.80	95	93
14 000	194	1730.4	1758.0	1460.1	1515.3	29.0	21.5	28.0	20.0	.95	1682.1	1482.2	.97	.85	100	83
14 000	194	1730.4	1747.6	1568.4	1530.5	28.0	23.5	27.0	22.0		1709.7	1461.5	.99	.83	93	87

[a]Values of elongation are not shown where fractures occurred outside the 2-inch gage length.

[b]Average of longitudinal and transverse values for each temperature and exposure.

[c]Percent of net section exhibiting shear-type failure.

TABLE VII.- YOUNG'S MODULUS IN TENSION AT 80° F (300° K)

FOR TITANIUM-ALLOY AND STAINLESS-STEEL SHEET

Material	Condition	Grain direction	Young's modulus (a)	
			ksi	MN/m^2
Titanium alloys				
Ti-8Al-1Mo-1V	AN	Longitudinal	18 000	124 000
Ti-6Al-4V	AN	Longitudinal	16 400	113 000
Ti-4Al-3Mo-1V	STA	Longitudinal	15 500	107 000
		Transverse	19 700	136 000
Ti-13V-11Cr-3Al	SA	Longitudinal	14 400	99 800
		Transverse	15 500	107 000
Stainless steels				
AM-350	CRT	Longitudinal	28 700	198 000
AM-350	DA	Longitudinal	28 500	197 000
PH 15-7 Mo	TH 1050	Longitudinal	29 600	204 000
PH 14-8 Mo	SRH 950	Longitudinal	28 500	197 000
AISI 301	CR	Longitudinal	24 800	171 000
		Transverse	29 200	202 000

[a]Tuckerman optical strain-gage measurements.

TABLE VIII.- RAPID-LOADING TESTS OF Ti-4Al-3Mo-1V (STA) AT ROOM TEMPERATURE

(a) U.S. customary units

Exposure at 550° F, hr	Tensile properties													Notch properties							
	Strain rate at yield, per sec		Test duration, msec		Tensile strength, ksi		Yield strength, ksi		Elongation in 2 in., percent		Uniform elongation, percent		Uniform elongation / Elongation in 2 in.	Test duration, msec		Notch strength, ksi		Notch strength ratio		Shear lip, percent	
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse		Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
Intermediate testing speeds (a)																					
0	0.570	0.522	74.0 99.0	108.0 129.0	162.5 160.5	179.0 181.0	143.0 142.0	169.0 166.0	7.5 9.0	8.5 8.5	5.0 8.0	6.0 4.0	0.69	180.0	175.0	145.2	164.0	0.85	0.96	100	100
2 000	.460	.511 .502	73.0 135.0	111.0 96.0	160.0	177.3 180.3	141.0	169.0 170.0	9.5	9.0 9.5	8.0	6.5 9.0	.84	101.0 194.0	164.0 138.0	149.3 149.0	171.5 171.5	.87 .86	.99 .99	100 100	100 100
4 000	.526 .568	.529 .525	97.0 156.0	200.0 198.0	161.7 159.0	181.5 183.0	141.5 138.0	171.5 173.5	8.5 10.0	7.0 8.0	8.0 8.0	6.0 6.5	.85	214.0 125.0	144.0 174.0	144.0 152.7	175.0 176.0	.84 .89	1.02 1.03	100 100	95 90
7 000	.498 .498	.546 .546	102.0 86.0	190.0 130.0	158.3 157.3	176.0 178.0	136.5 133.5	165.0 165.5	8.5 9.0	8.5 9.0	6.5 8.0	6.5 7.0	.80	101.0 181.0	145.0 255.0	148.3 142.0	177.0 182.0	.90 .85	1.06 1.09	100 100	100 100
10 000														100.0 100.5	145.0 142.0	147.7 148.9	178.7 174.5			100 100	100 100
14 000														95.0 90.0	150.0 150.0	146.5 143.2	179.3 178.0			100 100	100 95
Maximum testing speeds (b)																					
0	17.8	16.8 18.0	7.0 5.0 6.0	6.0 10.0	167.8 162.5 166.5	187.5 182.0	155.0 152.9 149.5	175.0 179.0	7.0 7.0 7.5	8.0 7.0 7.5	5.0 5.0 7.0	5.0 4.0 5.0	0.71	2.8 3.0	[c]2.5 7.2	161.8 162.0	195.0 192.0	0.93 .93	1.12 1.11	100 100	100 100
2 000	15.9 15.0		6.0 5.0	7.0 5.0	163.5 161.0	183.5	149.0 148.3		7.5 10.0	8.0 8.5	6.0 7.0	5.0 5.0	.68	2.8 2.6	7.0 6.6	160.5 162.0	186.5 185.8	.95 .96	1.10 1.10	100 95	100 100
4 000	15.2 16.4	16.4 18.0	6.0 6.0	6.0 6.0	166.8 165.8	185.5 188.5	157.5	174.0	9.5 10.0	8.0 8.5	8.5 9.0	6.5 7.0	.83	2.5 2.6	7.0 6.8	161.0 156.0	187.0 189.0	.91 .88	1.06 1.07	100 95	100 90
7 000	16.0	17.5	6.0 5.0	5.0 6.0	165.0 167.5	191.7 191.0	150.5 148.0	189.0	10.0 9.0	8.0 7.5	10.0 8.0	6.5 6.0	.88	2.6 2.8	7.0 7.2	162.8 161.7	189.5 188.2	.91 .90	1.06 1.05	100 100	100 80
10 000					169.5	188.5			9.0	8.0	8.0	6.0	.82	2.0 3.0	6.0 6.5	159.0 157.2	189.3 190.8	.89 .88	1.06 1.07	100 100	100 100
14 000														2.8 2.0	7.0 7.2	155.0 153.1	190.4 190.5			100 100	100 95

[a]Elastic strain rates approximately 0.05 to 0.12 per second.
[b]Elastic strain rates approximately 3.75 to 4.50 per second.
[c]Specimen with reduced thickness.

TABLE VIII.- RAPID-LOADING TESTS OF Ti-4Al-3Mo-1V (STA) AT ROOM TEMPERATURE - Concluded

(b) SI units

Exposure at 561° K, hr	Tensile properties													Notch properties							
	Strain rate at yield, per sec		Test duration, msec		Tensile strength, MN/m^2		Yield strength, MN/m^2		Elongation in 5.08 cm, percent		Uniform elongation, percent		Uniform elongation / Elongation in 5.08 cm	Test duration, msec		Notch strength, MN/m^2		Notch strength ratio		Shear lip, percent	
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse		Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
Intermediate testing speeds (a)																					
0	0.570	0.522	74.0 99.0	108.0 129.0	1121.3 1107.5	1235.1 1248.9	986.7 979.8	1166.1 1145.4	7.5 9.0	8.5 8.5	5.0 8.0	6.0 4.0	0.69	180.0	175.0	1001.9	1131.6	0.85	0.96	100	100
2 000	.460	.511 .502	73.0 135.0	111.0 96.0	1104.0	1223.4 1244.1	972.9	1166.1 1173.0	9.5	9.0 9.5	8.0	6.5 9.0	.84	101.0 194.0	164.0 138.0	1030.2 1028.1	1183.4 1183.4	.87 .86	.99 .99	100 100	100 100
4 000	.526 .568	.529 .525	97.0 156.0	200.0 198.0	1115.7 1097.1	1252.4 1262.7	976.4 952.2	1183.4 1197.2	8.5 10.0	7.0 8.0	8.0 8.0	6.0 6.5	.85	214.0 125.0	144.0 174.0	993.6 1053.6	1207.5 1214.4	.84 .89	1.02 1.03	100 100	95 90
7 000	.498 .498	.546 .546	102.0 86.0	190.0 130.0	1092.3 1085.4	1214.4 1228.2	941.9 921.2	1138.5 1142.0	8.5 9.0	8.5 9.0	6.5 8.0	6.5 7.0	.80	101.0 181.0	145.0 255.0	1021.2 979.8	1221.3 1255.8	.90 .85	1.06 1.09	100 100	100 100
10 000														100.0 100.5	145.0 142.0	1019.1 1027.4	1233.0 1204.1			100 100	100 100
14 000														95.0 90.0	150.0 150.0	1010.9 988.1	1237.2 1228.2			100 100	100 95
Maximum testing speeds (b)																					
0	17.8	16.8 18.0	7.0 5.0 6.0	6.0 10.0	1157.8 1121.3 1148.9	1293.8 1255.8	1069.5 1055.0 1031.6	1207.5 1235.1	7.0 7.0 7.5	8.0 7.0 7.5	5.0 5.0 7.0	5.0 4.0 5.0	0.71	2.8 3.0	[c]2.5 7.2	1116.4 1117.8	1345.5 1324.8	0.93 .93	1.12 1.11	100 100	100 100
2 000	15.9 15.0		6.0 5.0	7.0 5.0	1128.2 1110.9	1266.2	1028.0 1023.3		7.5 10.0	8.0 8.5	6.0 7.0	5.0 5.0	.68	2.8 2.6	7.0 6.6	1107.5 1117.8	1286.9 1282.0	.95 .96	1.10 1.10	100 95	100 100
4 000	15.2 16.4	16.4 18.0	6.0 6.0	6.0 6.0	1150.9 1144.0	1280.0 1300.7	1086.8	1200.6	9.5 10.0	8.0 8.5	8.5 9.0	6.5 7.0	.83	2.5 2.6	7.0 6.8	1110.9 1076.4	1290.3 1304.1	.91 .88	1.06 1.07	100 95	100 90
7 000	16.0	17.5	6.0 5.0	5.0 6.0	1138.5 1155.8	1322.7 1317.9	1038.5 1021.2	1304.1	10.0 9.0	8.0 7.5	10.0 8.0	6.5 6.0	.88	2.6 2.8	7.0 7.2	1123.3 1115.7	1307.6 1298.6	.91 .90	1.06 1.05	100 100	100 80
10 000					1169.6	1300.7			9.0	8.0	8.0	6.0	.82	2.0 3.0	6.0 6.5	1097.1 1084.7	1306.2 1316.5	.89 .88	1.06 1.07	100 100	100 100
14 000														2.8 2.0	7.0 7.2	1069.5 1056.4	1313.8 1314.5			100 100	100 95

[a]Elastic strain rates approximately 0.05 to 0.12 per second.
[b]Elastic strain rates approximately 3.75 to 4.50 per second.
[c]Specimen with reduced thickness.

TABLE IX.- SPOT-WELD TENSILE STRENGTHS FOR TITANIUM-ALLOY AND STAINLESS-STEEL SHEET AFTER EXPOSURE AT 550° F (561° K)

Titanium alloys

Material	Condition	Exposure at 550° F, hr	Number of tests	Average maximum load, P		P/P_o	Weld diameter		Penetration, percent (a)	Type of failure (a)
				lb	N		in.	cm		
Ti-13V-11Cr-3Al	DA, 0.064 in. (0.163 cm)	0	3	687	3056	1.00				Weld
		2 000	3	757	3367	1.10				
		4 000	3	694	3087	1.01				
		7 000	3	662	2945	.96				
		10 000	3	740	3292	1.08				
		14 000	3	681	3029	.99				
		22 000	3	537	2388	.78				
Ti-13V-11Cr-3Al	SA, 0.064 in. (0.163 cm)	0	2	449	1997	1.00				Weld
		2 000	3	390	1735	.87				
		4 000	3	369	1641	.82				
		7 000	3	406	1806	.90				
		10 000	3	379	1686	.84				
		14 000	3	382	1699	.85				
		18 000	2	376	1673	.84				
		22 000	4	274	1219	.61				
Ti-6Al-4V	AN	0	5	441	1962	1.00	0.18	0.46	80	Base metal
		2 000	5	385	1713	.87				
		4 000	5	394	1753	.89				
		7 000	5	407	1810	.92				
		10 000	5	321	1428	.73				
		14 000	5	370	1646	.84				
		18 000	4	310	1379	.70				
		22 000	4	328	1458	.74				
Ti-8Al-1Mo-1V	AN	0	4	489	2175	1.00	0.16	0.41	80	Base metal
		2 000	3	497	2211	1.01				
		4 000	3	485	2157	1.00				
		7 000	3	463	2059	.95				
		10 000	3	442	1966	.90				
		14 000	3	418	1859	.85				
Ti-4Al-3Mo-1V	STA	0	8	474	3888	1.00	0.23	0.58	80	Base metal
		2 000	8	770	3425	.88				
		4 000	8	713	3172	.82				
		7 000	8	714	3176	.82				
		10 000	8	568	2527	.65				
		14 000	8	590	2625	.67				

Stainless steels

Material	Condition	Exposure at 550° F, hr	Number of tests	Average maximum load, P		P/P_o	Weld diameter		Penetration, percent (a)	Type of failure
				lb	N		in.	cm		
AM-350	CRT	0	3	1597	7 104	1.00	0.14	0.36	85	Weld
		2 000	4	1209	5 378	.76				Weld
		4 000	4	2130	9 475	1.34				Base metal
		7 000	4	1879	8 358	1.18				
		10 000	3	1857	8 260	1.16				
		14 000	4	2274	10 115	1.42				
AM-350	DA (Weld after heat treatment)	0	4	300	1 334	1.00	0.15	0.38		Base metal
		2 000	4	260	1 156	.87				Weld
		4 000	4	223	992	.74				Base metal and weld
		7 000	4	214	952	.71				Weld
		10 000	4	194	863	.65				Weld
AM-350	DA (Weld before heat treatment)	0	4	1053 -	4 684	1.00	0.14	0.36	85	Weld
		2 000	4	1115	4 959	1.06				Base metal
		4 000	4	988	4 395	.94				
		7 000	4	1318	5 863	1.25				
		10 000	4	1156	5 142	1.10				
PH 15-7 Mo	TH1050 (Weld after heat treatment)	0	5	699	3 109	1.00	0.12	0.30	65	Base metal
		2 000	5	672	2 989	.96				
		4 000	5	568	2 567	.81				
		7 000	5	446	1 984	.64				
		14 000	5	276	1 228	.39				
		18 000	5	266	1 183	.38				
PH 15-7 Mo	TH1050 (Weld before heat treatment)	0	5	248	1 103	1.00	0.20	0.51	70	Base metal
		2 000	5	241	1 072	.97				Base metal and weld
		4 000	5	197	876	.80				
		7 000	5	197	876	.80				
		10 000	5	218	969	.88				
		14 000	5	218	969	.88				
		18 000	5	194	863	.78				
PH 14-8 Mo	SRH950 (Weld before heat treatment)	0	3	862	3 834	1.00	0.20	0.51	70	Base metal
		2 400	3	938	4 172	1.08				
		7 000	3	877	3 901	1.02				
		10 000	3	830	3 692	.96				
PH 14-8 Mo	SRH950 (Weld after heat treatment)	0	3	2100	9 341	1.00	0.25	0.63	80	Base metal
		2 400	3	2317	10 307	1.10				
		7 000	3	2218	9 866	1.05				
		10 000	3	1770	7 873	.84				
AISI 301	CR	0	4	2101	9 346	1.00	0.13	0.33	75	Weld
		2 000	4	2073	9 221	.98				
		4 000	4	1651	7 344	.79				
		7 000	4	1800	8 067	.86				
		10 000	4	2016	8 968	.96				Base metal
		14 000	4	1808	8 042	.86				Base metal

[a]Initial weld penetration.

TABLE X.- LATTICE-PARAMETER AND HARDNESS MEASUREMENTS

FOR TITANIUM-ALLOY AND STAINLESS-STEEL SHEET

(a) Titanium alloys

Alloy	Condition	Exposure at 550° F (561° K), hr	Lattice parameter		Knoop hardness (a)
			a, Å	c/a	
Ti-8Al-1Mo-1V	AN (single)	0	2.927	1.588	370
		14 000	2.926	1.589	370
Ti-6Al-4V	AN	0	2.922	1.597	370
		22 000	2.921	1.599	390
Ti-4Al-3Mo-1V	STA	0	2.938	1.597	430
		14 000	2.939	1.596	420
Ti-13V-11Cr-3Al	SA:				
	0.064 in. (0.163 cm)	0	3.184	1.000	380
		22 000	3.179	1.000	374
	0.040 in. (0.102 cm)	0	3.186	1.000	370
		10 000	3.181	1.000	372
	DA:				
	0.064 in. (0.163 cm)	0	3.189	1.000	347
		18 000	3.190	1.000	326
	0.040 in. (0.102 cm)	0	3.189	1.000	370
		10 000	3.189	1.000	355

[a]100-gram weight.

(b) Stainless steels

Alloy	Condition	Exposure at 550° F (561° K), hr	Lattice parameter			Knoop hardness (a)
			a, Å		c/a	
			Austenite	Martensite		
AM-350	CRT	0	3.536	2.906	1.006	540
		10 000	3.539	2.875	1.003	516
	DA	0	3.528	2.879	1.002	470
		10 000	3.532	2.878	1.000	450
PH 15-7 Mo	TH1050	0	3.525	2.857	1.003	526
		18 000	3.525	2.854	1.002	500
PH 14-8 Mo	SRH 950	0	3.523	2.865	1.001	547
		7 000	3.519	2.865	1.001	555
AISI 301	CR	0	3.593			493
		10 000	3.591	[b]3.880		547

[a]100-gram weight.
[b]Either Martensite or ferrite.

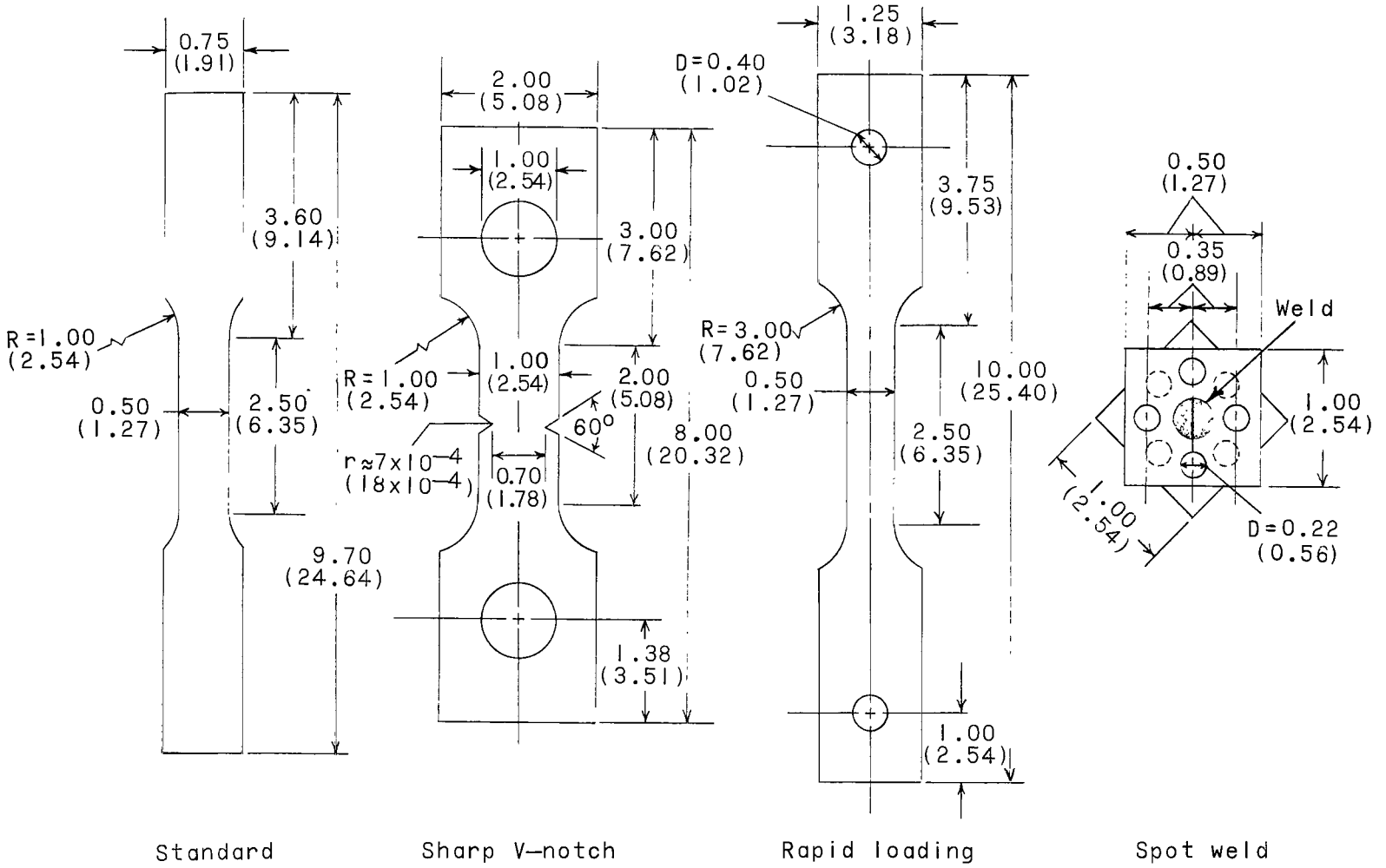
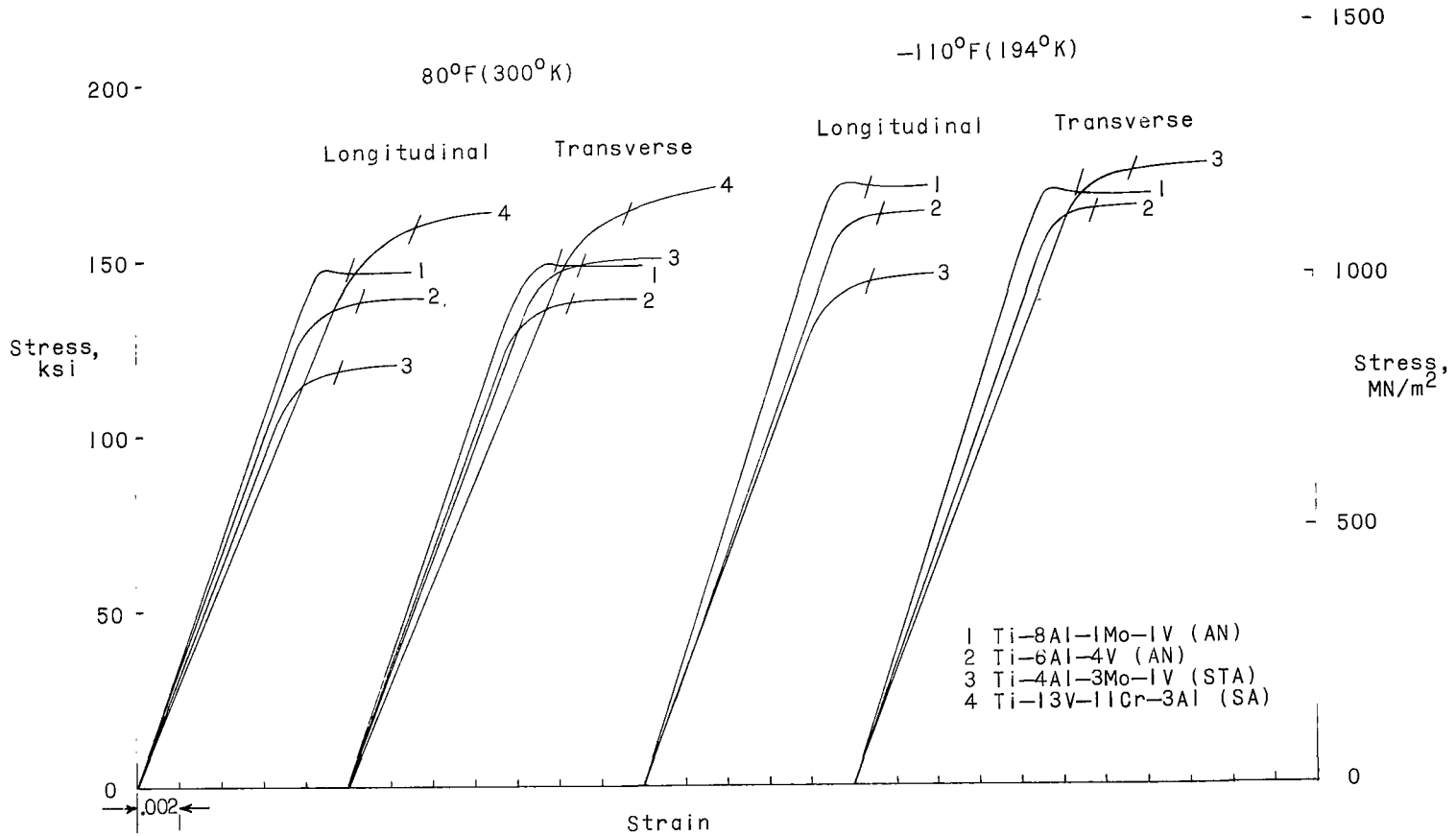
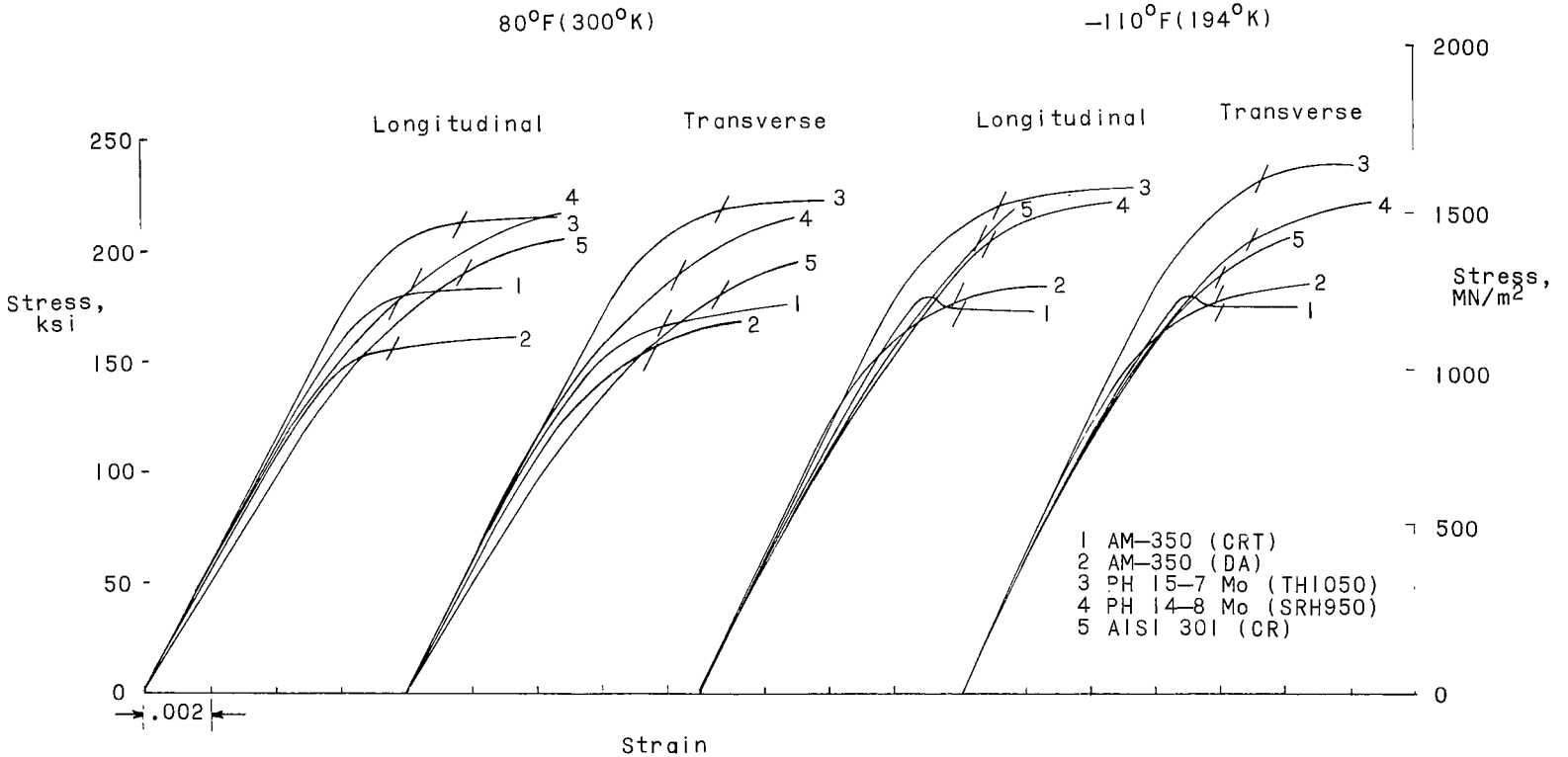


Figure 1.- Specimens used in tensile tests. (Except where otherwise noted, all dimensions are given in inches, with the equivalent measurement in centimeters shown in parentheses.)



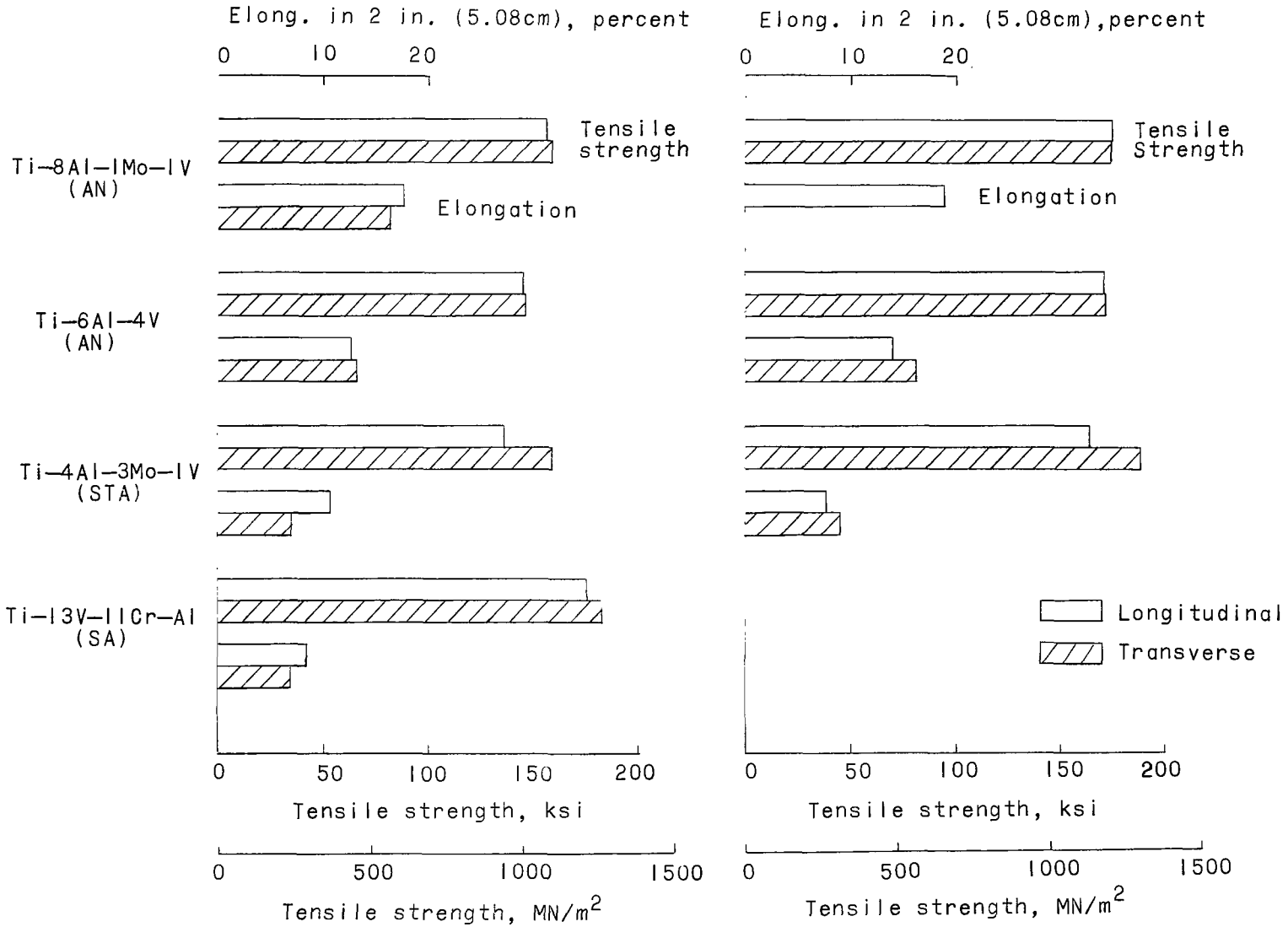
(a) Titanium alloys.

Figure 2.- Tensile stress-strain curves for titanium-alloy and stainless-steel sheet at 80° F (300° K) and at -110° F (194° K).



(b) Stainless steels.

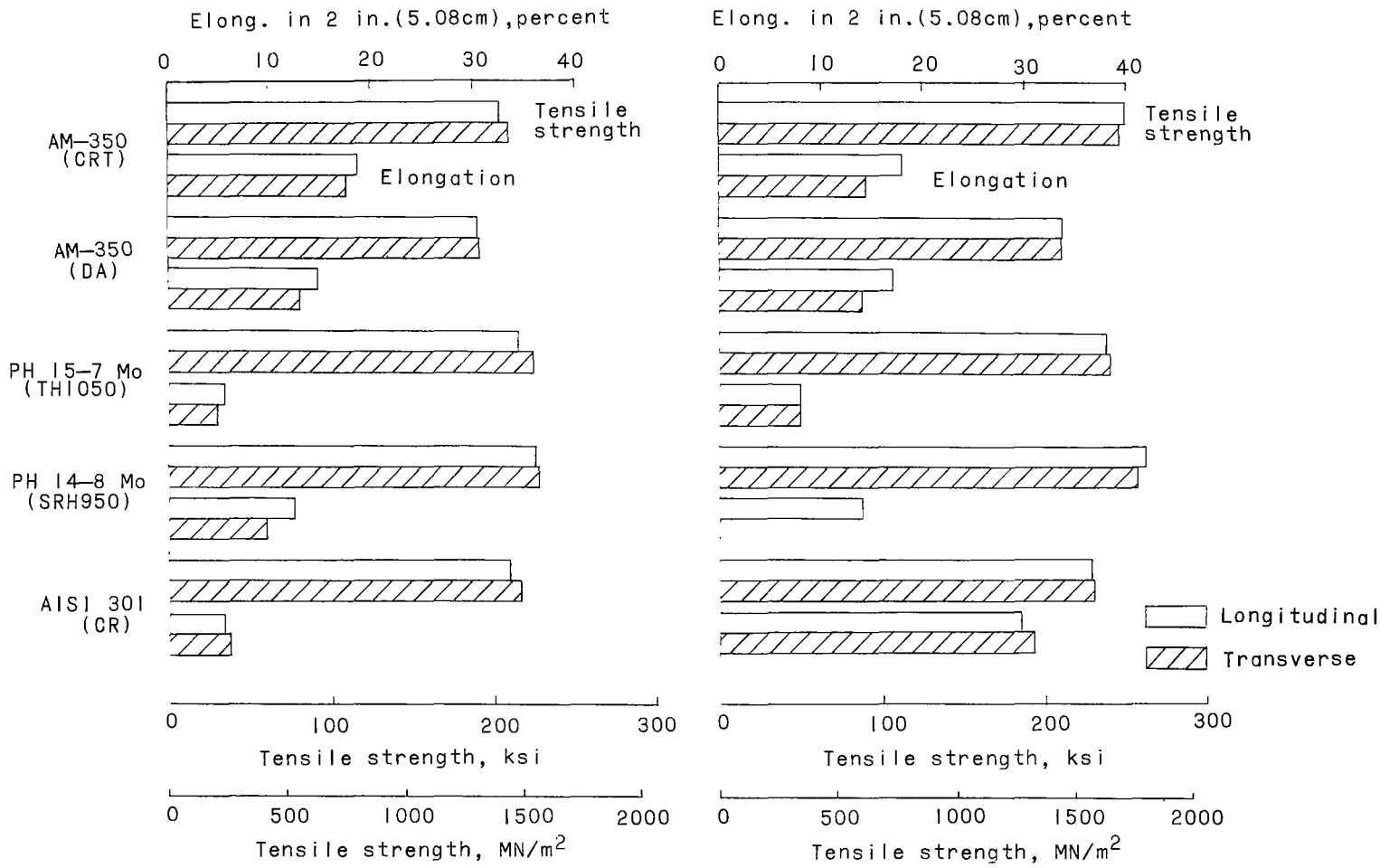
Figure 2.- Concluded.



(a) 80° F (300° K).

(b) -110° F (194° K).

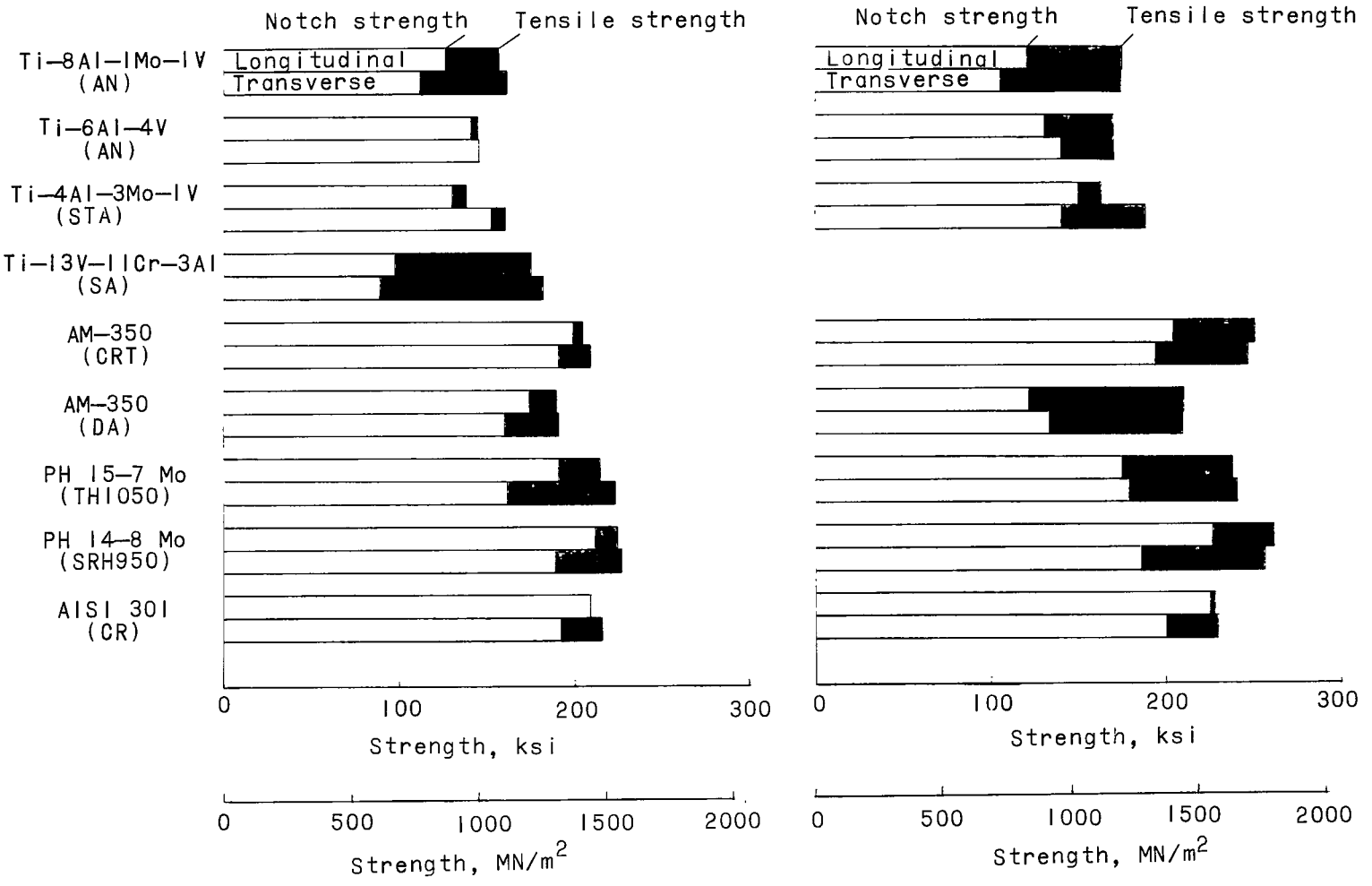
Figure 3.- Tensile properties of titanium-alloy sheet at 80° F (300° K) and at -110° F (194° K).



(a) 80° F (300° K).

(b) -110° F (194° K).

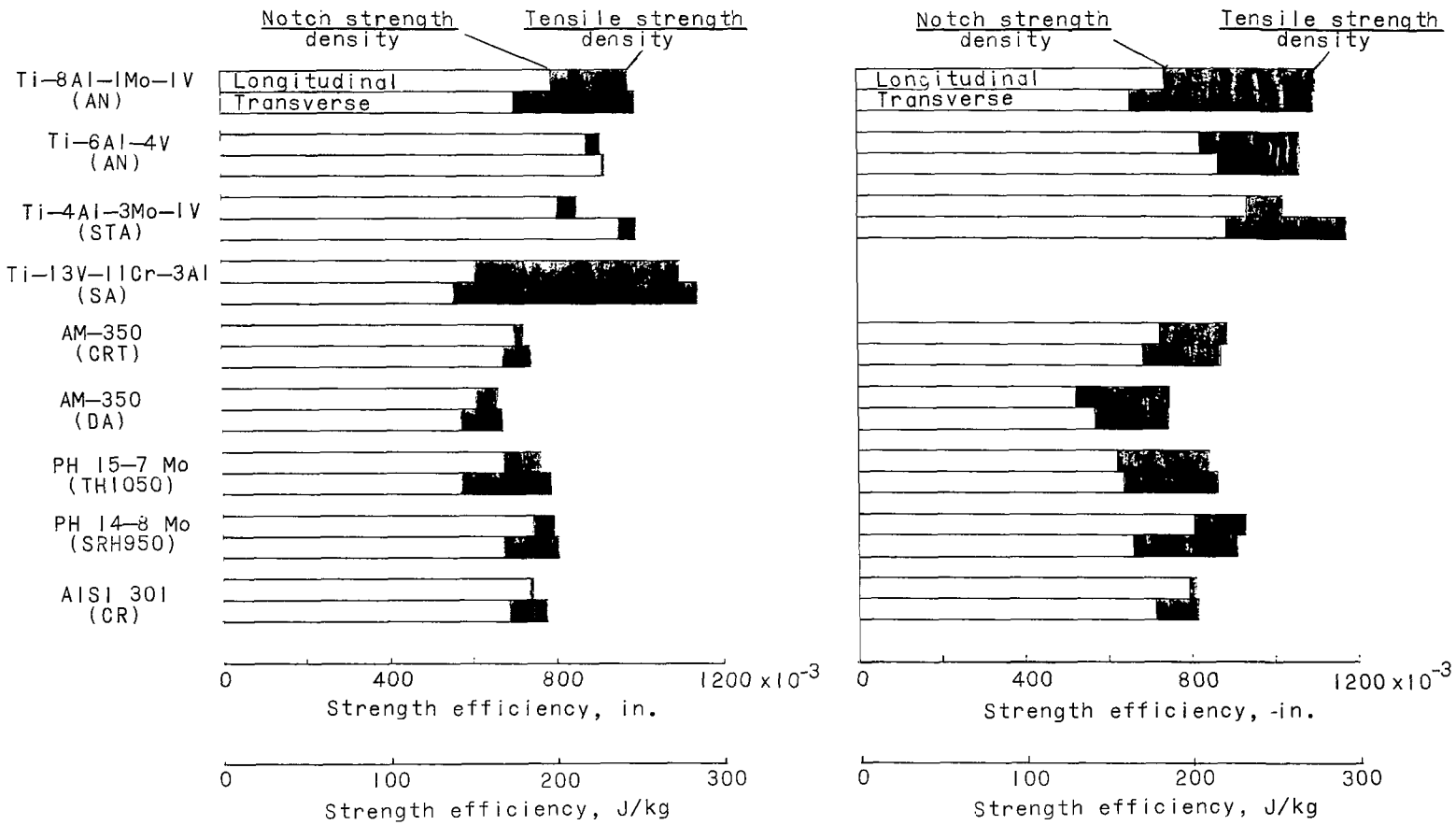
Figure 4.- Tensile properties of stainless-steel sheet at 80° F (300° K) and at -110° F (194° K).



(a) 80° F (300° K).

(b) -110° F (194° K).

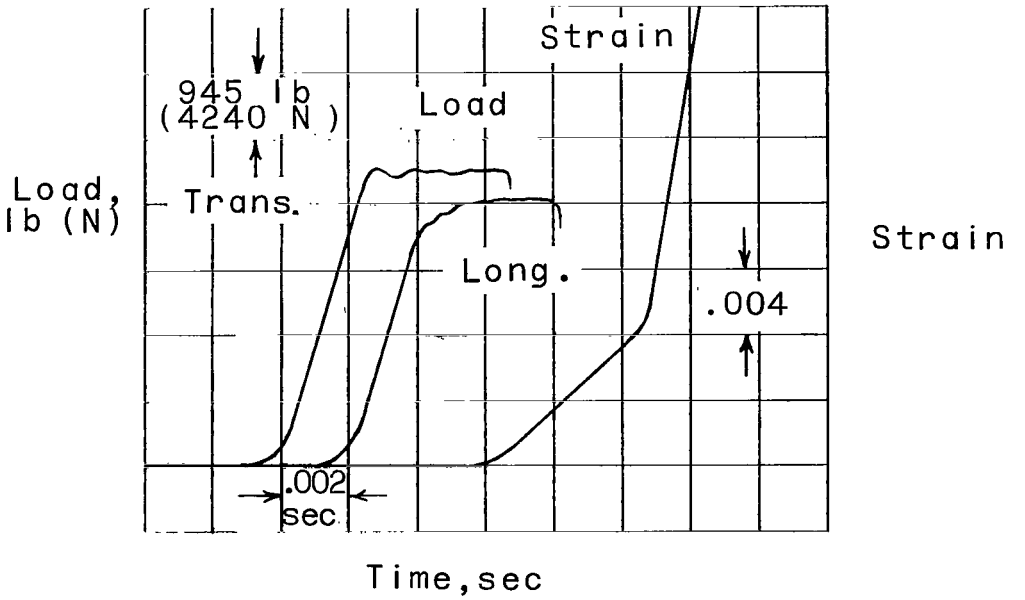
Figure 5.- Notch and tensile strengths of titanium-alloy and stainless-steel sheet at 80° F (300° K) and at -110° F (194° K).



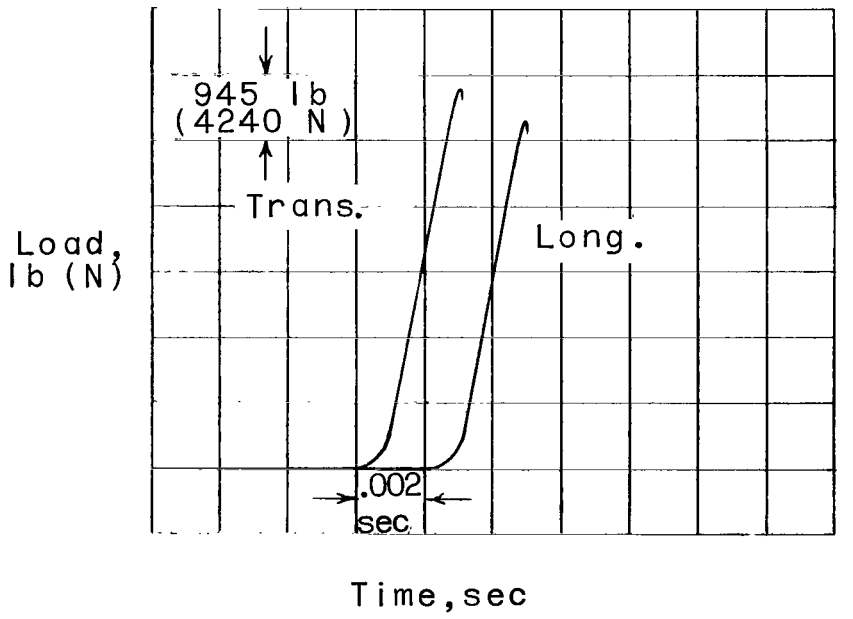
(a) 80° F (300° K).

(b) -110° F (194° K).

Figure 6.- Tensile- and notch-strength efficiencies for titanium-alloy and stainless-steel sheet at 80° F (300° K) and at -110° F (194° K).



(a) Standard specimen.



(b) Notch specimen.

Figure 7.- Representative load- and strain-time histories obtained in rapid-loading tensile tests at room temperature. (Note: Trans. and long. mean transverse and longitudinal, respectively.)

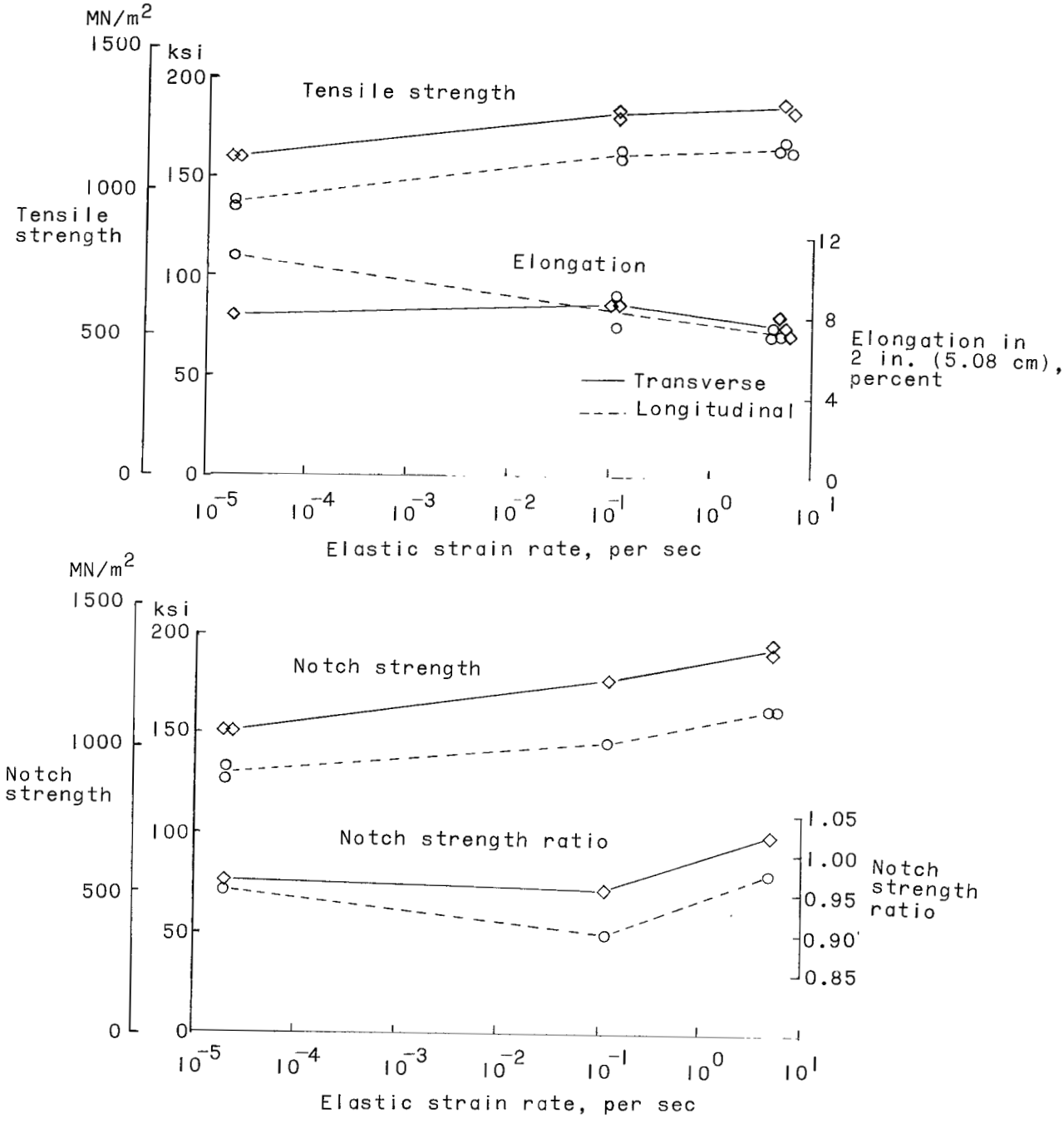
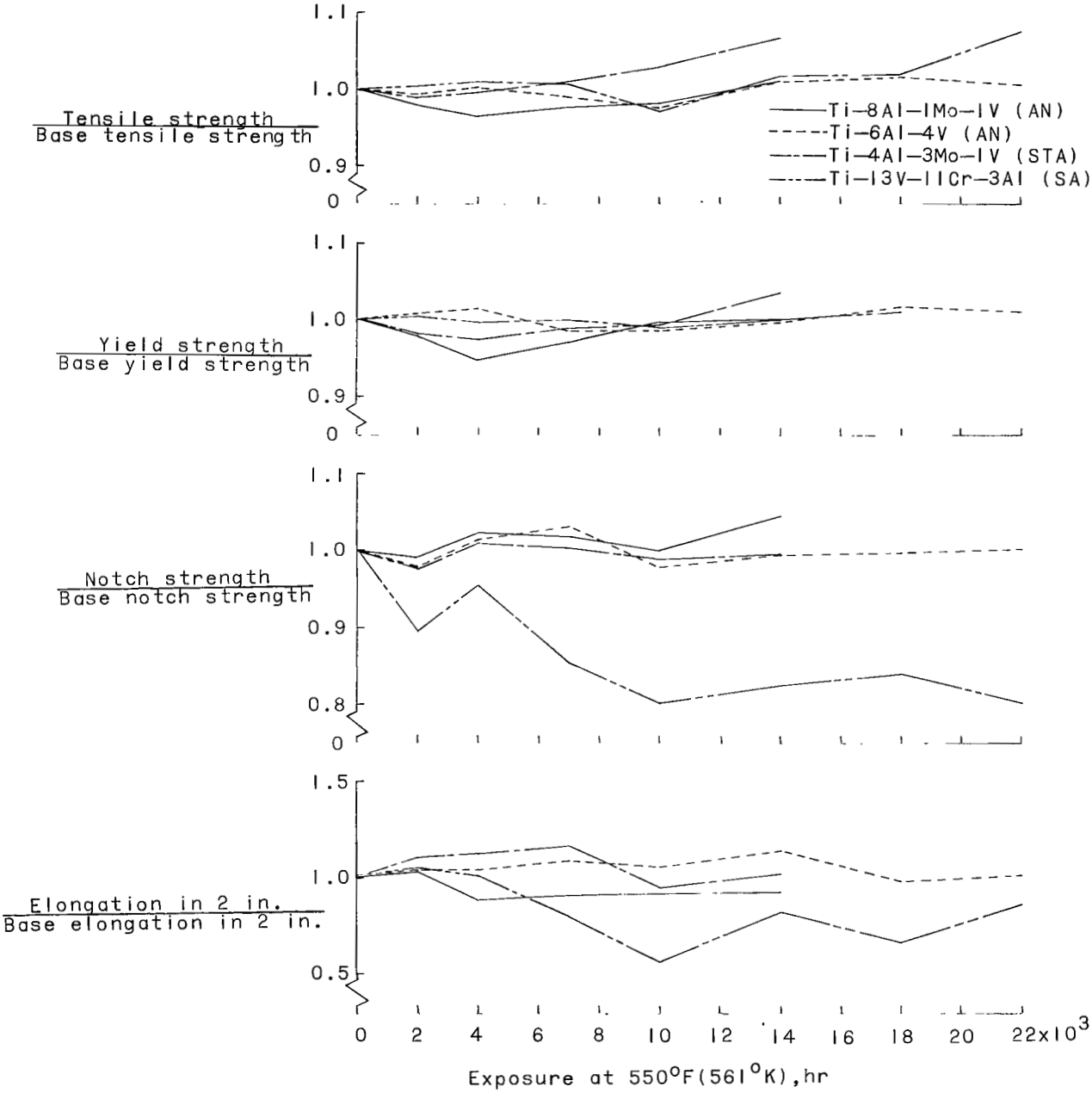
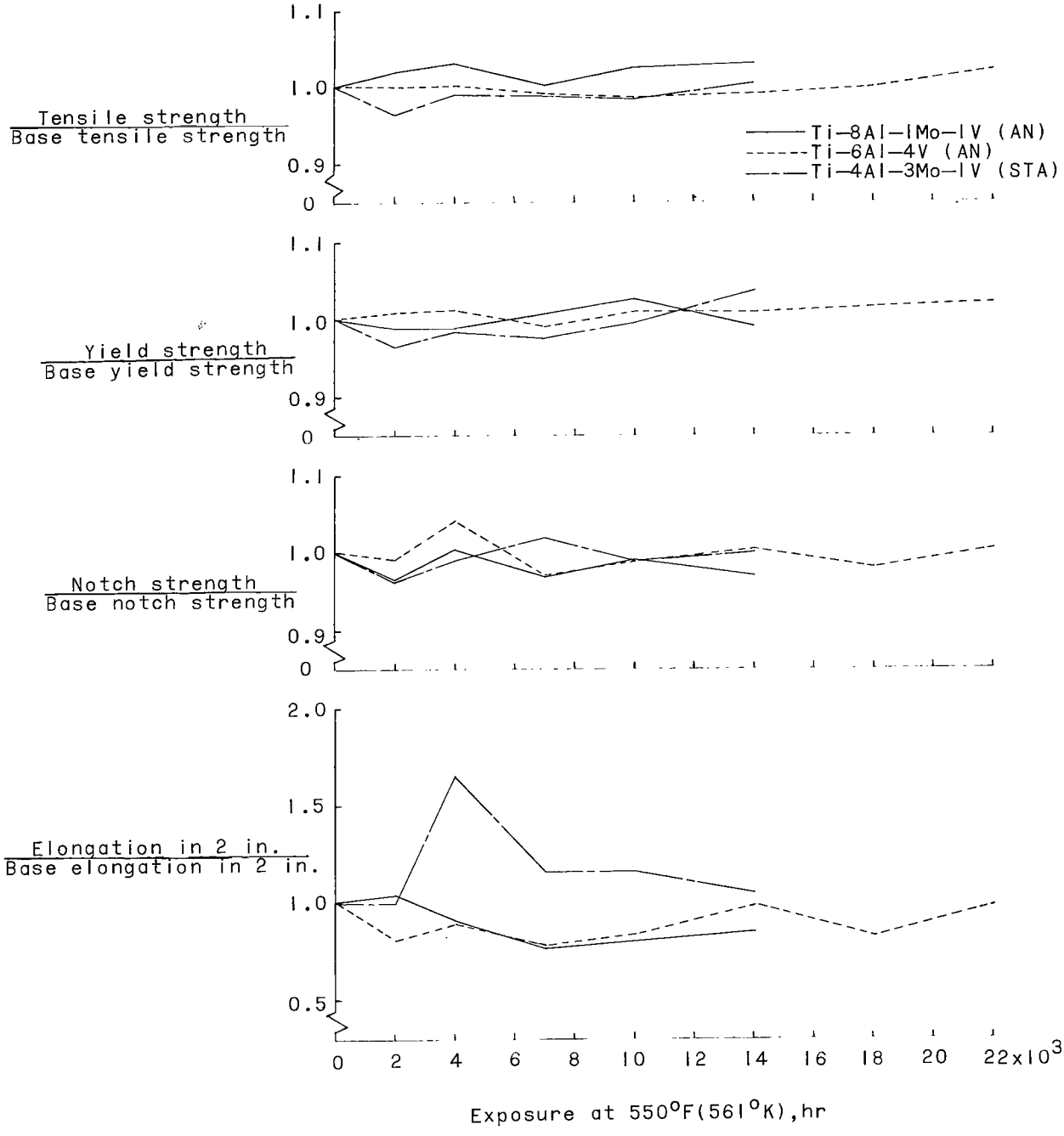


Figure 8.- Effect of strain rate on tensile and notch properties of Ti-4Al-3Mo-1V sheet at room temperature.



(a) Properties at room temperature.

Figure 9.- Effect of exposure at 550° F (561° K) on ratios of tensile strength, yield strength, notch strength, and elongation in 2 inches (5.08 centimeters) for titanium-alloy sheet at room temperature and at -110° F (194° K).



(b) Properties at -110° F (194° K).

Figure 9.- Concluded.

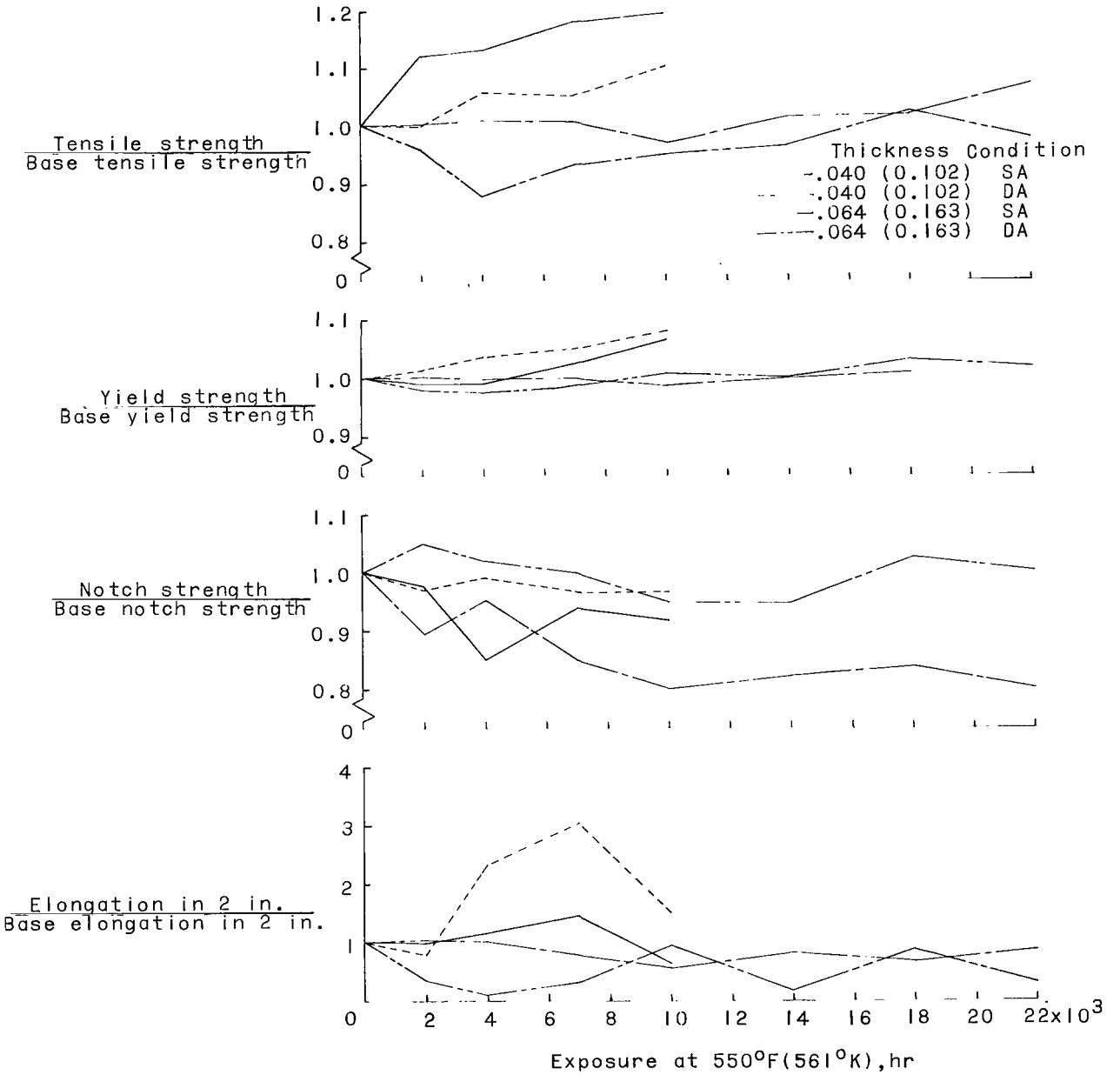
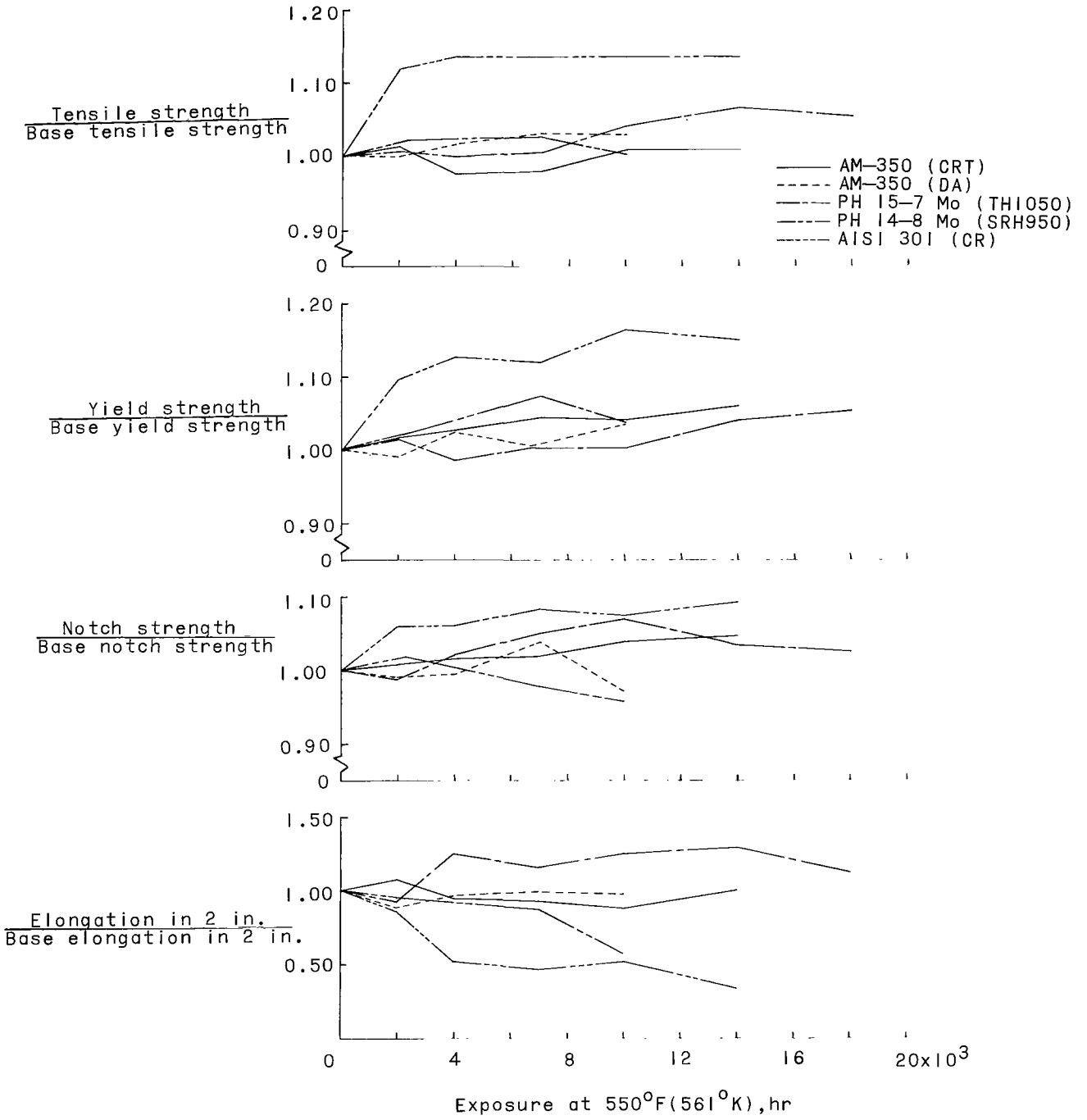
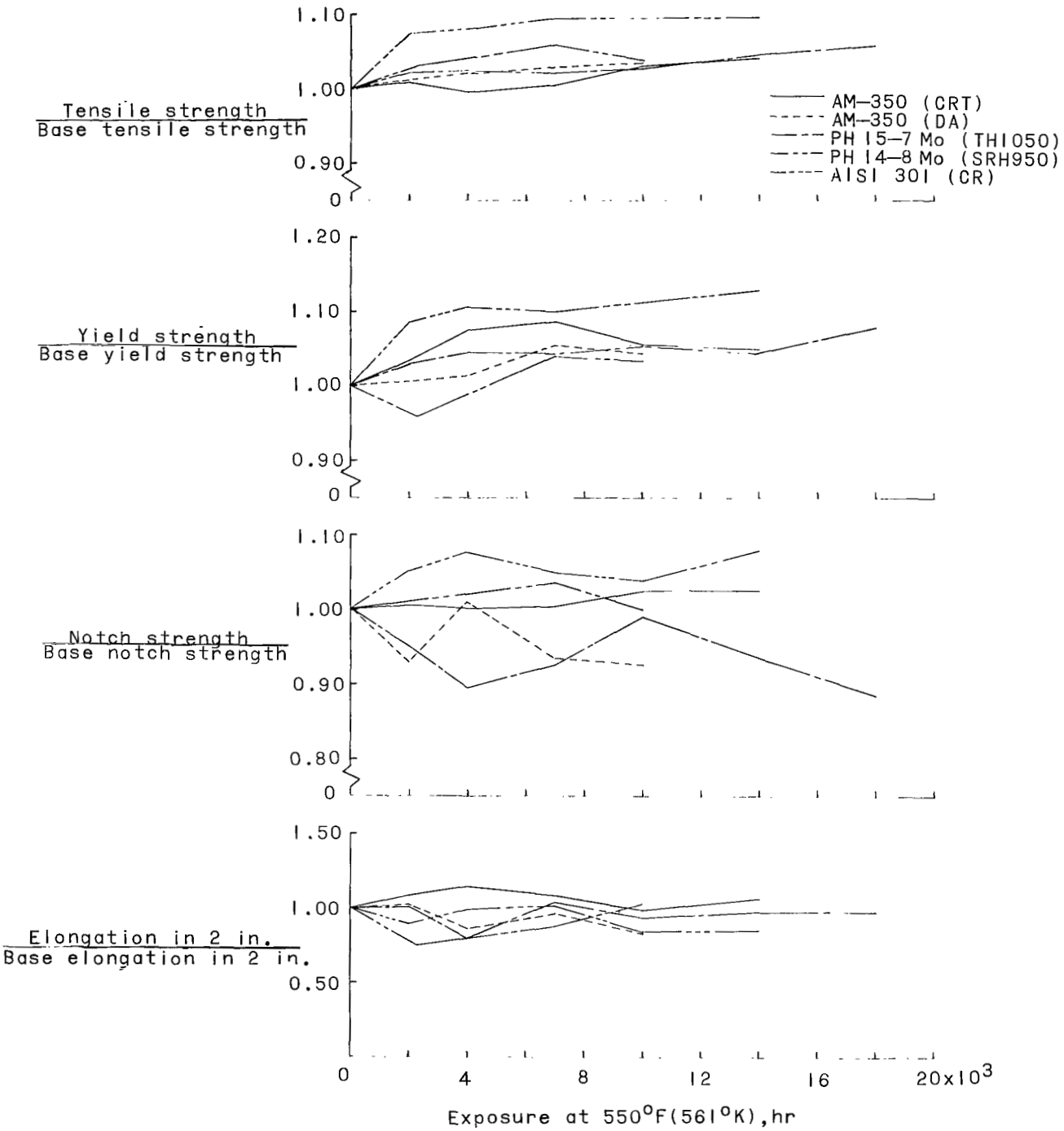


Figure 10.- Effect of exposure at 550° F (561° K) on ratios of tensile strength, yield strength, notch strength, and elongation in 2 inches (5.08 centimeters) for Ti-13V-11Cr-3Al at room temperature.



(a) Properties at room temperature.

Figure 11.- Effect of exposure at 550° F (561° K) on ratios of tensile strength, yield strength, notch strength, and elongation in 2 inches (5.08 centimeters) for stainless-steel sheet at room temperature and at -110° F (194° K).



(b) Properties at -110° F (194° K).

Figure 11.- Concluded.

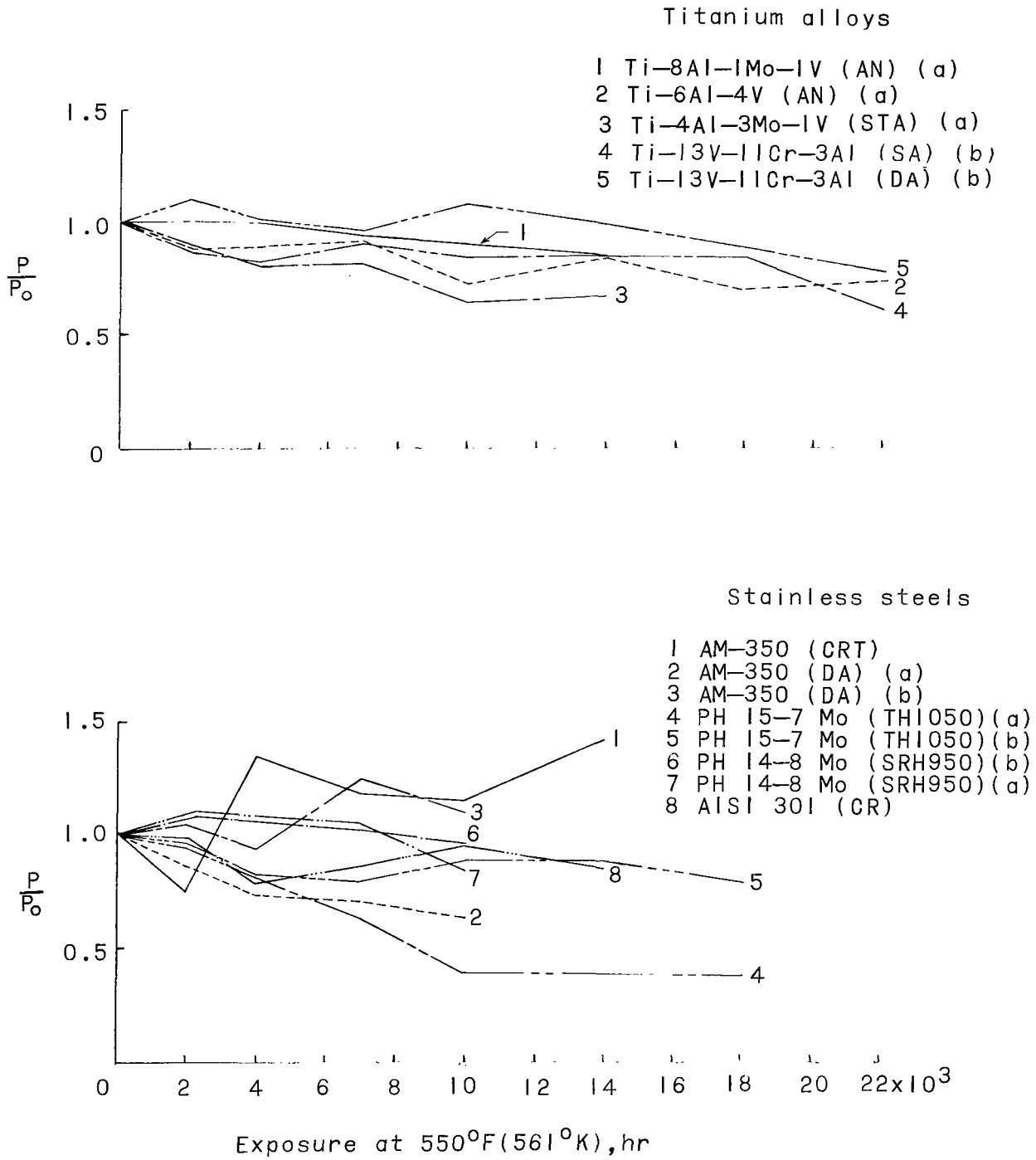


Figure 12.- Effect of exposure at 550° F (561° K) on tensile spot-weld strength of titanium-alloy and stainless-steel sheet at room temperature. (Note: (a) and (b) indicate materials welded after heat treatment and before heat treatment, respectively.)

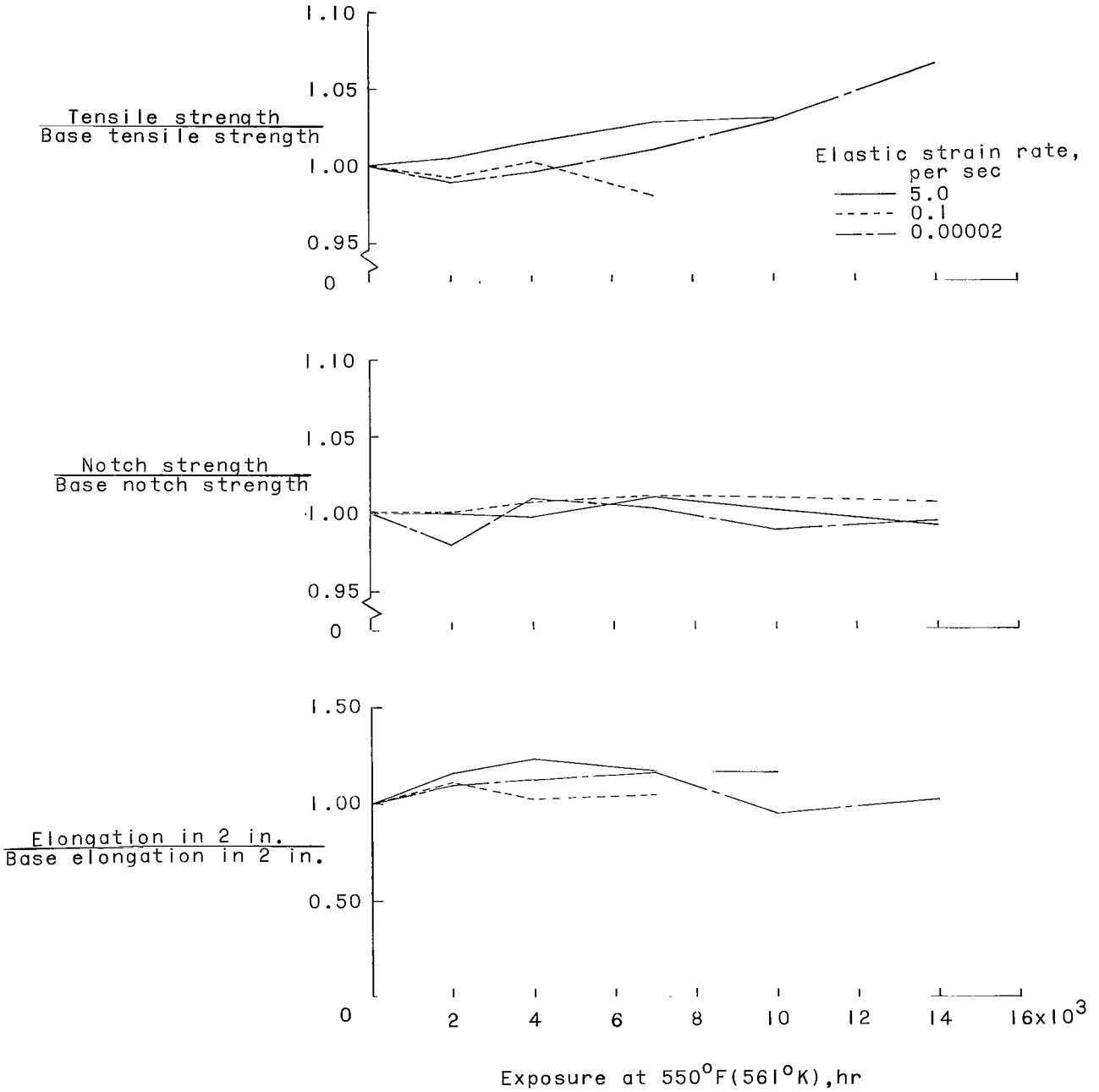


Figure 13.- Effect of exposure at 550° F (561° K) on strain-rate sensitivity of Ti-4Al-3Mo-1V at room temperature.

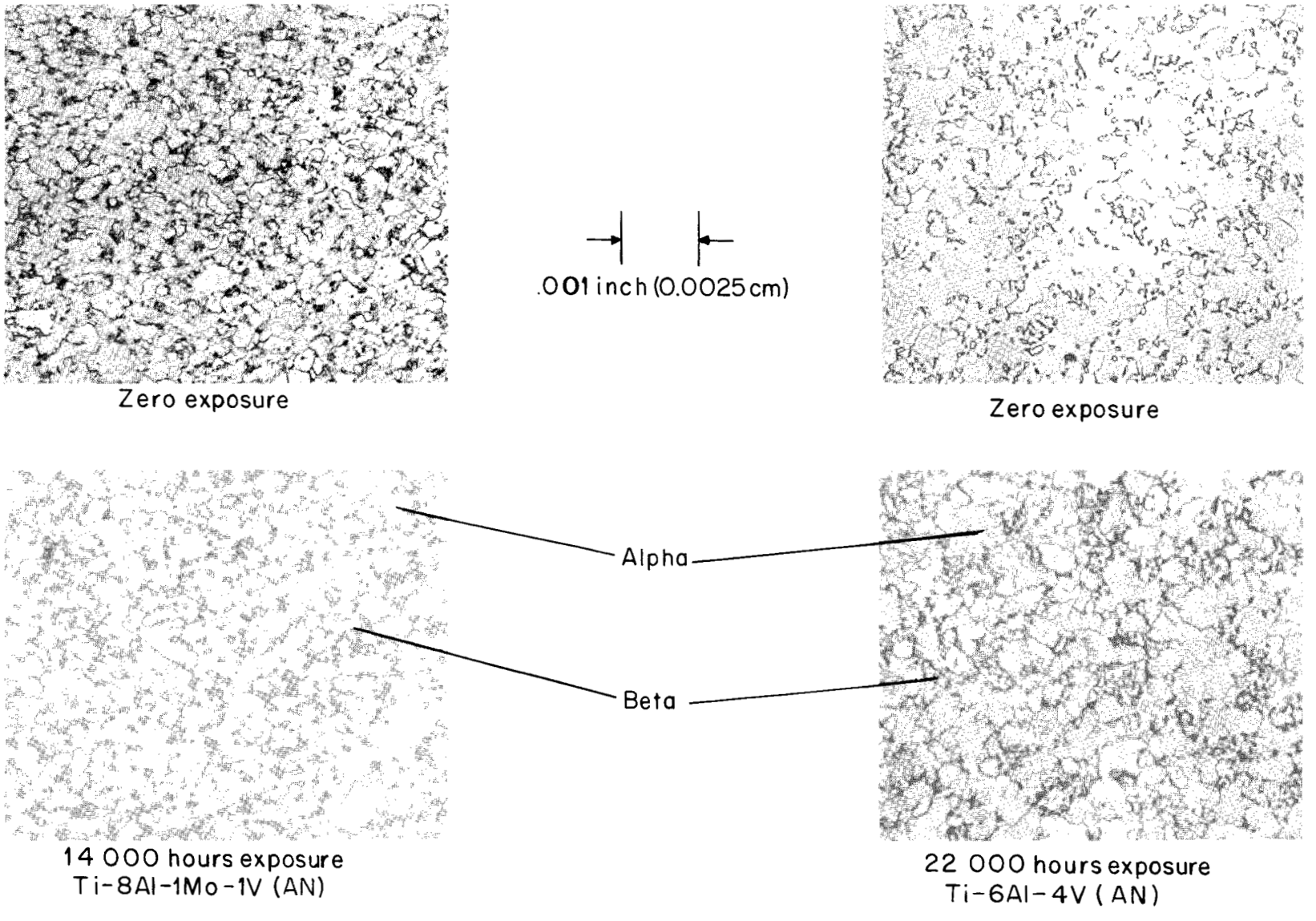


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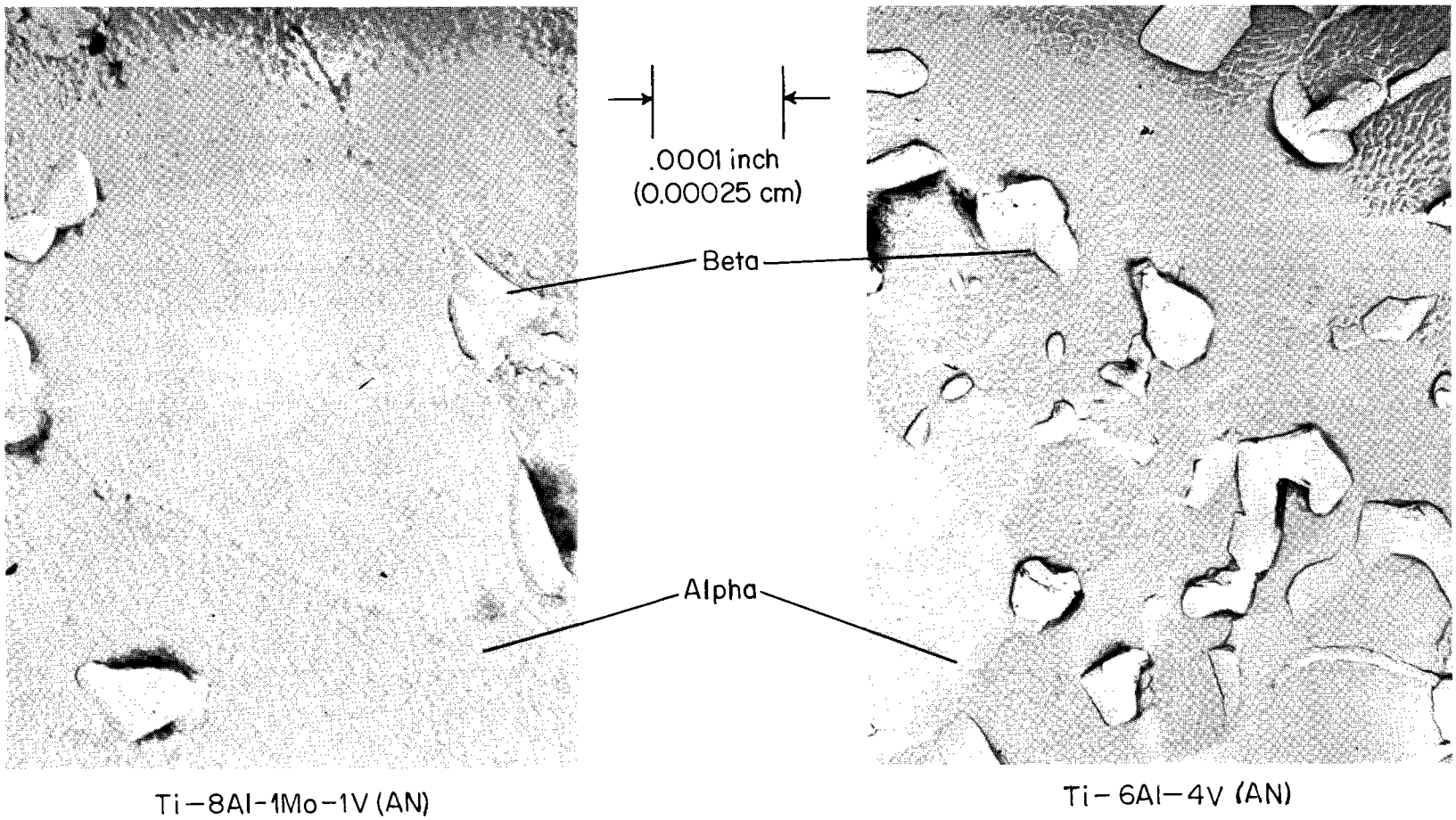
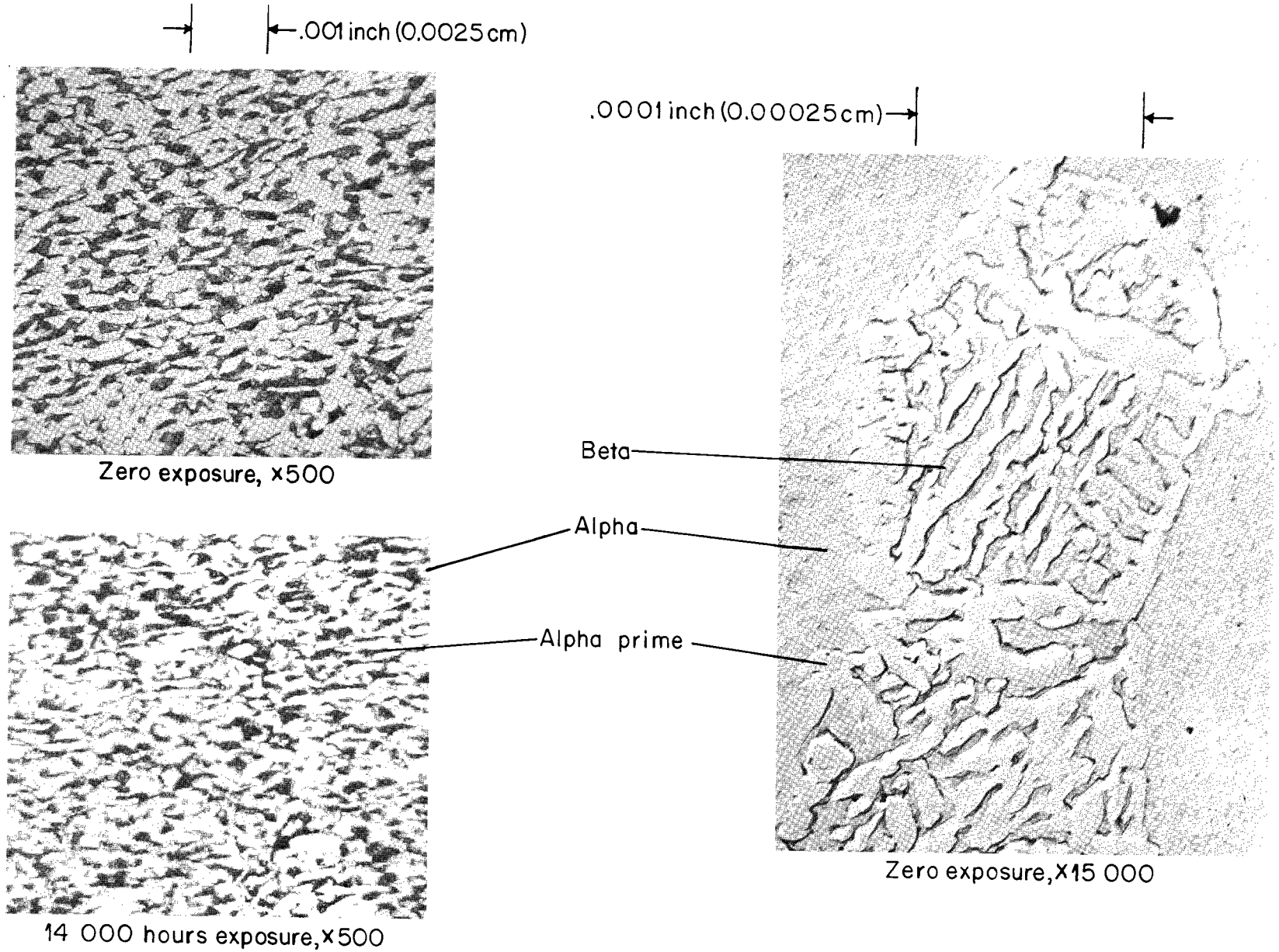
Figure 14.- Micrographs of Ti-8Al-1Mo-1V (AN) and Ti-6Al-4V (AN) sheet before and after exposure at 550° F (561° K). ×500.



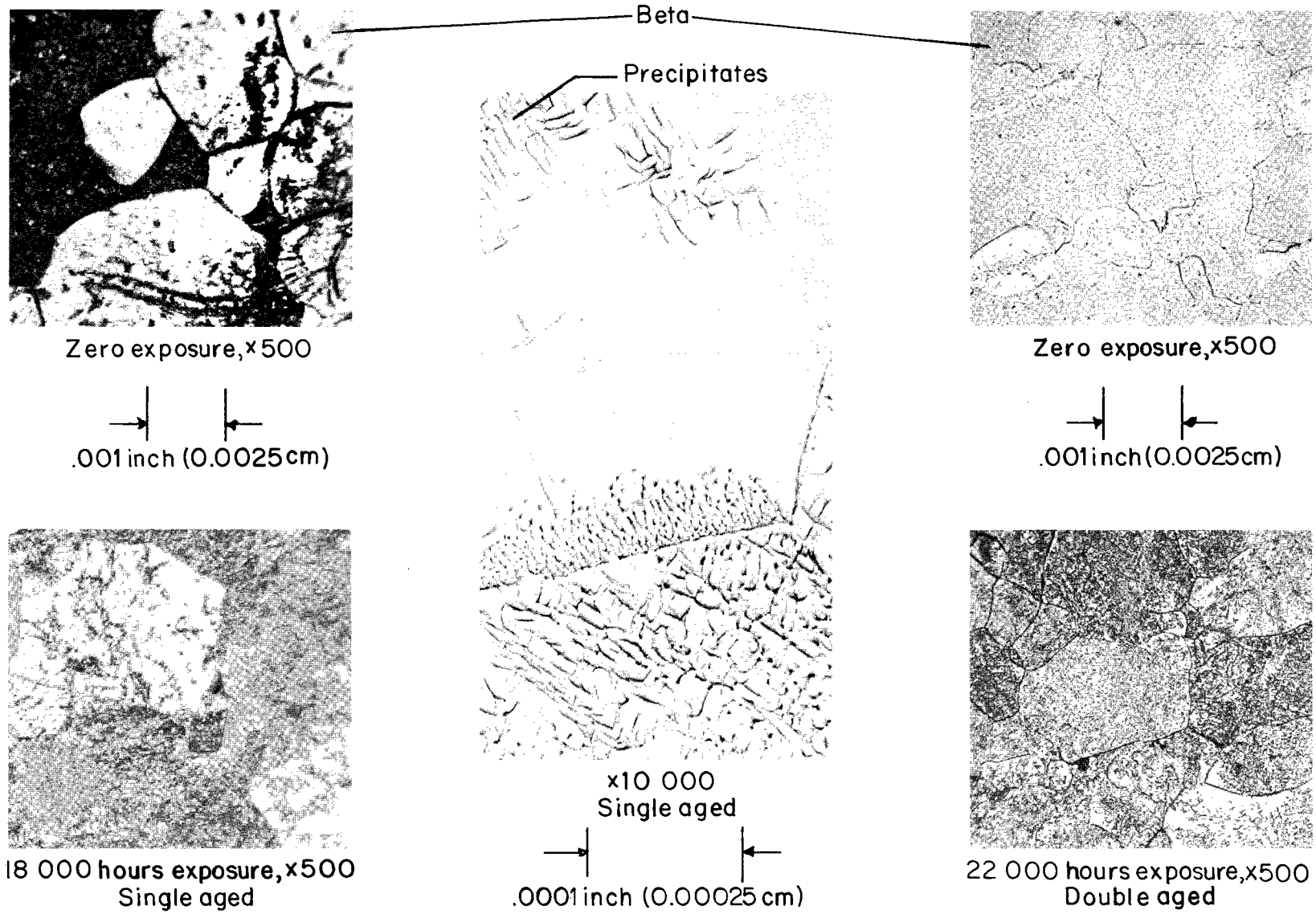
L-64-8385

Figure 15.- Micrographs of Ti-8Al-1Mo-1V (AN) and Ti-6Al-4V (AN) sheet before exposure. ×7500.



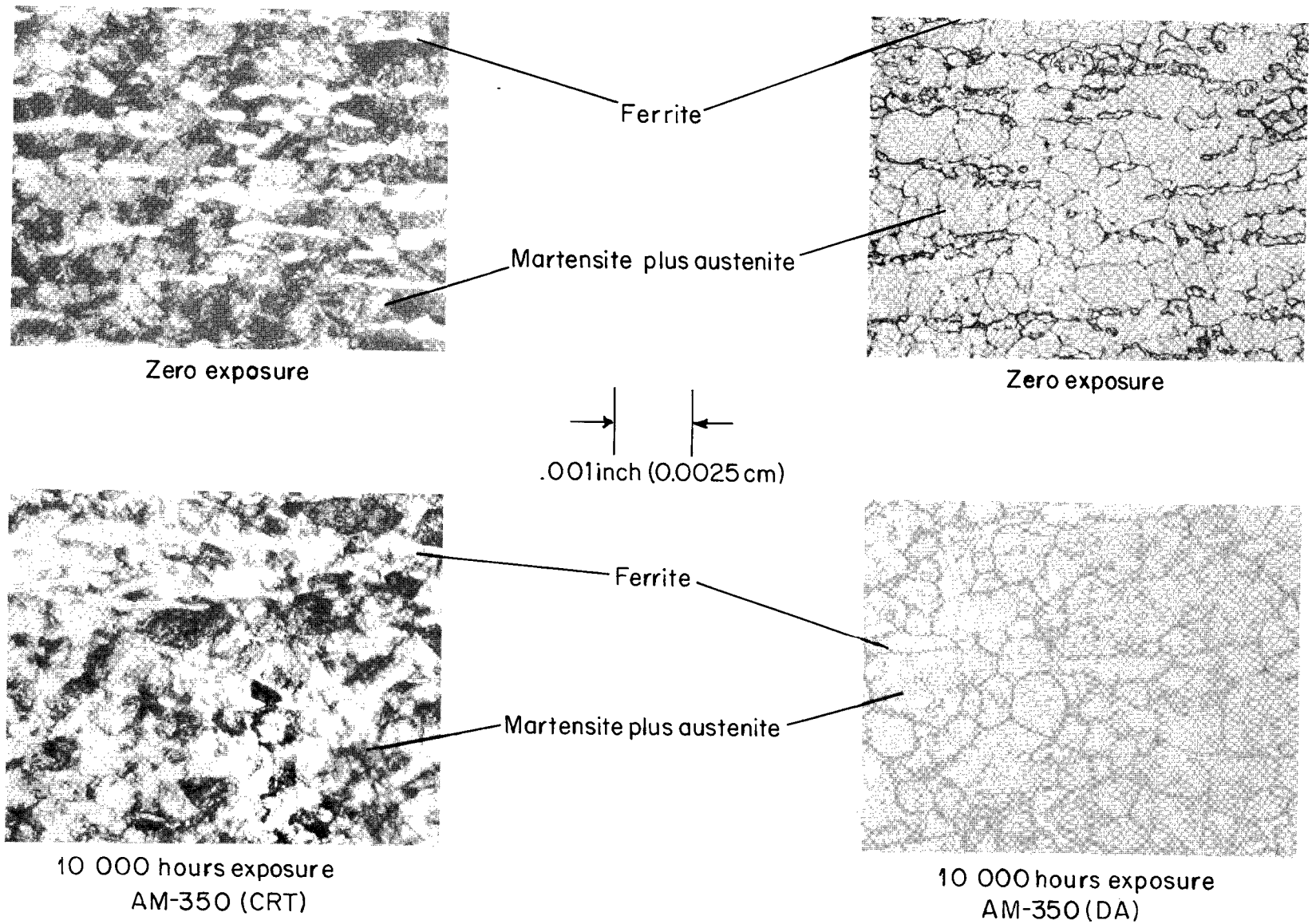
L-64-8386

Figure 16.- Micrographs of Ti-4Al-3Mo-1V (STA) sheet before and after exposure at 550° F (561° K).



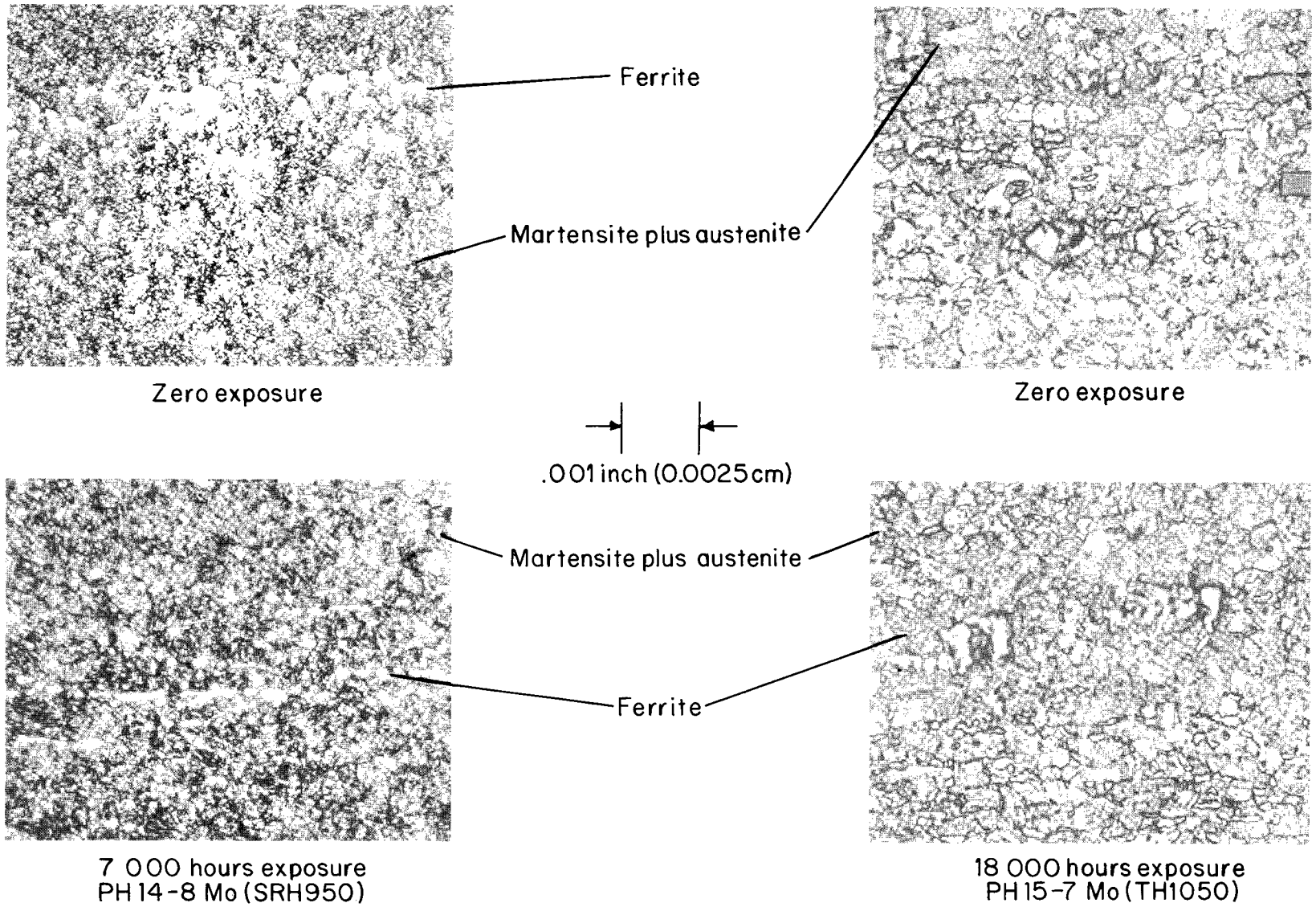
L-64-8387

Figure 17.- Micrographs of single- and double-aged Ti-13V-11Cr-3Al before and after exposure at 550° F (561° K).



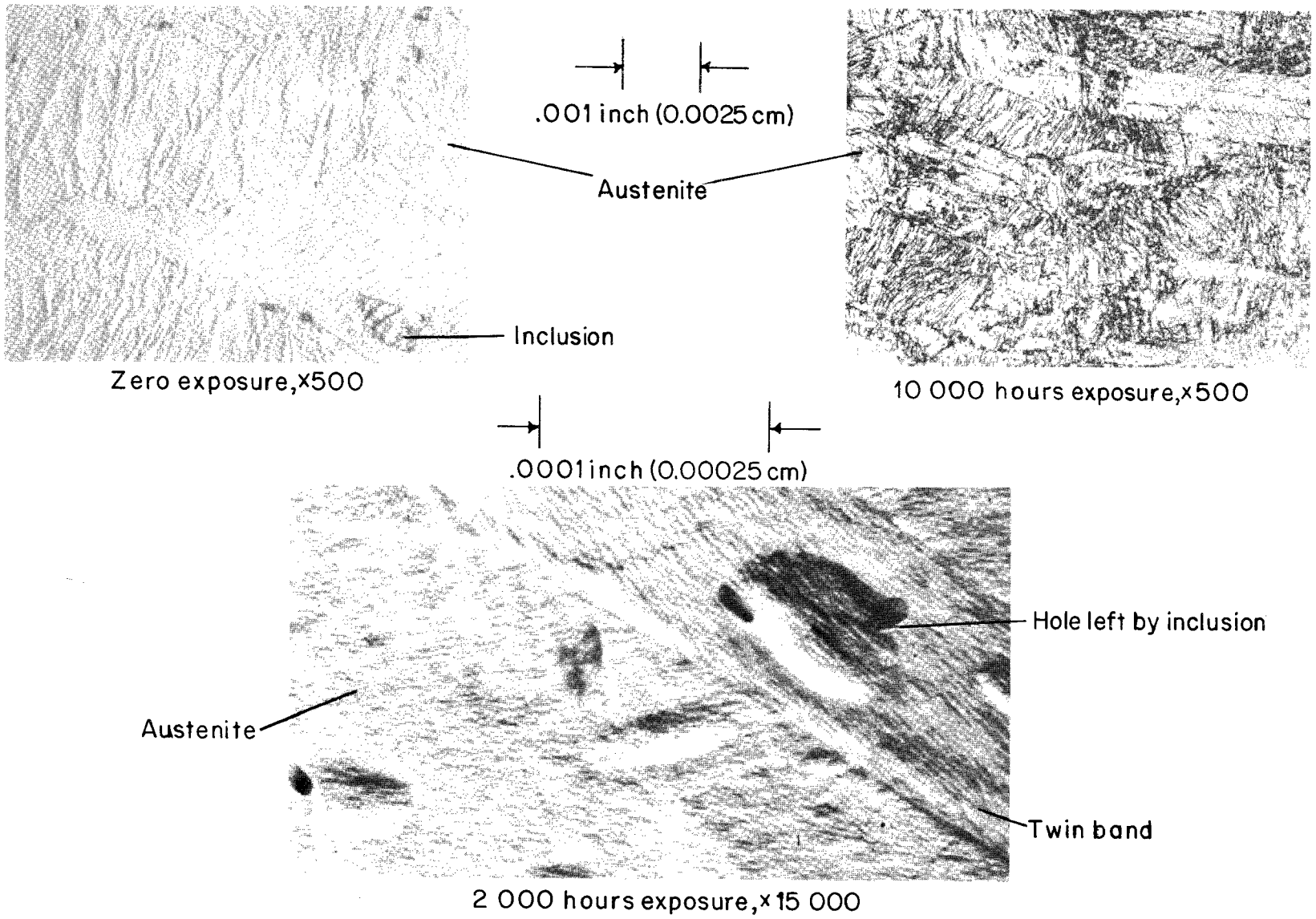
L-64-8388

Figure 18.- Micrographs of AM-350 (CRT) and AM-350 (DA) before and after exposure at 550° F (561° K). ×500.



L-64-8389

Figure 19.- Micrographs of PH 14-8 Mo (SRH 950) and PH 15-7 Mo (TH1050) before and after exposure at 550° F (561° K). ×500.



L-64-8390

Figure 20.- Micrographs of AISI 301 (CR) before and after exposure at 550° F (561° K).

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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