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DEVELOPMENT OF A STABLE-BETA TITANIUM ALLOY

by

D. B. Hunter

TITANIUM METALS CORPORATION OF AMERICA

233 BROADWAY

NEW YORK 7, NEW YORK

Tenth Quarter Report

October 1 to December 31, 1964

Contract DA-30-069-ORD-3743  
New York Procurement District

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## DEVELOPMENT OF A STABLE BETA TITANIUM ALLOY

### ABSTRACT

Evaluation of ageable beta alloys Ti-17V-2Fe-2Co-3Al, Ti-17V-7.5Co-3Al and Ti-8Mo-8V-5Co-3Al continued with room and elevated temperature smooth and notched tensile tests, creep stability, oxidation and stress-corrosion tests. Ti-17V-7.5Co-3Al aged more rapidly than Ti-8Mo-8V-5Co-3Al; after aging for 8 hours at 900F, Ti-17V-7.5Co-3Al had a yield strength of 198,000 psi, whereas that of Ti-8Mo-8V-5Co-3Al was only 158,000 psi. In smooth and notched tensile tests at 600F, Ti-17V-7.5Co-3Al displayed more strength than Ti-8Mo-8V-5Co-3Al because of its faster aging response in a given time. However, in creep stability tests and oxidation tests, Ti-8Mo-8V-5Co-3Al was the better alloy. Stress corrosion tests performed upon all five ageable beta alloys developed in this project showed that, in the annealed condition, Ti-8Mo-8V-2Fe-3Al was the most resistant to stress corrosion and Ti-17V-7.5Co-3Al and Ti-8Mo-8V-5Co-3Al the most susceptible. *Keywords: Titanium Alloys;*

*Vanadium. Cobalt. Aluminum. Molybdenum; Stress*



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## INTRODUCTION

The original object of this contract was to develop stable-beta titanium alloys capable of being hardened to useful combinations of strength and ductility. However, work has indicated that while hardening could be achieved by addition of sparingly soluble elements, such as Si, the high solution temperatures necessary to dissolve the compound present in such alloys produced a large grain size and low ductility. At the end of the first year's effort, the scope of the contract was expanded to include two other types of alloy: a non-hardening stable-beta alloy and a conventional metastable beta alloy hardening by alpha precipitation. However, work during the second year showed that the two stable-beta alloys selected for further investigation could not be welded, and they were replaced by two "stabilized" alloys, Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al.

This report details certain Phase III tests by which the candidate alloys for Phase IV were evaluated. These included room temperature and 600F smooth and notched tensile tests, hardness, creep, oxidation and stress-corrosion tests.

## MATERIALS AND PROCEDURES

Procedures used for tensile, hardness, creep, oxidation and stress-corrosion testing are identical to those described in previous reports. (1-9)

## RESULTS AND DISCUSSION

### Age Hardening Response of Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al

To determine the aging response of Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al, samples were solution treated for 10

minutes at 1500F, quenched, then aged at 800-950F for up to 24 hours. Vickers hardness readings were taken on the samples; results are given in Tables I and II.

These show that at all aging temperatures employed, Ti-17V-7.5Co-3Al had the faster aging response, with almost a 100-point hardness increase after 8 hours at 900F. For a similar aging time Ti-8Mo-8V-5Co-3Al had only a slight hardness increase.

#### Room Temperature Tensile Tests

To determine the relative room temperature mechanical properties of Ti-8Mo-5Co-3Al and Ti-17V-7.5Co-3Al, samples of each alloy were prepared for testing in various conditions of heat treatment. A uniform solution treatment of 1500F for 10 minutes was employed, terminated by water quenching. Samples were then aged at temperatures of 800-1000F for times up to 24 hours. Results are given in Tables III and IV, and plots of UTS against aging time for all aging temperatures are shown in Figures 1 and 2.

These tables and figures show that Ti-17V-7.5Co-3Al had the faster aging response at all aging temperatures employed. After aging for 8 hours at 900F, this alloy had an ultimate tensile strength of over 200,000 psi with a yield strength of 197,000 psi. Given the same aging treatment, Ti-8Mo-8V-5Co-3Al had an ultimate tensile strength of only 160,000 psi with a yield strength of 158,000 psi. This difference in aging response may be attributed to the greater beta stabilizing power of Mo in Ti-8Mo-8V-5Co-3Al. However, neither of these alloys confirmed previous indications of combining high strength with good ductility.<sup>(8)</sup> With yield strengths of 200,000 psi or more, uniform elongation was 0-3%, and total elongations ranged from 1-4%. Ti-17V-7.5Co-3Al seemed especially prone to breakage outside the gage length. Inspection of broken specimens eliminated variation of sheet thickness as a prime cause of this behavior. Microexamination was not helpful in providing an explanation.

To enable strength estimates to be made from hardness measurements on these alloys, statistical correlations between Vickers hardness values and ultimate tensile strengths were

determined. Vickers hardness readings were obtained on 36 broken tensile samples of each alloy; to insure accuracy, only tensile samples showing a yield stress and ultimate tensile strength were used in the correlation. For the purpose of the statistical calculations, Vickers hardness was plotted as the independent variable and ultimate tensile strength as the dependent variable, and a linear regression line assumed and plotted for each set of results. The method of calculation is given by Brownlee.<sup>(10)</sup> For Ti-8Mo-8V-5Co-3Al the relationship between Vickers hardness and ultimate tensile strength was expressed by the following equation:

$$UTS, \text{psi} = (\text{Vickers Hardness} \times 600) - 50,000,$$
and for Ti-17V-7.5Co-3Al:

$$UTS, \text{psi} = (\text{Vickers Hardness} \times 585) - 51,500.$$

The slopes of these plots are practically identical, Figures 3 and 4, and similar to the slopes previously obtained on other alloys.<sup>(8,9)</sup>

Confidence limits of 95% were also plotted on Figures 3 and 4; the degree of scatter was somewhat less with Ti-8Mo-8V-5Co-3Al.

600F Tensile Properties of Ti-17V-2Fe-2Co-3Al,  
Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al

To determine the elevated temperature properties of these three alloys, samples were tensile tested at 600F after solution treatment at 1500F and aging for 8 or 24 hours at 900F. Results are listed in Table V, and a comparison of the room temperature yield strengths and 600F yield strengths is given in Table VI. This shows the percentage of room temperature yield strength retained at 600F. Two other ageable beta alloys previously reported, Ti-17V-4Fe-3Al and Ti-8Mo-8V-2Fe-3Al are included for comparison.

Table VI indicates that the alloy retaining most strength at 600F was Ti-17V-7.5Co-3Al, and the least, Ti-8Mo-8V-5Co-3Al. Percentages of strength retained varied from 73-88%, depending upon the alloy and heat treatment condition.

### Creep Stability Tests

Following the 600F tensile tests of Ti-17V-2Fe-2Co-3Al, Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al, samples of these alloys were subjected to creep tests. Specimens were solution treated for 10 minutes at 1500F, quenched, then aged for either 8 or 24 hours at 900F. Exposure times of 150 hours at temperatures of 600F were used; loads of 90% of the yield stress at 600F were employed. Results are listed in Table VII.

These show that in both aged conditions Ti-8Mo-8V-5Co-3Al had the least amount of deformation, and Ti-17V-2Fe-2Co-3Al the most. Subsequent room temperature tensile tests indicated that both Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al tended to break in the head, outside the gage length. Metallographic examination revealed that cracks existed around similar areas of intact tensile samples.

### Room Temperature and 600F Notch Tensile Tests

Notch tensile tests at room temperature and 600F were performed on Ti-17V-2Fe-2Co-3Al, Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al using samples having a notch configuration of  $K_t=8$  as shown in Figure 5. Samples were solution treated for 10 minutes at 1500F, then aged for both 8 and 24 hours at 900F. Results are detailed in Table VIII.

In room temperature tensile tests, both Ti-17V-2Fe-2Co-3Al and Ti-8Mo-8V-5Co-3Al had higher values after aging for 24 hours, whereas Ti-17V-7.5Co-3Al showed a decline in notch tensile strengths after 24 hours aging. However, Ti-8Mo-8V-5Co-3Al had inferior notch tensile strengths, by comparison with the two other alloys, in both aged conditions.

Notch tensile tests at 600F indicated that there was little difference between Ti-17V-2Fe-2Co-3Al and Ti-8Mo-8V-5Co-3Al, whereas Ti-17V-7.5Co-3Al displayed somewhat lower strengths in both conditions of aging.

Room temperature ratios of notch tensile strength to ultimate tensile strength were relatively low, being between 0.48 - 0.6; at 600F the ratios were higher, being between 0.74 - 1.10.

### Oxidation Tests on Ageable Beta Alloys

To determine their relative resistance to oxidation, samples of Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al were subjected to exposure for 2 hours at 1500F. Details of the method used are the same as those previously described.<sup>(9)</sup> Results are given in Table IX. These indicate that Ti-8Mo-8V-5Co-3Al had the lower weight gain of the two alloys, with an average increase of only 0.0041 gms/sq.cm. of surface area after 2 hours at 1500F. As this result is comparable to that of Ti-8Mo-8V-2Fe-3Al, previously obtained, it appears that the presence of Mo in the alloy reduces the weight gain. To what extent, if any, MoO<sub>3</sub> is volatilized and lost during these tests is not known.

### Stress-Corrosion Tests

Stress -corrosion tests were carried out upon five ageable beta alloys, developed in this project, in the solution treated condition. Samples were solution treated for 10 minutes at 1500F and then air cooled, and stressed by bending them to a 2T radius. Samples were then coated with salt and exposed for 2 hours at 800F in the manner previously described.<sup>(9)</sup> For comparison purposes, the commercial ageable beta alloy Ti-13V-11Cr-3Al was included in these tests. All salt-coated samples broke upon reverse bending until flat. As the 2T bend may have been too severe, fresh tests as above were performed using samples bent to a 6T radius. This time, control samples were employed in the unexposed state, and also exposed for the same length of time without a salt coating. Results, given in Table X, indicate that under these conditions the best alloy was Ti-8Mo-8V-2Fe-3Al, with Ti-17V-4Fe-3Al a close second. The two alloys most susceptible to stress corrosion under these conditions appeared to be Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al.

### CONCLUSIONS

1. Hardness and room temperature tensile tests showed that Ti-17V-7.5Co-3Al had a faster aging response than did



Ti-8Mo-8V-5Co-3Al. After aging for 8 hours at 900F, the ultimate and yield strengths of Ti-17V-7.5Co-3Al were 206,000 and 197,000 psi respectively, whereas those of Ti-8Mo-8V-5Co-3Al were only 160,000 and 158,000 psi respectively.

2. Tensile tests at 600F on Ti-17V-2Fe-2Co-3Al, Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al indicated that, because of its faster aging response, the latter alloy had the higher tensile strength, especially after the 8 hour age at 900F.
3. Creep stability tests of 150 hours on the same three alloys indicated that Ti-8Mo-8V-5Co-3Al had the lowest amount of deformation. Subsequent room temperature tensile tests suggested that both Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al became notch sensitive.
4. Room temperature notch tensile tests on the above three alloys showed that Ti-8Mo-8V-5Co-3Al had the lowest notch tensile strengths after aging for either 8 or 24 hours at 900F; NTS/UTS ratios were low. In 600F notch tensile tests, Ti-17V-7.5Co-3Al had the lowest strengths in both conditions of aging.
5. Oxidation tests on Ti-17V-7.5Co-3Al and Ti-8Mo-8V-5Co-3Al indicated that the latter alloy had the lowest weight gain after exposure.
6. Stress-corrosion tests performed on the five ageable beta alloys under consideration suggested that, in the annealed condition and under the test conditions, Ti-8Mo-8V-2Fe-3Al was most resistant to stress corrosion and Ti-8Mo-8V-5Co-3Al and Ti-17V-7.5Co-3Al were the most susceptible.

#### REFERENCES

1. Rosenberg, H. W., "Development of a Stable-Beta Alloy," First Quarter Report, Contract DA-30-069-ORD-3743.
2. Hunter, D. B., "Development of a Stable-Beta Alloy," Second Quarter Report, Contract DA-30-069-ORD-3743.

3. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Third Quarter Report, Contract DA-30-069-ORD-3743.
4. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Fourth Quarter Report, Contract DA-30-069-ORD-3743.
5. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Fifth Quarter Report, Contract DA-30-069-ORD-3743.
6. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Sixth Quarter Report, Contract DA-30-069-ORD-3743.
7. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Seventh Quarter Report, Contract DA-30-069-ORD-3743.
8. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Eighth Quarter Report, Contract DA-30-096-ORD-3743.
9. Hunter, D. B., "Development of a Stable-Beta Alloy,"  
Ninth Quarter Report, Contract DA-30-069-ORD-3743.
10. Brownlee, K. A., "Industrial Experimentation," Chapter IX  
Chemical Publishing Co., Inc., 1953.

TABLE I

## AGE HARDENING RESPONSE FOR T1-17V-7.5Co-3Al

| Ingot No. | Alloy            | Solution Treatment | Aging Time, Hours | Vickers Hardness at Given Aging Temperature, $H_V$ |     |     |     |     |
|-----------|------------------|--------------------|-------------------|----------------------------------------------------|-----|-----|-----|-----|
|           |                  |                    |                   | 0                                                  | 800 | 850 | 900 | 950 |
| V-2920    | T1-17V-7.5Co-3Al | 1500F(10min)WQ     | 0                 | 340                                                |     |     |     |     |
| "         | "                | "                  | 1                 |                                                    | 340 | 344 | 353 | 362 |
| "         | "                | "                  | 2                 |                                                    | 343 | 353 | 383 | 396 |
| "         | "                | "                  | 4                 |                                                    | 351 | 412 | 416 | 405 |
| "         | "                | "                  | 8                 |                                                    | 417 | 426 | 433 | 433 |
| "         | "                | "                  | 16                |                                                    | 459 | 449 | 452 | 446 |
| "         | "                | "                  | 24                |                                                    | 411 | 464 | 455 | 429 |

TABLE II

## AGE HARDENING RESPONSE FOR T1-8Mo-8V-5Co-3Al

| Ingot No. | Alloy             | Solution Treatment | Aging Time, Hours | Vickers Hardness at Given Aging Temperature, $H_V$ |     |     |     |     |
|-----------|-------------------|--------------------|-------------------|----------------------------------------------------|-----|-----|-----|-----|
|           |                   |                    |                   | 0                                                  | 800 | 850 | 900 | 950 |
| V-2900    | T1-8Mo-8V-5Co-3Al | 1500F(10min)WQ     | 0                 | 344                                                |     |     |     |     |
| "         | "                 | "                  | 1                 |                                                    | 346 | 335 | 329 | 331 |
| "         | "                 | "                  | 2                 |                                                    | 334 | 335 | 330 | 328 |
| "         | "                 | "                  | 4                 |                                                    | 337 | 337 | 336 | 332 |
| "         | "                 | "                  | 8                 |                                                    | 343 | 351 | 353 | 357 |
| "         | "                 | "                  | 16                |                                                    | 374 | 388 | 391 | 371 |
| "         | "                 | "                  | 24                |                                                    | 373 | 404 | 401 | 426 |

TABLE III

TENSILE PROPERTIES OF T1-8Mo-8V-5Co-3Al, INGOT NO. V-2900

| Heat Treatment               | UTS<br>Ksi | YS<br>Ksi | % Elongation |                        | Modulus<br>x 10 <sup>-6</sup> |
|------------------------------|------------|-----------|--------------|------------------------|-------------------------------|
|                              |            |           | Local        | Uniform<br>in 2 inches |                               |
| 1500F(10min)WQ               | 134        | 132       | 60           | 15.0                   | 12.2                          |
| "                            | 136        | 134       | 60           | 16.25                  | 12.0                          |
| 1500F(10min)WQ+800F(1hr)AC   | 152        | 150       | 60           | 2.5                    | 13.8                          |
| "                            | 148        | 147       | 65           | 2.5                    | 13.2                          |
| 1500F(10min)WQ+800F(8hrs)AC  | 141        | 139       | 50           | 11.25                  | 12.8                          |
| "                            | 139        | 136       | 50           | 11.25                  | 12.4 (1)                      |
| 1500F(10min)WQ+800F(16hrs)AC | 168        | 161       | 5            | 1.25                   | 13.8 (1)                      |
| "                            | 165        | 153       | 30           | 3.75                   | 12.9                          |
| 1500F(10min)WQ+800F(24hrs)AC | 187        | 172       | 20           | 1.25                   | 13.8                          |
| "                            | 183        | 176       | 30           | 1.25                   | 13.9                          |
| 1500F(10min)WQ+850F(1hr)AC   | 144        | 144       | 50           | 0                      | 12.8                          |
| "                            | 151        | 151       | 45           | 3.75                   | 13.5                          |
| 1500F(10min)WQ+850F(4hrs)AC  | 151        | 150       | 30           | 7.5                    | 13.5 (1)                      |
| "                            | 155        | 154       | 50           | 6.25                   | 13.9                          |
| 1500F(10min)WQ+850F(16hrs)AC | 184        | 175       | 20           | 6.25                   | 14.0                          |
| "                            | 185        | 176       | 15           | 3.75                   | 13.9                          |
| 1500F(10min)WQ+850F(24hrs)AC | 226        | 218       | 5            | 0                      | 15.3 (2)                      |
| "                            | ---        | ---       | ---          | ---                    | 14.7 (2)                      |
| 1500F(10min)WQ+900F(1hr)AC   | 145        | 144       | 50           | 1.25                   | 13.4                          |
| 1500F(10min)WQ+900F(4hrs)AC  | 149        | 148       | 40           | 11.25                  | 12.9                          |
| "                            | 149        | 147       | 50           | 10.0                   | 13.0                          |
| 1500F(10min)WQ+900F(8hrs)AC  | 161        | 160       | 25           | 1.25                   | 13.1                          |

(1) Sample broke outside gage length.

(2) Sample broke in head test finished in file grips.

TABLE III (continued)

| Heat Treatment                | UTS<br>Ksi | YS<br>Ksi | Local | % Elongation |             | Modulus<br>x 10 <sup>-6</sup> |
|-------------------------------|------------|-----------|-------|--------------|-------------|-------------------------------|
|                               |            |           |       | Uniform      | in 2 inches |                               |
| 1500F(10min)WQ+900F(8hrs)AC   | 160        | 156       | 15    | 7.5          | 11.0        | 13.7                          |
| 1500F(10min)WQ+900F(12hrs)AC  | 176        | 166       | 20    | 5.0          | 7           | 13.7                          |
| "                             | 172        | 167       | 10    | 1.25         | 4           | 13.8                          |
| 1500F(10min)WQ+900F(16hrs)AC  | 192        | 180       | 10    | 1.25         | 3           | 14.7                          |
| "                             | 178        | 172       | 10    | 0            | 3           | 14.0                          |
| 1500F(10min)WQ+900F(24hrs)AC  | 216        | 203       | 10    | 1.25         | 2.5         | 15.6(2)                       |
| "                             | ---        | ---       | --    | ----         | ----        | 15.3(1)                       |
| 1500F(10min)WQ+950F(1hr)AC    | 147        | 146       | 45    | 0            | 3.5         | 13.4                          |
| "                             | 147        | 146       | 40    | 0            | 7           | 13.4                          |
| 1500F(10min)WQ+950F(2hrs)AC   | 147        | 146       | 30    | 5.0          | 9.5         | 13.3                          |
| "                             | 153        | 151       | 45    | 15.0         | 21.5        | 13.4                          |
| 1500F(10min)WQ+950F(4hrs)AC   | 155        | 153       | 30    | 8.75         | 15.5        | 13.8                          |
| "                             | 156        | 155       | 5     | 6.25         | 7.5         | 13.7                          |
| 1500F(10min)WQ+950F(8hrs)AC   | 179        | 169       | --    | ----         | ----        | 14.6(1)                       |
| "                             | 175        | 172       | 10    | 1.25         | 4           | 14.3                          |
| 1500F(10min)WQ+950F(16hrs)AC  | 201        | 189       | 20    | 5.0          | 9.5         | 15.5                          |
| "                             | 186        | 175       | 15    | 2.5          | 6           | 14.4(1)                       |
| 1500F(10min)WQ+950F(24hrs)AC  | 205        | 192       | 5     | 0            | 1           | 15.7                          |
| "                             | ---        | ---       | --    | ----         | ----        | 15.3(1)                       |
| 1500F(10min)WQ+1000F(1hr)AC   | 153        | 151       | 30    | 11.25        | 16          | 13.9                          |
| "                             | 147        | 147       | 20    | 0            | 6           | 13.6(1)                       |
| 1500F(10min)WQ+1000F(2hrs)AC  | 153        | 151       | 25    | 3.75         | 12          | 13.8                          |
| "                             | 153        | 150       | 20    | 2.5          | 7.5         | 13.8                          |
| 1500F(10min)WQ+1000F(4hrs)AC  | 157        | 154       | 20    | 3.75         | 8.5         | 14.0                          |
| "                             | 154        | 146       | 25    | 11.25        | 16          | 13.4                          |
| 1500F(10min)WQ+1000F(8hrs)AC  | 179        | 167       | 20    | 7.5          | 9.5         | 14.5                          |
| "                             | 181        | 170       | 35    | 7.5          | 13          | 14.9                          |
| 1500F(10min)WQ+1000F(12hrs)AC | 187        | 179       | 30    | 1.25         | 6.5         | 15.3(1)                       |
| "                             | 185        | 175       | 30    | 5.0          | 11          | 15.1                          |
| 1500F(10min)WQ+1000F(16hrs)AC | 198        | ---       | --    | ----         | ----        | 16.3(1)                       |
| "                             | 197        | 189       | 25    | 0            | 5           | 14.9(2)                       |

(1) Sample broke outside gage length.

(2) Sample broke in head, test finished in file grips.

TABLE IV

TENSILE PROPERTIES OF T1-17V-7.5Co-3Al, INGOT NO. V-2920

| Heat Treatment               | UTS<br>Ksi | YS<br>Ksi | % Elongation |                        | Modulus<br>x 10 <sup>-6</sup> |
|------------------------------|------------|-----------|--------------|------------------------|-------------------------------|
|                              |            |           | Local        | Uniform<br>in 2 inches |                               |
| 1500F(10min)WQ               | 149        | 147       | 30           | 1.25                   | 12.7(1)                       |
| "                            | 151        | 148       | 55           | 13.75                  | 13.0                          |
| 1500F(10min)WQ+800F(1hr)AC   | 154        | 153       | 5            | 0                      | 13.3(1,2)                     |
| "                            | 153        | 151       | 20           | 1.25                   | 13.2(1)                       |
| 1500F(10min)WQ+800F(8hrs)AC  | 192        | 179       | 10           | 1.25                   | 13.8(2)                       |
| "                            | 193        | 182       | 10           | 1.25                   | 13.9(1)                       |
| 1500F(10min)WQ+800F(16hrs)AC | 214        | 211       | --           | ----                   | 15.1(1,3)                     |
| "                            | 224        | 214       | 5            | 1.25                   | 15.0(2,3)                     |
| 1500F(10min)WQ+800F(24hrs)AC | 227        | 223       | 5            | 0                      | 15.3(1,3)                     |
| "                            | 222        | 218       | 5            | 0                      | 15.1(1)(3)                    |
| 1500F(10min)WQ+850F(1hr)AC   | 152        | 149       | 50           | 13.75                  | 13.2                          |
| "                            | 152        | 148       | 40           | 5.0                    | 13.5(1)                       |
| 1500F(10min)WQ+850F(4hrs)AC  | 174        | 172       | 10           | 0                      | 13.9(1,2)                     |
| "                            | 172        | 168       | 10           | 0                      | 13.9(1)                       |
| 1500F(10min)WQ+850F(8hrs)AC  | 184        | 181       | 20           | 0                      | 14.2(1)                       |
| "                            | 187        | 180       | 20           | 0                      | 14.5(1)                       |
| 1500F(10min)WQ+850F(16hrs)AC | 207        | 201       | 5            | 0                      | 14.9(2)                       |
| "                            | 206        | 200       | 20           | 0                      | 12.3(1,2)                     |
| 1500F(10min)WQ+850F(24hrs)AC | 229        | 217       | 10           | 1.25                   | 15.2(1)                       |
| "                            | 220        | 215       | --           | ----                   | 14.7(1,2)                     |
| 1500F(10min)WQ+900F(1hr)AC   | 152        | 148       | 20           | 7.5                    | 13.4                          |
| "                            | 155        | 153       | 20           | 0                      | 13.3(1)                       |
| 1500F(10min)WQ+900F(2hrs)AC  | 176        | 172       | 20           | 0                      | 14.2(1)                       |
| "                            | 177        | 171       | 20           | 0                      | 13.7(1)                       |
| 1500F(10min)WQ+900F(4hrs)AC  | 189        | 180       | 5            | 1.25                   | 14.1                          |
| "                            | 193        | 183       | 5            | 1.25                   | 14.6(1)                       |
| 1500F(10min)WQ+900F(6hrs)AC  | 193        | 186       | 20           | 1.25                   | 14.6                          |
| "                            | 198        | 187       | 10           | 2.5                    | 14.2(1)                       |
| 1500F(10min)WQ+900F(8hrs)AC  | 210        | 199       | 5            | 1.25                   | 14.9(2)                       |
| "                            | 202        | 197       | 5            | 0                      | 14.5(1,2)                     |

(1) Sample broke outside gage length.

(2) Sample broke in head, test finished in file grips.

(3) Five other samples given the same heat treatment, broke before reaching yield stress.

TABLE IV (continued)

| Heat Treatment                | UTS<br>Ksi | YS<br>Ksi | % Elongation |         | in 2 inches | Modulus<br>x 10 <sup>-6</sup> |
|-------------------------------|------------|-----------|--------------|---------|-------------|-------------------------------|
|                               |            |           | Local        | Uniform |             |                               |
| 1500F(10min)WQ+900F(16hrs)AC  | 213        | 203       | 5            | 1.25    | 2           | 14.9                          |
| "                             | 227        | 216       | 10           | 0       | 3           | 15.3(2)                       |
| 1500F(10min)WQ+900F(24hrs)AC  | 220        | 207       | 10           | 3.75    | 4.5         | 15.4(1,2)                     |
| "                             | 218        | 207       | 5            | 1.25    | 3           | 15.2(2)                       |
| 1500F(10min)WQ+950F(1hr)AC    | 149        | 146       | 20           | 1.25    | 8.5         | 13.3                          |
| "                             | 147        | 142       | 20           | 10.0    | 11.5        | 13.2(2)                       |
| 1500F(10min)WQ+950F(2hrs)AC   | 167        | 166       | --           | ----    | ----        | 14.0(2)                       |
| "                             | 168        | 162       | 5            | 1.25    | 4           | 14.2                          |
| 1500F(10min)WQ+950F(4hrs)AC   | 168        | 160       | 20           | 3.75    | 8.5         | 13.9                          |
| "                             | 167        | 161       | 5            | 1.25    | 1.5         | 13.7(1)                       |
| 1500F(10min)WQ+950F(6hrs)AC   | 190        | 181       | 5            | 1.25    | 2           | 14.6(2)                       |
| "                             | 170        | 164       | 5            | 0       | 1.5         | 14.3                          |
| 1500F(10min)WQ+950F(8hrs)AC   | 198        | 196       | 5            | 0       | 0           | 14.8(2)                       |
| "                             | 206        | 190       | 20           | 1.25    | 5           | 14.7                          |
| 1500F(10min)WQ+950F(16hrs)AC  | 213        | 198       | 10           | 0       | 3.5         | 14.9(2)                       |
| "                             | 212        | 199       | 10           | 1.25    | 4.5         | 15.0(2)                       |
| 1500F(10min)WQ+950F(24hrs)AC  | 195        | 182       | 15           | 3.75    | 8           | 14.3                          |
| "                             | 197        | 184       | 15           | 3.75    | 8           | 15.1                          |
| 1500F(10min)WQ+1000F(1hr)AC   | 162        | 162       | 5            | 0       | 2.5         | 13.4(1,2)                     |
| "                             | 157        | 153       | 5            | 0       | 0.5         | 13.6(1)                       |
| 1500F(10min)WQ+1000F(2hrs)AC  | 173        | 167       | 5            | 5.0     | 5           | 14.1(2)                       |
| "                             | 167        | 160       | 10           | 0       | 4           | 13.9(1)                       |
| 1500F(10min)WQ+1000F(4hrs)AC  | 189        | 176       | 10           | 5       | 6.5         | 12.1                          |
| "                             | 183        | 173       | 20           | 1.25    | 5           | 14.6(1)                       |
| 1500F(10min)WQ+1000F(8hrs)AC  | 190        | 179       | 5            | 1.25    | 3           | 15.1(2)                       |
| "                             | 189        | ---       | --           | ----    | ----        | 13.8(1,2)                     |
| 1500F(10min)WQ+1000F(16hrs)AC | 199        | 190       | 10           | 2.5     | 4           | 14.9(2)                       |
| "                             | ---        | ---       | --           | ----    | ----        | 14.5(1,2)                     |

(1) Sample broke outside gage length.

(2) Sample broke in head test finished in file grips.

(3) Five other samples given the same heat treatment, broke before reaching yield stress.

**TABLE V**  
**600F TENSILE PROPERTIES OF AGEABLE BETA ALLOYS**

| Heat Treatment                              | UTS<br>Ksi | YS<br>Ksi | % Elongation |         | in 1-inch | Modulus<br>x 10 <sup>6</sup> |
|---------------------------------------------|------------|-----------|--------------|---------|-----------|------------------------------|
|                                             |            |           | Local        | Uniform |           |                              |
| <u>Ti-17V-2Fe-2Co-3Al, Ingot No. V-2858</u> |            |           |              |         |           |                              |
| 1500F(10min)WQ+900F(8hrs)AC                 | 159        | 131       | 20           | 5.0     | 10        | 13.9                         |
| "                                           | 161        | 137       | 20           | 2.5     | 6         | 13.3                         |
| "                                           | 155        | 129       | 20           | 2.5     | 7         | 12.4                         |
| 1500F(10min)WQ+900F(24hrs)AC                | 193        | 173       | 10           | 0       | 4         | ----(1)                      |
| "                                           | 194        | 173       | 5            | 0       | 2         | 16.4                         |
| "                                           | 189        | ---       | 5            | 0       | 2         | ----(1)                      |
| "                                           | 191        | 168       | 5            | 2.5     | 3         | 16.0                         |
| <u>Ti-8Mo-8V-5Co-3Al, Ingot No. V-2900</u>  |            |           |              |         |           |                              |
| 1500F(10min)WQ+900F(8hrs)AC                 | 136        | 122       | 35           | 5.0     | 13        | 12.4                         |
| "                                           | 144        | 128       | 40           | 5.0     | 14        | 13.0                         |
| "                                           | 142        | 126       | 20           | 5.0     | 9         | 15.0                         |
| 1500F(10min)WQ+900F(24hrs)AC                | 185        | 153       | 20           | 2.5     | 8         | 16.3                         |
| "                                           | 184        | 160       | 20           | 2.5     | 8         | 14.2                         |
| "                                           | 175        | 153       | 40           | 5.0     | 14        | 11.7                         |
| <u>Ti-17V-7.5Co-3Al, Ingot No. V-2920</u>   |            |           |              |         |           |                              |
| 1500F(10min)WQ+900F(8hrs)AC                 | 186        | 162       | 10           | 2.5     | 6         | 13.3                         |
| "                                           | 192        | 172       | 10           | 2.5     | 4         | 13.7                         |
| "                                           | 181        | ---       | 10           | 2.5     | 4         | 14.6(1)                      |
| "                                           | 188        | ---       | 10           | 2.5     | 4         | 13.2(1)                      |
| "                                           | 191        | 168       | 10           | 2.5     | 4         | 14.2                         |
| 1500F(10min)WQ+900F(24hrs)AC                | 197        | 184       | 5            | 0       | 1         | 15.3                         |
| "                                           | 200        | 184       | 5            | 0       | 1         | 14.0                         |
| "                                           | 208        | 184       | 5            | 2.5     | 3         | 13.9                         |
| "                                           | 198        | 176       | 10           | 0       | 2         | 17.7                         |

(1) Extensometer slipped.



TABLE VI

PERCENTAGES OF ROOM TEMPERATURE YIELD STRENGTH RETAINED AT 600F, BY ALLOY AND HEAT TREATMENT

| Alloy              | Heat Treatment               | RT<br>Yield<br>Strength<br>psi | 600F<br>Yield<br>Strength<br>psi | % of<br>RT Yield Strength<br>Retained at 600F |
|--------------------|------------------------------|--------------------------------|----------------------------------|-----------------------------------------------|
| T1-17V-2Fe-2Co-3Al | 1500F(10min)WQ+900F(8hrs)AC  | 181,000                        | 132,000                          | 73                                            |
| "                  | 1500F(10min)WQ+900F(24hrs)AC | 203,000                        | 171,000                          | 84                                            |
| T1-8Mo-8V-5Co-3Al  | 1500F(10min)WQ+900F(8hrs)AC  | 158,000                        | 125,000                          | 79                                            |
| "                  | 1500F(10min)WQ+900F(24hrs)AC | 203,000                        | 155,000                          | 76                                            |
| T1-17V-7.5Co-3Al   | 1500F(10min)WQ+900F(8hrs)AC  | 198,000                        | 167,000                          | 84                                            |
| "                  | 1500F(10min)WQ+900F(24hrs)AC | 207,000                        | 182,000                          | 88                                            |
| T1-17V-4Fe-3Al     | 1500F(10min)WQ+900F(8hrs)AC  | 156,000                        | 120,000                          | 77                                            |
| "                  | 1500F(10min)WQ+900F(24hrs)AC | 184,000                        | 156,000                          | 85                                            |
| T1-8Mo-8V-2Fe-3Al  | 1500F(10min)WQ+900F(8hrs)AC  | 180,000                        | 142,000                          | 79                                            |
| "                  | 1500F(10min)WQ+900F(24hrs)AC | 191,000                        | 154,000                          | 81                                            |

TABLE VII

## CREEP STABILITY PROPERTIES OF THREE AGEABLE BETA ALLOYS

| Heat Treatment                                                      | Temp.<br>Of | Exposure      |               | UTS<br>Ksi | YS<br>Ksi | Subsequent Tensile Properties |                 |                               |
|---------------------------------------------------------------------|-------------|---------------|---------------|------------|-----------|-------------------------------|-----------------|-------------------------------|
|                                                                     |             | Stress<br>Ksi | Time<br>Hours |            |           | %<br>Def.                     | %<br>Elongation | Modulus<br>x 10 <sup>-6</sup> |
| Ti-17V-2Fe-2Co-3Al, Ingot No. V-2858<br>1500F(10min)AC+900F(8hrs)AC | ---         | ---           | ---           | ---        | ---       | ---                           | ---             | ---                           |
|                                                                     | 600         | 119           | 150           | 197        | 180       | 0.655                         | 3.75            | 14.9 (1)                      |
|                                                                     | "           | "             | "             | 199        | 179       | 0.971                         | 2.5             | 13.4 (1)                      |
|                                                                     | "           | "             | "             | 200        | 195       | 0.611                         | 0               | 14.3                          |
|                                                                     | ---         | ---           | ---           | 202        | 182       | ---                           | 0               | 15.1 (1)                      |
| 1500F(10min)AC+900F(24hrs)AC                                        | ---         | ---           | ---           | 220        | 204       | 0.582                         | 2.5             | 15.3                          |
|                                                                     | 600         | 154           | 150           | 213        | 210       | 0.560                         | 0               | 15.5                          |
|                                                                     | "           | "             | "             | 215        | 211       | 0.665                         | 5.0             | 15.3                          |
|                                                                     | "           | "             | "             | 208        | 207       | ---                           | 2.5             | 15.3                          |
|                                                                     | ---         | ---           | ---           | ---        | ---       | ---                           | ---             | ---                           |
| Ti-8Mo-8V-5Co-3Al, Ingot No. V-2900<br>1500F(10min)AC+900F(8hrs)AC  | ---         | ---           | ---           | 160        | 156       | 0.164                         | 7.5             | 13.7 (2)                      |
|                                                                     | 600         | 113           | 150           | 156        | 152       | 0.167                         | 2.5             | 13.8 (2)                      |
|                                                                     | "           | "             | "             | 156        | 152       | 0.160                         | 2.5             | 10.8 (2)                      |
|                                                                     | "           | "             | "             | 167        | 161       | ---                           | 2.5             | 13.8 (2)                      |
|                                                                     | ---         | ---           | ---           | 216        | 203       | 0.171                         | 1.25            | 15.6 (2)                      |
| 1500F(10min)AC+900F(24hrs)AC                                        | 600         | 140           | 150           | 186        | ---       | 0.182                         | ---             | 15.0 (1)                      |
|                                                                     | "           | "             | "             | ---        | ---       | 0.200                         | ---             | 14.6 (1)                      |
|                                                                     | "           | "             | "             | 193        | 190       | ---                           | 0               | 11.7 (2)                      |
|                                                                     | ---         | ---           | ---           | ---        | ---       | ---                           | ---             | ---                           |
|                                                                     | ---         | ---           | ---           | ---        | ---       | ---                           | ---             | ---                           |
| Ti-17V-7.5Co-3Al, Ingot No. V-2920<br>1500F(10min)AC+900F(8hrs)AC   | ---         | ---           | ---           | 209        | 208       | 0.353                         | 0               | 14.0 (2)                      |
|                                                                     | 600         | 150           | 150           | 206        | 199       | 0.240                         | ---             | 14.9 (1, 2)                   |
|                                                                     | "           | "             | "             | 203        | 199       | 0.356                         | 0               | 15.6 (1, 2)                   |
|                                                                     | "           | "             | "             | ---        | ---       | ---                           | ---             | 13.8 (1, 2)                   |
|                                                                     | ---         | ---           | ---           | 218        | 207       | 0.255                         | 3.75            | 15.4 (1, 2)                   |
| 1500F(10min)AC+900F(24hrs)AC                                        | 600         | 164           | 150           | 220        | 213       | 0.516                         | 2.5             | 15.5                          |
|                                                                     | "           | "             | "             | 216        | ---       | 0.382                         | ---             | 15.8 (2)                      |
|                                                                     | "           | "             | "             | 226        | 203       | ---                           | 2.5             | 14.4 (2)                      |
|                                                                     | ---         | ---           | ---           | ---        | ---       | ---                           | ---             | ---                           |
|                                                                     | ---         | ---           | ---           | ---        | ---       | ---                           | ---             | ---                           |

(1) Sample broke outside gage length.

(2) Sample broke in head test finished in file grips.

(3) Total elongation in 2-inches.

TABLE VIII (continued)

| Ingot No. | Alloy              | Heat Treatment               |   | Test Temp. °F | NTS Ksi | Average | Smooth UTS Ksi | Ratio NTS/UTS |
|-----------|--------------------|------------------------------|---|---------------|---------|---------|----------------|---------------|
| V-2858    | Ti-17V-2Fe-2Co-3Al | 1500F(10min)WQ+900F(8hrs)AC  | " | 600           | 162)    |         |                |               |
| "         | "                  | "                            | " | "             | 152)    | 161     | 159            | 1.02          |
| "         | "                  | "                            | " | "             | 149)    |         |                |               |
| "         | "                  | "                            | " | "             | 167)    |         |                |               |
| "         | "                  | "                            | " | "             | 174)    |         |                |               |
| "         | "                  | 1500F(10min)WQ+900F(24hrs)AC | " | "             | 166)    |         |                |               |
| "         | "                  | "                            | " | "             | 161)    |         |                |               |
| "         | "                  | "                            | " | "             | 165)    | 164     | 193            | 0.85          |
| "         | "                  | "                            | " | "             | 169)    |         |                |               |
| "         | "                  | "                            | " | "             | 159)    |         |                |               |
| V-2900    | Ti-8Mo-8V-5Co-3Al  | 1500F(10min)WQ+900F(8hrs)AC  | " | "             | 158)    |         |                |               |
| "         | "                  | "                            | " | "             | 154)    | 156     | 142            | 1.10          |
| "         | "                  | "                            | " | "             | 156)    |         |                |               |
| "         | "                  | 1500F(10min)WQ+900F(24hrs)AC | " | "             | 167)    |         |                |               |
| "         | "                  | "                            | " | "             | 169)    | 167     | 182            | 0.92          |
| "         | "                  | "                            | " | "             | 164)    |         |                |               |
| V-2920    | Ti-17V-7.5Co-3Al   | 1500F(10min)WQ+900F(8hrs)AC  | " | "             | 153)    |         |                |               |
| "         | "                  | "                            | " | "             | 156)    | 150     | 188            | 0.80          |
| "         | "                  | "                            | " | "             | 141)    |         |                |               |
| "         | "                  | 1500F(10min)WQ+900F(24hrs)AC | " | "             | 146)    |         |                |               |
| "         | "                  | "                            | " | "             | 148)    | 148     | 200            | 0.74          |
| "         | "                  | "                            | " | "             | 149)    |         |                |               |

TABLE VIII

ROOM TEMPERATURE AND 600F NOTCH TENSILE PROPERTIES OF THREE AGEABLE BETA ALLOYS  
(Notch Configuration K-8)

| Ingot No. | Alloy              | Heat Treatment               | Test Temp. Of | NTS Ksi | Average | Smooth UTS Ksi | Ratio NTS/UTS |
|-----------|--------------------|------------------------------|---------------|---------|---------|----------------|---------------|
| V-2858    | T1-17V-2Fe-2Co-3Al | 1500F(10min)WQ+900F(8hrs)AC  | RT            | 106)    |         |                |               |
| "         | "                  | "                            | "             | 119)    |         |                |               |
| "         | "                  | "                            | "             | 127)    | 120     | 200            | 0.60          |
| "         | "                  | "                            | "             | 121)    |         |                |               |
| "         | "                  | "                            | "             | 127)    |         |                |               |
| "         | "                  | 1500F(10min)WQ+900F(24hrs)AC | "             | 127)    |         |                |               |
| "         | "                  | "                            | "             | 132)    |         |                |               |
| "         | "                  | "                            | "             | 129)    | 129.5   | 219            | 0.59          |
| "         | "                  | "                            | "             | 134)    |         |                |               |
| "         | "                  | "                            | "             | 126)    |         |                |               |
| V-2900    | T1-8Mo-8V-5Co-3Al  | 1500F(10min)WQ+900F(8hrs)AC  | "             | 87)     |         |                |               |
| "         | "                  | "                            | "             | 98)     |         |                |               |
| "         | "                  | "                            | "             | 106)    |         |                |               |
| "         | "                  | "                            | "             | 78)     | 87      | 160            | 0.54          |
| "         | "                  | "                            | "             | 71)     |         |                |               |
| "         | "                  | "                            | "             | 83)     |         |                |               |
| "         | "                  | "                            | "             | 83)     |         |                |               |
| "         | "                  | "                            | "             | 92)     |         |                |               |
| "         | "                  | 1500F(10min)WQ+900F(24hrs)AC | "             | 107)    |         |                |               |
| "         | "                  | "                            | "             | 81)     |         |                |               |
| "         | "                  | "                            | "             | 95)     |         |                |               |
| "         | "                  | "                            | "             | 102)    |         |                |               |
| "         | "                  | "                            | "             | 100)    | 95      | 198            | 0.48          |
| "         | "                  | "                            | "             | 89)     |         |                |               |
| "         | "                  | "                            | "             | 108)    |         |                |               |
| "         | "                  | "                            | "             | 81)     |         |                |               |
| V-2920    | T1-17V-7.5Co-3Al   | 1500F(10min)WQ+900F(8hrs)AC  | "             | 117)    |         |                |               |
| "         | "                  | "                            | "             | 117)    | 115     | 205            | 0.56          |
| "         | "                  | "                            | "             | 110)    |         |                |               |
| "         | "                  | 1500F(10min)WQ+900F(24hrs)AC | "             | 106)    |         |                |               |
| "         | "                  | "                            | "             | 114)    | 107     | 218            | 0.49          |
| "         | "                  | "                            | "             | 101)    |         |                |               |

TABLE IX

OXIDATION TESTS ON Ti-8Mo-8V-5Co-3Al AND Ti-17V-7.5Co-3Al  
(All Samples Exposed for 2 Hours at 1500F)

| Ingot No. | Alloy             | Sample | Weight Sample grams | Weight Sample+ Crucible Unexposed | Weight Sample+ Crucible After Exposure | Weight Gain, grams | Gain in Grams/sq. cm. of Surface Area |
|-----------|-------------------|--------|---------------------|-----------------------------------|----------------------------------------|--------------------|---------------------------------------|
| V-2900    | Ti-8Mo-8V-5Co-3Al | A      | 4.3502              | 35.0244                           | 35.1131                                | 0.0887)            | 0.0041 average                        |
| "         | "                 | B      | 4.5128              | 32.1921                           | 32.2680                                | 0.0759)            |                                       |
| "         | "                 | C      | 4.4929              | 32.0712                           | 32.1278                                | 0.0566)            |                                       |
| V-2920    | Ti-17V-7.5Co-3Al  | A      | 3.6372              | 27.6895                           | 27.8465                                | 0.1570)            | 0.0147 average                        |
| "         | "                 | B      | 3.6962              | 29.0907                           | 29.2646                                | 0.1739)            |                                       |
| "         | "                 | C      | 3.7646              | 31.9180                           | 32.1460                                | 0.2360)            |                                       |

TABLE X

## STRESS CORROSION TESTS ON SIX AGEABLE BETA ALLOYS

| Ingot No. | Alloy              | Bend Radius | Treatment             | Reverse Bending Until Flat | Result of |
|-----------|--------------------|-------------|-----------------------|----------------------------|-----------|
| V-2858    | Ti-17V-2Fe-2Co-3Al | 6.2T        | None (control)        | No cracks                  |           |
| "         | "                  | 5.6T        | 800F(2hrs), No salt   | No cracks                  |           |
| "         | "                  | 5.6T        | 800F(2hrs), Salt coat | Small cracks               |           |
| "         | "                  | 5.4T        | 800F(2hrs), Salt coat | Small cracks               |           |
| "         | "                  | 6.2T        | 800F(2hrs), Salt coat | Small cracks               |           |
| V-2859    | Ti-17V-4Fe-3Al     | 6.5T        | None (control)        | No cracks                  |           |
| "         | "                  | 6.5T        | 800F(2hrs), No salt   | No cracks                  |           |
| "         | "                  | 6.5T        | 800F(2hrs), Salt coat | No cracks                  |           |
| "         | "                  | 6.5T        | 800F(2hrs), Salt coat | No cracks                  |           |
| "         | "                  | 6.5T        | 800F(2hrs), Salt coat | No cracks                  |           |
| V-2860    | Ti-8Mo-8V-2Fe-3Al  | 6.0T        | None (control)        | Few small cracks           |           |
| "         | "                  | 6.0T        | 800F(2hrs), No salt   | No cracks                  |           |
| "         | "                  | 5.6T        | 800F(2hrs), Salt coat | No cracks                  |           |
| "         | "                  | 5.7T        | 800F(2hrs), Salt coat | No cracks                  |           |
| "         | "                  | 6.0T        | 800F(2hrs), Salt coat | No cracks                  |           |
| V-2900    | Ti-8Mo-8V-5Co-3Al  | 5.7T        | None (control)        | No cracks                  |           |
| "         | "                  | 6.0T        | 800F(2hrs), No salt   | No cracks                  |           |
| "         | "                  | 5.7T        | 800F(2hrs), Salt Coat | Sample broke               |           |
| "         | "                  | 5.8T        | 800F(2hrs), Salt coat | Sample broke               |           |
| "         | "                  | 6.3T        | 800F(2hrs), Salt coat | Sample broke               |           |
| V-2920    | Ti-17V-7.5Co-3Al   | 6.2T        | None (control)        | No cracks                  |           |
| "         | "                  | 6.3T        | 800F(2hrs), No salt   | No cracks                  |           |
| "         | "                  | 5.7T        | 800F(2hrs), Salt coat | Sample broke               |           |
| "         | "                  | 5.8T        | 800F(2hrs), Salt coat | Sample broke               |           |
| D-3002    | Ti-13V-11Cr-3Al    | 5.8T        | None (control)        | No cracks                  |           |
| "         | "                  | 5.8T        | 800F(2hrs), No Salt   | No cracks                  |           |
| "         | "                  | 5.8T        | 800F(2hrs), Salt coat | Numerous small cracks      |           |
| "         | "                  | 5.8T        | 800F(2hrs), Salt coat | Numerous small cracks      |           |
| "         | "                  | 5.8T        | 800F(2hrs), Salt coat | Numerous small cracks      |           |

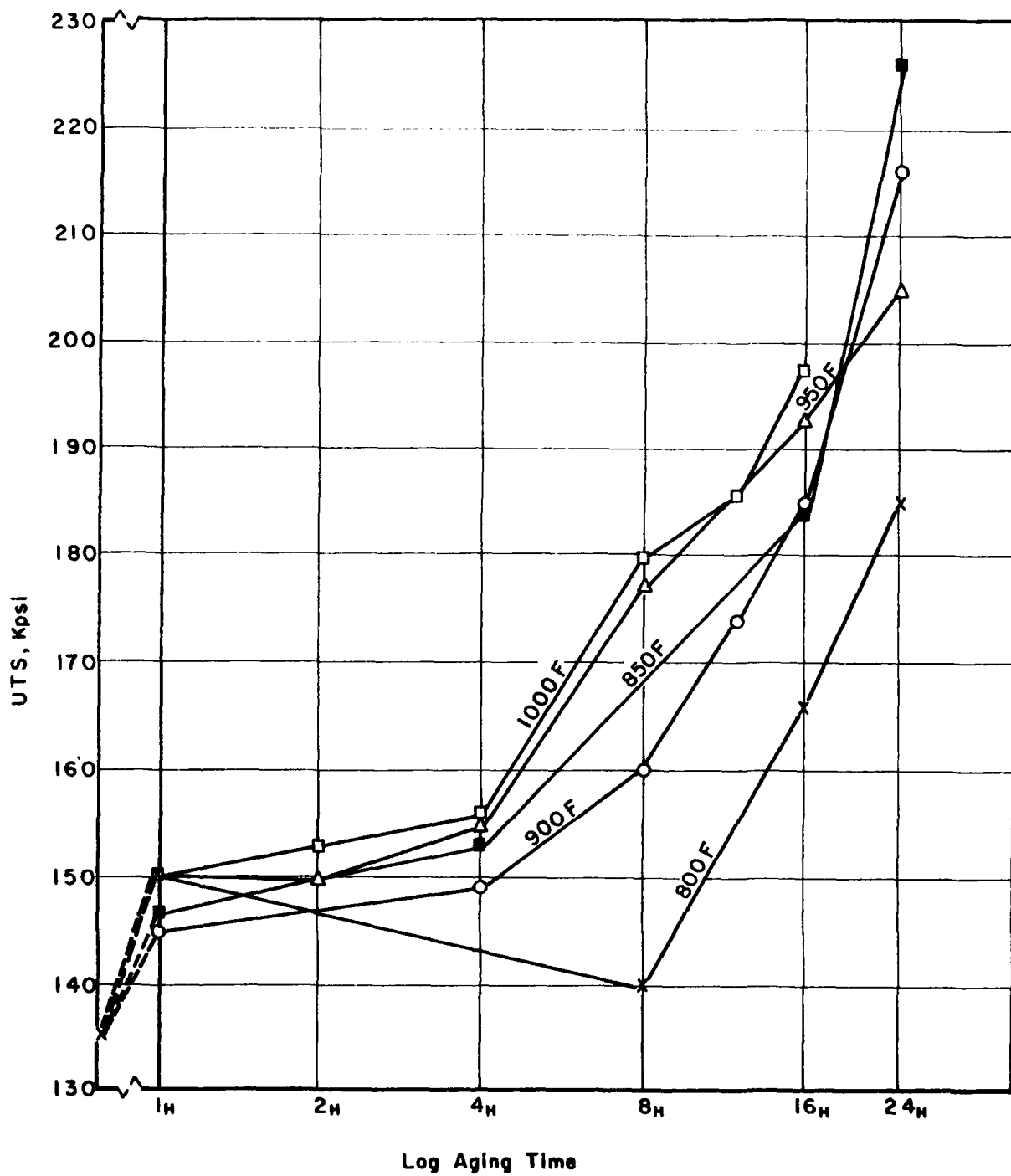


FIGURE 1. ULTIMATE TENSILE STRENGTH OF Ti-8Mo-8V-5Co-3Al AFTER AGING AT TEMPERATURE OF 800-1000F. (SOLUTION TREATMENT: 1500F-10 MINUTES W.Q.)

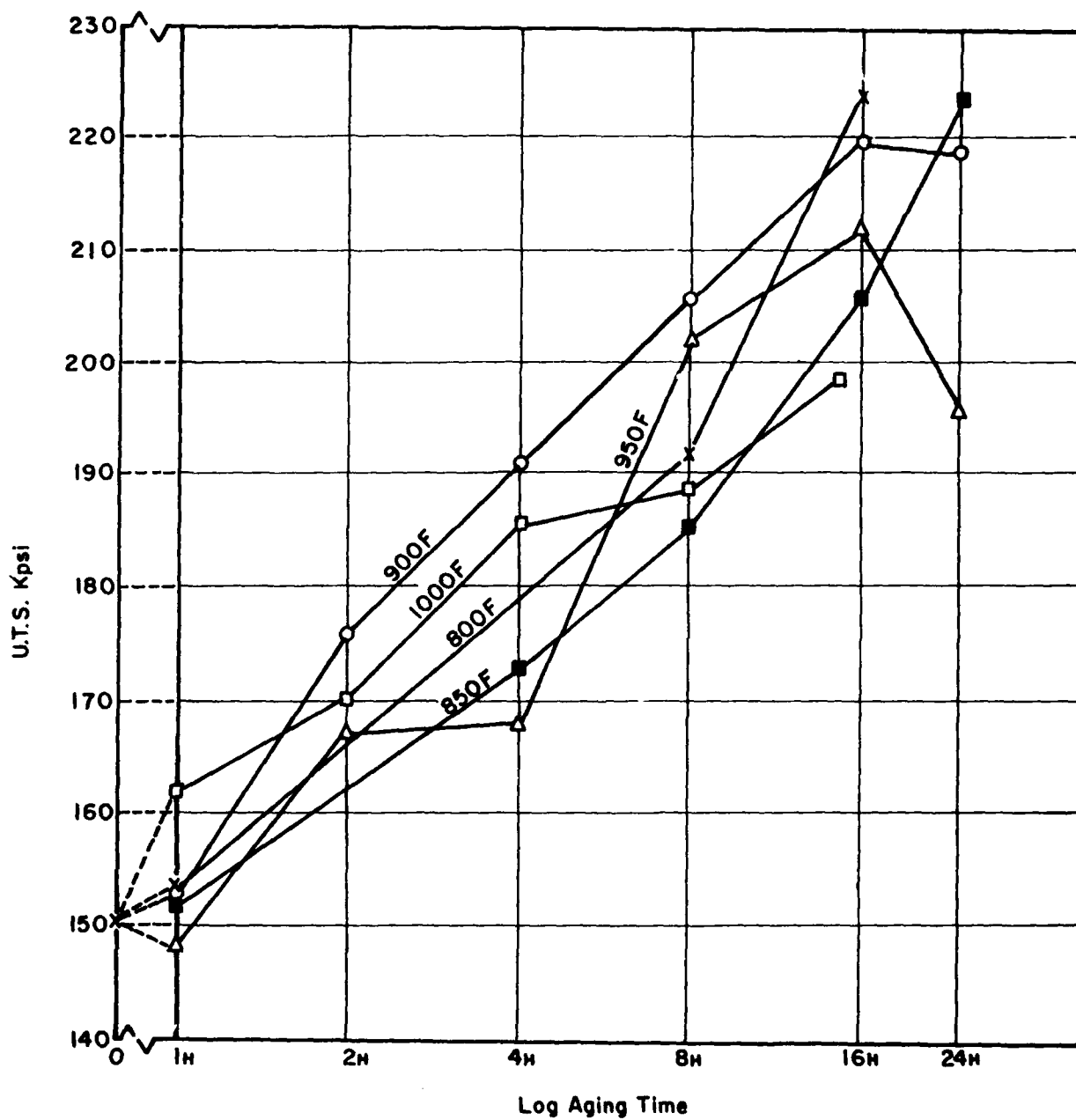


FIGURE 2. ULTIMATE TENSILE STRENGTH OF Ti-17V-7.5Co-3Al AFTER AGING AT TEMPERATURES OF 800-1000F. (SOLUTION TREATMENT: 1500F-10 MINUTES, W.Q.)



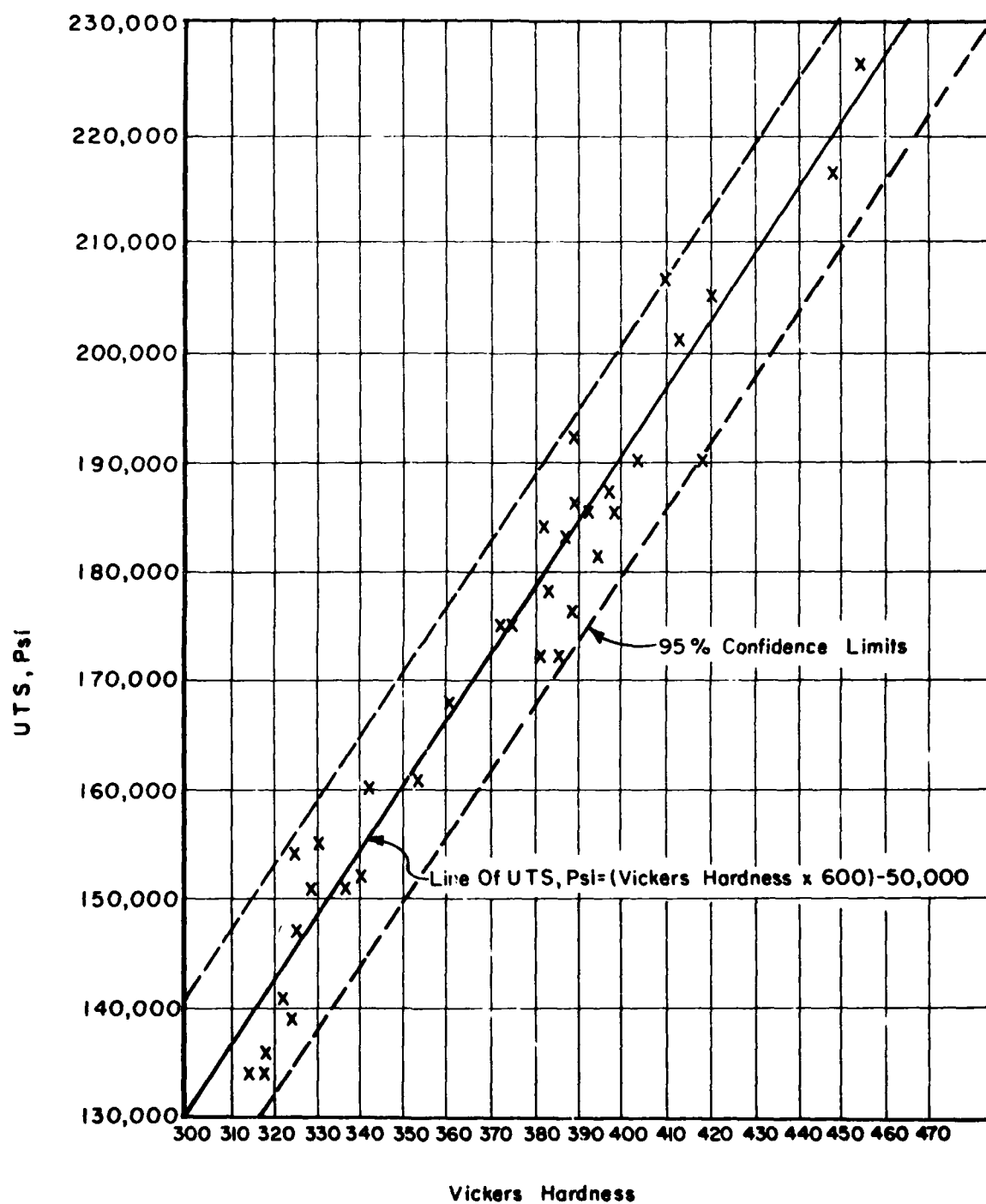


FIGURE 3. STATISTICAL RELATIONSHIP BETWEEN VICKERS HARDNESS AND UTS OF Ti-8Mo-8V-5Co-3Al.

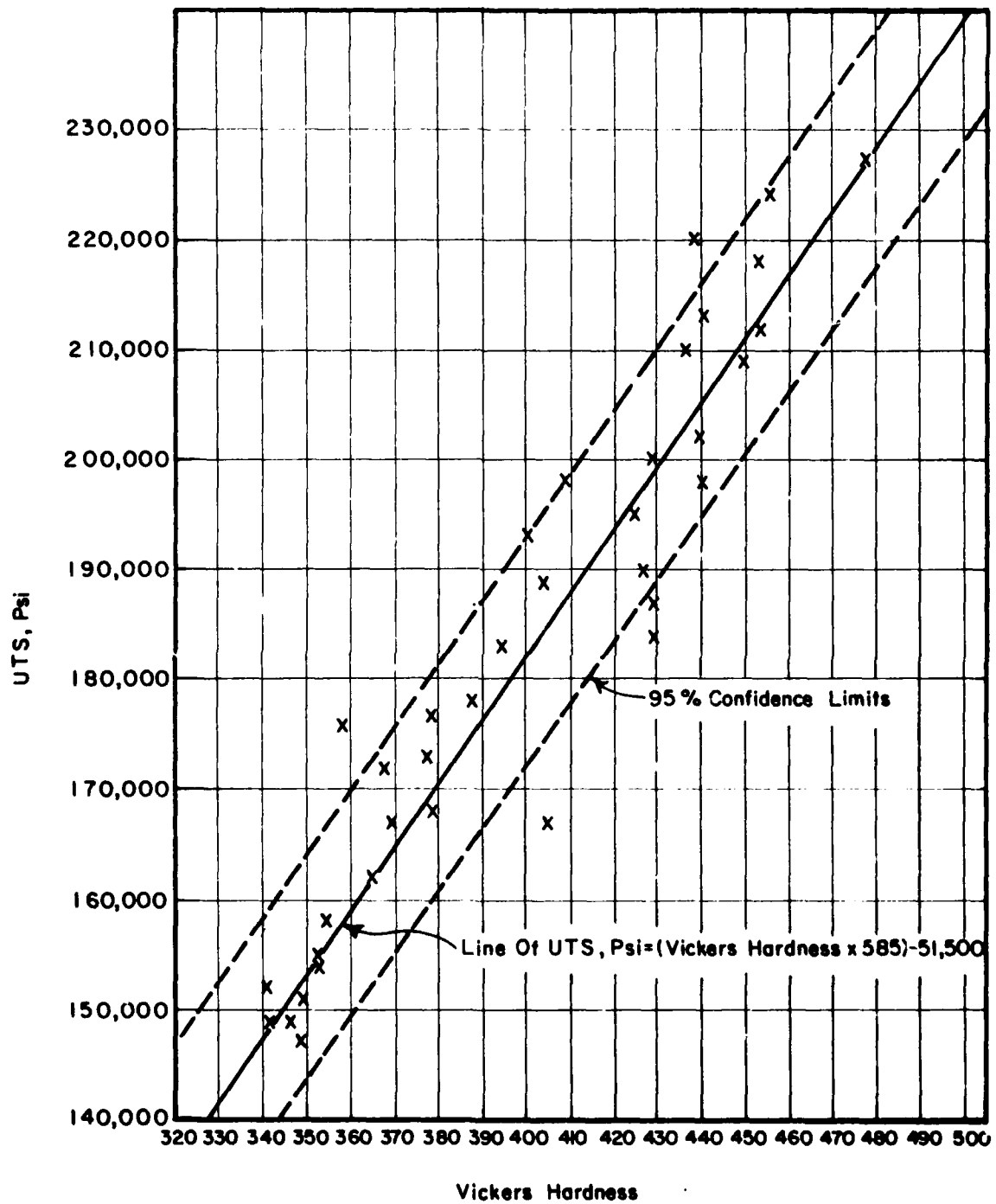
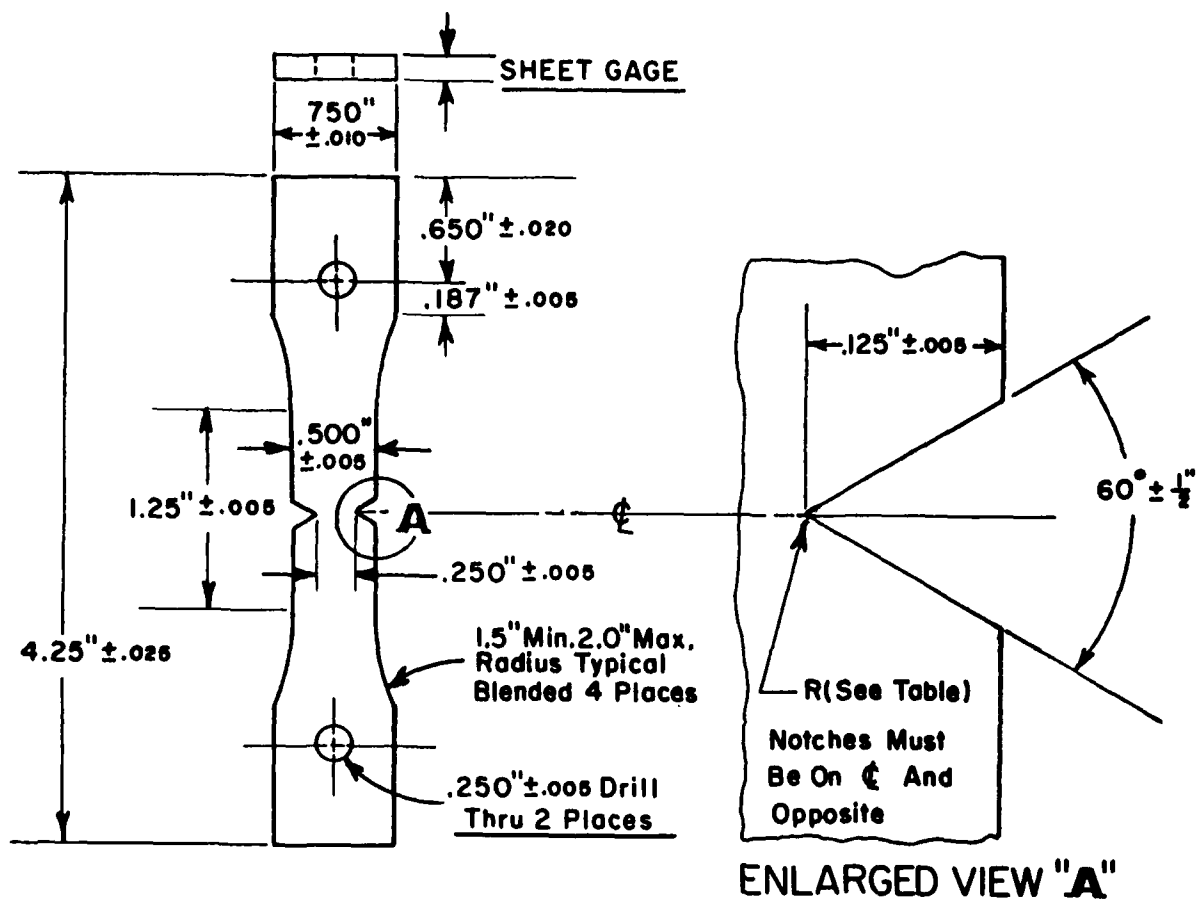


FIGURE 4. STATISTICAL RELATIONSHIP BETWEEN VICKERS HARDNESS AND UTS OF Ti-17V-7.5Co-3Al.



| TABLE              |                |
|--------------------|----------------|
| R                  | K <sub>T</sub> |
| .0025" $\pm .0005$ | 8.0            |

FIGURE 5. NOTCHED SHEET TENSILE SPECIMEN.

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