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AUTHOR: J. L. SHANNON, JR.

NONFERROUS ALLOYS

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

1. GENERAL

Ti-8Mo-8V-2Fe-3Al is an ageable, metastable beta alloy developed under U. S. Army Contract DA-30-069-ORD-3743. It was developed primarily as a high strength, formable sheet alloy but also possesses hardenability in 4 inch sections (possibly 6 inch sections (9)(10)) and potential as a fastener alloy. In common with its competitor, Ti-13V-11Cr-3Al (B 120 VCA), the alloy's body centered cubic phase (high temperature allotrope) is retained on cooling from solution temperatures to ambient temperature at relatively slow rates. The stability of the beta phase, however, is such that the alloy can be subsequently strengthened by reheating above 800F through the conventional precipitation of alpha phase (close packed hexagonal structure).

The alloy is superior to B 120 VCA in aging kinetics, requiring less aging time to achieve high strength levels. In addition, the alloy is claimed to surpass B 120 VCA in notch fatigue strength, modulus of elasticity, stability at 600F, and, in the annealed condition, salt water corrosion resistance (8)(9). The major disadvantages of this and other beta alloys compared to alpha-beta alloys are high density and relatively poor creep properties at elevated temperatures. This alloy does not appear to possess smooth fatigue resistance commensurate with its higher strength when compared to Ti-6Al-4V.

The alloy is a relatively new composition which, in some respects, is still in a state of development. Data presented in this chapter were obtained using laboratory heats (0.5, 10, and 30 pound ingots) and small commercial heats (500 and 1800 pound ingots). Current studies are being carried out on full commercial heats (28 inch diameter, 6000 to 7000 pound ingots). Since typical properties for this alloy have not yet been established, actual test values are reported in this chapter for a broader-than-usual range of material and test conditions. In all cases, the ingot size and processing are identified. Much of the data for sheet were developed for simulated hand mill product (hot cross rolled) and simulated mill strip (rolled unidirectionally and received some cold work). Data are also presented for forgings and fastener stock.

1.01 Commercial Designation

8Mo-8V-2Fe-3Al Titanium Alloy

1.02 Alternate Designations

Ti-8Mo-8V-2Fe-3Al

1.03 Specifications

None.

1.04 Composition

1.041 Producer's specified composition, Table 1.041.

TABLE 1.041

Source	(5)	
Element	Weight Percent	
	Minimum	Maximum
Molybdenum	7.5	8.5
Vanadium	7.5	8.5
Iron	1.75	2.25
Aluminum	2.5	3.5
Oxygen	0.10	0.18
Nitrogen	-	0.08
Carbon	-	0.05
Hydrogen	-	*
Other Elements: Each	-	0.10
Total	-	0.30
Titanium	Balance	

* Bar and billet, 0.015 maximum.
Sheet and wire, 0.02 maximum.

1.042 Compositional variations. General. The conventional tensile properties and hardness of this alloy are markedly affected by certain compositional variations. Studies have been conducted with 0.050 inch sheet to define the individual effect of iron content variations above and below the nominal value and extending slightly beyond the specified range. The influence of total alloy content variations has also been determined for the following limiting cases: normal minimum alloy content, normal maximum alloy content, composition corresponding to lowest alpha-beta ratio, and composition corresponding to highest alpha-beta ratio. The following two sections summarize the results of these investigations.

1.043 Iron Content. Increasing iron content produces an increase in elastic modulus for both the solution treated and the solution treated plus aged conditions (see Table 3.0621). The strength and ductility (elongation) rise with increasing iron content for the solution treated condition; strength drops and ductility is unaffected for the solution treated plus aged condition (see Table 3.0212). The aging response established by Vickers hardness measurements is greater for lower iron contents at aging temperatures from 800 to 950F and aging times up to 24 hours (see Figure 1.061).

1.044 Total alloy content. The influence of total alloy content variations on the elastic modulus and on strength and ductility are presented in Tables 3.0622 and 3.0213, respectively. For the solution treated condition, the normal maximum alloy content corresponds to the highest elastic modulus and the normal minimum alloy content the lowest. The modulus of compositions corresponding to both the lowest and highest alpha-beta ratios lie between these extremes. Solution treated strengths vary only slightly with total alloy content variations within the range investigated. Elongations of solution treated stock of normal maximum alloy content and highest alpha-beta ratio composition are equal and exceed those for the normal minimum alloy content and lowest alpha-beta ratio composition, the latter two also equal. In contrast the elongation values for all compositions studied are nearly equal and low for the solution treated plus aged condition while the strengths vary somewhat. Thus the strength of normal maximum alloy content material is least and that of the highest alpha-beta ratio composition greatest. The strength of normal minimum alloy content stock and stock of lowest alpha-beta ratio composition are equal and intermediate in value. The influence of total alloy variations on aging response is seen in Figures 1.062 through 1.065, where Vickers hardness values are presented as a function of aging time up to 24 hours at aging temperatures ranging from 800 to 950F. For these aging conditions, the highest achievable hardness and most rapid aging response characterizes the composition corresponding to the highest alpha-beta ratio and is followed, in descending order, by compositions of normal minimum alloy content, normal maximum alloy content, and of lowest alpha-beta ratio.

1.05 Heat Treatment

(see also 4.04)

1.051 Sheet and plate. Recommended heat treatment schedules for sheet and plate have not yet been established. However, some developmental results are available for simulated hand mill sheet and simulated mill strip 50 percent and 100 percent recrystallized (by selective solution treatments) and variously aged. A description of simulated hand mill sheet and mill strip and a discussion of recrystallization studies are given in Section 4.04.

Smooth tensile properties corresponding to a wide range of aging conditions are presented in Figures 3.0215 through 3.02110. These show that, for simulated hand mill product, 800-900F aged yield strengths range from 185 to 200 ksi with elongations as low as 1 percent. "Stabilized" yield strengths (1100F age) are around 140 ksi with elongations exceeding 8 percent. In general, the strength/ductility combinations of 50 percent recrystallized material are superior to those for fully recrystal-

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Ti - 8Mo-
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lized stock. Thus 1475F, 30 min, AC + 900F, 8 hr , AC is rated the best heat treatment to produce high strength, and 1475F, 30 min, AC + 1100F, 16 hr, AC is judged best to provide "stabilized" material (4).

Results for simulated mill strip show that 25 percent and 50 percent cold reductions have little if any effect on the strength and ductility of aged material compared with simulated hand mill product, independent of the degree of recrystallization. Thus 1450F, 10 min, AC + 900F, 8 hr, AC heat treatment representing 25 percent cold rolled, 50 percent recrystallized and aged material (see Figure 3.0217) was selected for additional mechanical property determinations so as to simplify comparisons with hand mill product.

In broadest terms, the hardness of material aged at 900F approaches or exceeds 400 Vickers points; aging curves for material stabilization aged at 1100F show a tendency to flatten out at or above 300 VHN. Aging curves established by Vickers hardness measurements are presented in Figures 1.066 through 1.0611.

The greater part of mechanical property data presented in this chapter was developed for material in the three aforementioned conditions; namely, hand mill product 50 percent recrystallized and aged at 900F or 1100F and 25 percent cold rolled mill strip 50 percent recrystallized and aged at 900F.

1.052 Bar, billet, and forgings. Solution treat and age: 1475F, 1 hr minimum (for sections greater than 2 inches), WQ (AC for sections less than 2 inches) + 1000F, 8 hr, AC.

1.053 Fastener stock. Solution treat: 1400F, 15 min, AC (as-received condition for bar or coil). This condition recommended for applications where severe cold heading is required and long term thermal exposure does not exceed 400F, 2000 hours. This is a condition of moderate strength.

Solution treat plus age: 1400F, 15 min, AC + 900F, 8 hr AC. This treatment recommended where high strength is required. Alloy cannot be cold worked in this condition.

Solution treat plus stabilization age: 1400F, 15 min, AC + 1200F, 8 hr, AC. This treatment recommended where long term thermal exposures exceed 400F but not 600F and where modest cold heading is required.

1.06 Hardness

1.061 Effect of aging time and temperature on hardness of solution treated sheet of two iron contents, Figure 1.061.

1.062 Effect of aging time and temperature on hardness of solution treated sheet of normal minimum alloy content, Figure 1.062.

1.063 Effect of aging time and temperature on hardness of solution treated sheet of normal maximum alloy content, Figure 1.063.

1.064 Effect of aging time and temperature on hardness of solution treated sheet of composition corresponding to lowest alpha-beta ratio, Figure 1.064.

1.065 Effect of aging time and temperature on hardness of solution treated sheet of composition corresponding to hightest alpha-beta ratio, Figure 1.065.

1.066 Effect of aging time and temperature on hardness of annealed sheet 50 percent recrystallized, Figure 1.066.

1.067 Effect of aging time and temperature on hardness of annealed sheet 100 percent recrystallized, Figure 1.067.

1.068 Effect of aging time and temperature on hardness of 25 percent cold rolled sheet 50 percent recrystallized, Figure 1.068.

1.069 Effect of aging time and temperature on hardness of 25 percent cold rolled sheet 100 percent recrystallized, Figure 1.069.

1.0610 Effect of aging time and temperature on hardness of 50 percent cold rolled sheet 50 percent recrystallized, Figure 1.0610.

1.0611 Effect of aging time and temperature on hardness of 50 percent cold rolled sheet 100 percent recrystallized, Figure 1.0611.

1.0612 Statistical relationship between hardness and strength for sheet, Figure 1.0612.

1.0613 Since hardness is, in general, related to alloy strength characteristics, the variation in strength properties with heat treated section size provides a useful measure of alloy hardenability. Figure 3.02113 shows the influence of heat treated section size on the solution treated and aged smooth tensile properties of forged sections up to 4 inches square. As expected, the highest strengths were obtained for the edge location, but were generally no more than about 10 ksi greater than the center location over the range of sizes investigated. Some strength directionality is observed, but this does not exceed the center-to-edge variation. On the other hand, a sizeable directionality is noted for the edge location reduction of area for the largest bar size investigated. It is implied that higher breakdown temperatures than those used in this study (see processing schedule in Table 4.012) would promote macrograin size refinement and lower finishing temperatures than those used (also shown in Table 4.012) would produce improved microstructural refinement, both of which would improve property uniformity (1). Table 3.02114 suggests that cross forging would also tend to improve property uniformity.

Unpublished results on 4 inch bar sandwiched between 1 inch plates to simulate the cooling rate expected in 6 inch sections suggest that through-hardening would be obtained in 6 inch sections (10).

1.07 Forms and Conditions Available

Sheet, strip, bar, billet, forging stock, and fastener stock. Alloy is not yet in full commercial production. However, the full range of commercial sizes in any form can be produced on request.

1.08 Melting and Casting Practice

Alloy is double consumable electrode vacuum melted. Alloy is not yet considered castable.

1.09 Special Considerations

1.091 Stability. The effect of exposure in air at 600F for times up to 500 hours at stresses up to 90 percent of the 600F yield strength on subsequent room temperature smooth tensile properties of sheet and strip is presented in Tables 3.02118 through 3.02121. Similar data for 150 hour exposure at temperatures up to 650F without load for fastener stock are illustrated in Figure 3.02122. The data are not consistent but do show that small elevations in strength and large reductions in elongation can obtain for hand mill sheet and mill strip aged at 900F and exposed at 600F with load (see Tables 3.02120 and 3.02121). Hand mill sheet stabilization aged at 1100F appears insensitive to the exposure conditions investigated (see Tables 3.02119 and 3.02120) while mill strip similarly aged and exposed can suffer serious losses in ductility (Table 3.02121).

Stabilization aged fastener stock exhibits large increases in strength and reductions in elongation for 650F exposure without load (see Figure 3.02122).

600F exposure with load has only a slight effect on the elastic modulus of hand mill sheet and mill strip (see Tables 3.06220 and 3.06221).

No data are available on the influence of exposure on other mechanical properties but should be determined for applications where metallurgical stability is an important design consideration.

1.092 Fatigue. R. R. Moore rotating beam fatigue tests were performed on smooth specimens from a small, aircraft type closed die forging (F_{ty} = 180 ksi) - results are presented in Figure 3.051. Although there is considerable scatter in the data, the 10^7 cycles fatigue strength appears to be 70 ksi or only slightly higher. This is approximately the same level as is observed in normally processed, annealed Ti-6Al-4V forgings (2). Apparently

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8	Mo
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the high strength achieved in Ti-8Mo-8V-2Fe-3Al is not accompanied by corresponding high fatigue strength.

1.093 Fastener application. For fastener application the alloy possesses acceptable cold upsettability, double shear strength and stability to 600F for 150 hours. No data are available for longer exposure times or the influence of exposure for any duration on other critical mechanical properties.

1.094 Low temperature embrittlement. Tables 3.0314 and 3.0315 show serious losses in elongation at -65F for hand mill product and mill strip aged at either 900F or 1100F.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range.

2.012 Phase change. Alloy transforms on cooling from beta to alpha + beta at 1425 ± 25F, but the reaction is so sluggish that for all but extremely low cooling rates the beta phase is retained to room temperature (1)(6).

2.0121 Time-temperature-transformation diagrams.

2.013 Thermal conductivity.

2.014 Thermal expansion.

2.015 Specific heat.

2.016 Thermal diffusivity.

2.02 Other Physical Properties

2.021 Density. 0.175 lb per cu in, 4.852 gr per cu cm (1)(3).

2.022 Electric properties.

2.023 Magnetic properties. Alloy is nonmagnetic.

2.024 Emissivity.

2.025 Damping capacity.

2.03 Chemical Properties

2.031 Corrosion resistance. General. In common with other titanium alloys, Ti-8Mo-8V-2Fe-3Al is susceptible to solid salt stress corrosion at elevated temperatures and exhibits delayed failure of cracked specimens at room temperature in aqueous salt environments. Since only limited data are available, a complete characterization of this alloy in terms of its corrosion behavior cannot be made at this time. In general, however, it appears that this alloy is slightly more susceptible to solid salt stress corrosion than Ti-13V-11Cr-3Al but less susceptible than Ti-8Al-1Mo-1V, Ti-5Al-2.5Sn, and Ti-6Al-4V (4). Delayed failure characteristics of this alloy in aqueous salt solutions are not sufficiently developed to permit much of a comparison with other alloys. It is claimed, however, that the salt water corrosion resistance of Ti-8Mo-8V-2Fe-3Al is superior to that of Ti-13V-11Cr-3Al for the annealed condition (8). No comparisons have been made for other heat treated conditions or other alloy compositions.

2.032 Solid salt stress corrosion. Solid salt stress corrosion bend tests were performed using 3 inch x 1/2 inch specimens of 0.050 inch sheet solution treated 1500F, 10 min, AC. Specimens were bent around a die to produce a free bend radius of 6t and coated with a saturated NaCl solution which was subsequently dried in air to produce a deposit of solid salt on all surfaces. After 2 hour exposure at 800F in still air, the specimens were washed with water, flattened and examined metallographically for cracking. No cracks were observed (3)(4).

Tension specimens coated with solid salt in the manner described above were exposed at 600, 800, and 1000F at various stress levels for 200 hours. Results shown in Figures 2.033 and 2.034 indicate that the maximum stress which can be tolerated at 600F is 50 ksi, and at 800F, 25 ksi. No evidence of stress corrosion was found on specimens exposed at 10-15 ksi at 1000F. These results appear to be independent of aging treatment.

Tables 2.035 through 2.038 show the influence of hot salt exposure with load on the subsequent room temperature tensile properties. As expected, the effect of exposure increases with increasing exposure stress and temperature.

2.033 Hot salt stress corrosion behavior of simulated mill strip solution treated (50 percent recrystallized) and aged, Figure 2.033.

2.034 Hot salt stress corrosion behavior of simulated mill strip solution treated (50 percent recrystallized) and stabilization aged, Figure 2.034.

2.035 Effect of hot salt exposure with load on subsequent room temperature tensile properties of simulated mill strip solution treated (50 percent recrystallized) and aged, Table 2.035.

TABLE 2.035

Source	(4)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	0.060 Inch Sheet (a)			
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch) (b) + 1450F, 10 Min, AC(c) + 900F, 8 Hr, AC			
200 Hr, Hot Salt Exposure		Subsequent RT Tensile Properties(d)		
Temperature F	Stress ksi	F_{tu} ksi	F_{ty} ksi	e(1 in) Percent
None		204	198	5.5
None		201	187	4.0
600	80	Broke on tensile test loading at 87 ksi(e)		
600	65	175	173	1.0(e)
600	50	195	185	2.0
600	40	202	185	4.0
800	45	(Failed at 31 hours)		
800	35	(Failed at 63.5 hours)		
800	30	Broke on tensile test loading (e)		
800	25	215	201	5.0
800	25	211	200	1.5
1000	10	155	151	1.0
1000	7.5	182	174	5.0
1000	5	169	163	1.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) 50 percent recrystallized.
(d) Transverse. Tested in as-exposed condition.
(e) Stress corrosion present.

	Ti
8	Mo
8	V
2	Fe
3	Al

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2.036 Effect of hot salt exposure with load on subsequent room temperature tensile properties of simulated mill strip solution treated (50 percent recrystallized) and stabilization aged, Table 2.036.

TABLE 2.036

Source	(4)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	0.060 Inch Sheet (a)			
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch)(b) + 1450F, 10 Min, AC (c) + 1100F, 24 Hr, AC			
200 Hr, Hot Salt Exposure		Subsequent RT Tensile Properties (d)		
Temperature F	Stress ksi	F_{tu} ksi	F_{ty} ksi	e(1 in) Percent
None		148	137	14.0
None		149	139	18.5
600	85	135	131	5.0(e)
600	75	(Failed at 138 hours)		
600	60	131	125	1.0(e)
600	50	144	135	8.0
600	40	145	136	8.0
800	50	(Failed at 60.75 hours)		
800	40	(Failed at 79.5 hours)		
800	30	Broke on tensile test loading (e)		
800	25	136	-	(f)
800	25	162	150	13.0
800	20	162	150	14.0
1000	15	130	125	(f)
1000	10	118	-	(f)
1000	7.5	152	138	15.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) 50 percent recrystallized.
(d) Transverse. Tested in as-exposed condition.
(e) Stress corrosion present.
(f) Broke outside gage length.

2.037 Effect of hot salt exposure with load on room temperature elastic modulus of simulated mill strip solution treated (50 percent recrystallized) and aged, Table 2.037.

TABLE 2.037

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.060 Inch Sheet (a)	
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch)(b) + 1450F, 10 Min, AC(c) + 900F, 8 Hr, AC	
200 hr, Hot Salt Exposure		
Temperature - F	Stress - ksi	$E - 10^3$ ksi (d)
None		17.2
600	80	Not determined(e)
600	65	14.2(e)
600	50	15.1
600	40	15.5
800	45	(Failed at 31 hours)
800	35	(Failed at 63.5 hours)
800	30	Not determined(e)
800	25	16.2
800	25	15.9
1000	10	15.1
1000	7.5	15.9
1000	5	15.7

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) 50 percent recrystallized.
(d) Transverse. Tested in as-exposed condition. (see Table 2.035 for balance of tensile properties)
(e) Stress corrosion present.

2.038 Effect of hot salt exposure with load on room temperature elastic modulus of simulated mill strip solution treated (50 percent recrystallized) and stabilization aged, Table 2.038.

TABLE 2.038

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.060 Inch Sheet (a)	
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch) (b) + 1450F, 10 Min, AC (c) + 1100F, 24 Hr, AC	
200 Hr, Hot Salt Exposure		
Temperature - F	Stress - ksi	$E - 10^3$ ksi (d)
None		15.7
None		16.2
600	85	15.4(e)
600	75	(Failed at 138 hours)
600	60	14.3(e)
600	50	14.9
600	40	15.5
800	50	(Failed at 60.75 hours)
800	40	(Failed at 79.5 hours)
800	30	Not determined(e)
800	25	15.5
800	25	15.2
800	20	15.3
1000	15	17.3
1000	10	18.2
1000	7.5	16.4

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) 50 percent recrystallized.
(d) Transverse. Tested in as-exposed condition (see Table 2.036 for balance of tensile properties).
(e) Stress corrosion present.

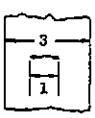
2.039 Delayed failure.

2.0310 Effect of salt water exposure with load on failure time of fatigue-cracked sheet specimens, Table 2.0310.

TABLE 2.0310

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.060 Inch Sheet **	
Condition	3.5 Percent NaCl Solution Exposure (pH = 7.5)	
	Net Stress - ksi	Time to Failure
Furnace Annealed:	105	1 min
1285F, 4 Hr, FC to 1000F,	100	1 min
AC	97.5	1 min
	95	3 hours*
Solution Treated:	110	3 hours*
1450F, 10 Min, AC	105	15 hours, 39 min*
	95	3 hours*
Solution Treated and Aged:	95	0
1450F, 10 Min, AC + 900F,	75	0
24 Hr, AC	50	0.5 min
	40	3 hours*

* Did not fail - test discontinued.
** Prepared from 500 pound ingot mill processed as described in Table 4.011.



Transverse Direction

ASTM Center Fatigue Crack Specimen

2.0311 Oxidation. Oxidation results are presented in Table 2.0312. The weight gains reported exceed those measured for beta alloy Ti-13V-11Cr-3Al for the same exposure conditions (4). Tables 2.0313 and 2.0314 show essentially no effect of superficial aging-treatment oxidation on the smooth tensile properties of sheet.

2.0312 Oxidation characteristics of sheet, Table 2.0312.

TABLE 2.0312

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	0.060 Inch Sheet (a)(b)				
Exposure Temperature F	Exposure Time hours	Unexposed Sample Weight gm	Exposed Sample Weight Gain gm	Exposed Sample Weight Gain Percent	Exposed Sample Weight Gain gm per sq cm of surface
1500	2	4.5131	0.0345	0.764	0.0027
1500	4	5.0055	0.1839	3.674	0.0142
1500	8	4.6346	0.5147	11.11	0.0399
1800	2	4.4362	0.5116	11.53	0.0396
1800	4	4.4241	1.0516	23.77	0.0815
1800	8	4.4398	2.7117	61.08	0.2101
1900	2	4.6497	0.5679	12.20	0.0440
1900	4	4.4410	1.3710	29.30	0.1062
1900	8	4.4628	2.7059	60.63	0.2097
2200	2	4.1004	0.9221	22.49	0.0714
2200	4	4.7734	1.9491	40.83	0.1518
2200	8	4.5793	2.6106	57.01	0.2023

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Samples 1 inch x 1 inch x 0.060 inch, exposed in air in open crucibles.

2.0313 Effect of superficial aging-treatment oxidation on room temperature tensile properties of solution treated and aged sheet, Table 2.0313.

TABLE 2.0313

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.050 Inch Sheet *		
Condition	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent
1500 F, 10 Min, AC + 900 F, 24 Hr, AC; sandblast and pickle to remove 0.005 inch of gage, machine specimen and test. (No surfaces of specimen oxidized.)	199	189	6.5
1500 F, 10 Min, AC + Sandblast and pickle to remove 0.005 inch of gage, age 24 hr at 900 F, machine specimen and test. (Only sheet surfaces of test specimen oxidized.)	196	180	5.5
1500 F, 10 Min, AC, sandblast and pickle to remove 0.005 inch of gage, machine specimen, age 24 hrs at 900 F and test. (Sheet surfaces and edges of test specimen oxidized.)	204	188	5.8

* Prepared from 30 pound ingot as described in Table 3.0241. Transverse Direction.

2.0314 Effect of superficial aging-treatment oxidation on room temperature tensile elastic modulus of solution treated and aged sheet, Table 2.0314.

TABLE 2.0314

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.050 Inch Sheet *	
Condition		E - 10^3 ksi
1500 F, 10 Min, AC + 900 F, 24 hr, AC; sandblast and pickle to remove 0.005 inch of gage, machine specimen and test. (No surfaces of test specimen oxidized.)		16.2
1500 F, 10 Min, AC, sandblast and pickle to remove 0.005 inch of gage, age 24 hr at 900 F, machine specimen and test. (Only sheet surfaces of test specimen oxidized.)		16.4
1500 F, 10 Min, AC, sandblast and pickle to remove 0.005 inch of gage, machine specimen, age 24 hr at 900 F and test. (Sheet surfaces and edges of test specimen oxidized.)		16.1

* Prepared from 30 pound ingot as described in Table 3.0241. Transverse Direction. (see Table 2.0313 for balance of tensile properties)

2.04 Nuclear Properties

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties
None.

3.02 Mechanical Properties at Room Temperature
3.021 Tension.
3.0211 Stress-strain diagrams.
3.0212 Effect of variation in iron content on tensile properties of solution treated and solution treated plus aged sheet, Table 3.0212.

Ti	
8	Mo
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2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

TABLE 3.0212

Source	(3)					
Form	0.050 Inch Sheet (a)					
Condition	1500 F, 15 Min, WQ			1500 F, 15 Min, WQ + 900 F, 8 Hr, AC		
Alloy	F_{tu} ksi	F_{ty} ksi	e Percent	F_{tu} ksi	F_{ty} ksi	e Percent
Ti-8Mo-8V-1Fe-3Al(b)	123	116	16 (c)	197	181	5 (c)
Ti-8Mo-8V-2Fe-3Al(d)	124	119	17 (e)	198	181	5 (e)
Ti-8Mo-8V-3Fe-3Al(b)	126	124	26 (c)	174	162	6 (c)

(a) Transverse direction tested only.
(b) Prepared from 1/2 pound ingot as described in Figure 1.061.
(c) 1 inch gage length.
(d) Prepared from 30 pound ingot as described in Table 3.0241.
(e) 2 inch gage length.

3.0213 Effect of variation in total alloy composition on tensile properties of solution treated and solution treated plus aged sheet, Table 3.0213.

TABLE 3.0213

Source	(4)					
Form	0.050 Inch Sheet *					
Condition	1500 F, 15 Min, WQ			1500 F, 15 Min, WQ + 900 F, 8 Hr, AC		
Alloy	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent
Ti-8.5Mo-8.5V-2.25Fe-3.5Al-0.18O (Normal Maximum Alloy Content)	134	132	25	186	170	6
Ti-7.5Mo-7.5V-1.75Fe-2.5Al-0.10O (Normal Minimum Alloy Content)	131	124	18	198	186	7
Ti-8.5Mo-8.5V-2.25Fe-2.5Al-0.10O (Composition corresponding to lowest alpha-beta ratio)	126	122	19	194	182	8
Ti-7.5Mo-7.5V-1.75Fe-3.5Al-0.18O (Composition corresponding to highest alpha-beta ratio)	131	126	24	218	204	6

* Prepared from 10 pound ingot in same manner as described in Table 3.0241 for 30 pound ingot.
Values average of duplicate tests. Transverse direction.

3.0214 Effect of aging time and temperature on tensile properties of solution treated sheet, Figure 3.0214.
3.0215 Effect of aging time at 900 and 1100 F on tensile properties of anncaled, simulated hand mill sheet 50 percent recrystallized, Figure 3.0215.
3.0216 Effect of aging time at 800, 900, and 1100 F on tensile properties of annealed, simulated hand mill sheet 100 percent recrystallized, Figure 3.0216.
3.0217 Effect of aging time at 800, 900, and 1100 F on tensile properties of 25 percent cold rolled, simulated mill strip 50 percent recrystallized, Figure 3.0217.
3.0218 Effect of aging time at 900, 1000, and 1100 F on tensile properties of 25 percent cold rolled, simulated mill strip 100 percent recrystallized, Figure 3.0218.

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

3.0219 Effect of aging time at 800, 900, 1100, and 1200F on tensile properties of 50 percent cold rolled, simulated mill strip 50 percent recrystallized, Figure 3.0219.

3.02110 Effect of aging time at 800, 900, 1100, and 1200F on tensile properties of 50 percent cold rolled, simulated mill strip 100 percent recrystallized, Figure 3.02110.

3.02111 Tensile properties of solution treated plate, Table 3.02111.

TABLE 3.02111

Source	(4)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	Plate (a)			
Condition	1500F, 10 Min, AC			
Plate Thickness Inches	Room Temperature Tensile Properties (b)(c)			
	F_{tu} ksi	F_{ty} ksi	RA Percent	e(1 In) Percent
1/2	116-119	114-118	48-53	24-29
2	111-115	108-114	31-42	18-23

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Range of values from three tests for 1/2 inch plate and from five tests for 2 inch plate.
(c) Center properties, longitudinal direction.

3.02112 Tensile properties of solution treated and aged plate, Table 3.02112.

TABLE 3.02112

Source	(4)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	Plate (a)			
Condition	1500F, 10 Min, AC + 900F, 16 Hr, AC			
Plate Thickness Inches	Room Temperature Tensile Properties (b)(c)			
	F_{tu} ksi	F_{ty} ksi	RA Percent	e(1 In) Percent
1/2	209-210	195-197	4.0-9.5	4-8
2	202-212	196-204	2.5-5.5	1-2

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Range of values from three tests for 1/2 inch plate and from five tests for 2 inch plate.
(c) Center properties, longitudinal direction.

3.02113 Effect of heat treated section size on tensile properties of unidirectionally forged bars, Figure 3.02113.

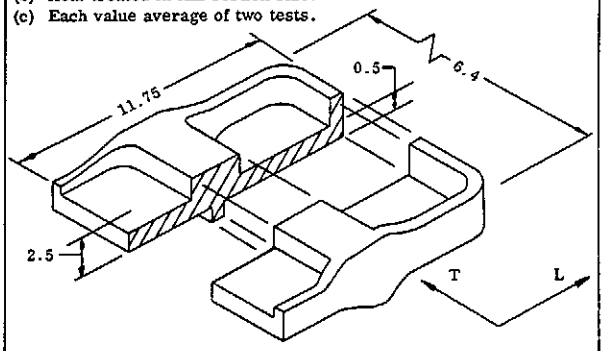
3.02114 Effect of cross forging on tensile properties of 3 inch and 4 inch solution treated and aged forged square bars, Table 3.02114.

3.02115 Tensile properties of solution treated and aged closed die forging, Table 3.02115.

TABLE 3.02115

Source	(2)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	Closed Die Forging (a)					
Condition	1475F, 1 Hr, WQ + 1000F, 8 Hr, AC (b)					
Direction	Section Size Inches	Location	Room Temperature Tensile Properties (c)			
			F_{tu} ksi	F_{ty} ksi	e(1 In) Percent	RA Percent
Longitudinal	0.5	Center	187.8	181.7	4.2	7.7
Transverse	0.5	Center	188.1	181.0	4.8	6.2
Transverse	2.5	Outside	183.4	177.8	3.0	7.2
Transverse	2.5	Center	184.0	177.5	4.5	11.3

(a) Forged in three steps (rough shaping on flat dies followed by blocker and finishing cycles), each at 1700F working temperature - starting section 4 in x 4 in x 12 in, processed from 1800 pound ingot as described in Table 4.012.
(b) Heat treated in full section size.
(c) Each value average of two tests.



Closed-Die Forging

TABLE 3.02114

Source		(1)											
Alloy		Ti-8Mo-8V-2Fe-3Al											
Form		Forged Bar											
Condition		1475F, 1 Hr, WQ + 1000F, 8 Hr, AC *											
		F_{tu} - ksi			F_{ty} - ksi			e(4D) - Percent			RA - Percent		
		(Four inch Square Forged Bar)**											
		(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Long	Edge	170.7	179.5	179.4	159.3	170.7	174.3	10.0	5.5	5.0	24.1	9.4	13.1
	Mid-radius	173.7	177.6	173.6	166.9	170.5	169.9	8.0	5.0	5.0	14.6	11.2	14.6
	Center	171.5	173.7	172.1	168.3	170.8	170.2	9.0	7.0	5.0	16.6	14.2	16.6
Trans	Edge	177.3	181.7	187.3	168.5	172.0	177.2	5.0	6.0	3.0	5.0	13.4	4.0
	Mid-radius	179.9	179.8	181.2	170.6	175.4	177.8	6.5	-	5.0	11.7	10.2	12.3
	Center	179.1	174.9	177.2	169.6	170.5	176.2	7.0	7.0	6.0	10.9	14.7	20.4
		(Three inch Square Forged Bar)**											
		(d)	(e)		(d)	(e)		(d)	(e)		(d)	(e)	
Long	Edge	173.8	179.9		164.5	168.1		10.0	6.0		16.1	10.9	
	Mid-radius	168.5	174.6		166.3	171.4		9.5	5.0		15.3	13.1	
	Center	174.3	181.2		164.8	169.7		9.5	7.5		16.8	9.8	
Trans	Edge	180.3	184.6		169.5	174.8		5.0	5.0		10.2	10.9	
	Mid-radius	170.8	176.1		167.9	170.2		7.0	5.0		15.4	13.5	
	Center	178.6	182.4		169.5	175.0		4.5	5.0		5.5	13.8	

(a) 4 inch square bar unidirectionally forged 1650F (Beta + 225F).
(b) 4 inch square x 7 inch long upset 1600F to 4 inch thick, cross forged to 4 inch square x length.
(c) 4 inch square x 7 inch long upset 1700F to 4 inch thick, cross forged to 4 inch square x length.
(d) 3 inch square bar unidirectionally forged 1650F (Beta + 225F).
(e) 3 inch square x 5 inch long upset 1400F to 3 inch thick, cross forged to 3 inch square x length.
* Heat treated in full section size.
** Starting bars processed from 1800 pound ingot as described in Table 4.012.

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

3.02116 Effect of aging temperature on room temperature tensile properties of cold rolled plus solution treated and aged fastener stock, Figure 3.02116.

3.02117 Tensile properties of solution treated and solution treated plus stabilization aged fastener stock, Table 3.02117.

TABLE 3.02117

Source	(8)(11)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	0.256 Inch Diameter Wire (Fastener Stock)			
Condition	Cold Rolled 9 Percent + Heat Treat			
Heat Treatment	RT Tensile Properties			
	F_{tu} ksi	F_{ty} ksi	e Percent	RA Percent
1450F, 15 Min, AC	124	117	34.0	58.0
1450F, 15 Min, AC + 1200F, 8 Hr, AC	142	125	21.0	36.2

3.02118 Effect of exposure to elevated temperature with load on room temperature tensile properties of solution treated and aged sheet, Table 3.02118.

TABLE 3.02118

Source	(3)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	0.050 Inch Sheet (a)					
Condition	Solution Treated and Aged					
Exposure Conditions				Subsequent Room Temperature Tensile Properties (b)		
Temperature F	Stress ksi	Time hours	Permanent Deformation percent	F_{tu} ksi	F_{ty} ksi	e(1 in) percent
1500F, 15 Min, WQ + 900F, 8 Hr, AC						
	None			197	180	5(c)
600	128	150	0.320	203	196	6
600	128	150	0.264	204	197	6
600	128	150	0.276	201	194	5
600	128	500	0.429	206	200	4
600	128	500	0.367	205	200	4
600	128	500	0.382	204	198	4
1500F, 15 Min, WQ + 900F, 24 Hr, AC						
	None			204	191	5(c)
600	138	150	0.292	208	202	6
600	138	150	0.288	208	201	6
600	138	150	0.248	206	200	6
600	138	500	0.364	204	201	4
600	138	500	0.407	206	203	5
600	138	500	0.396	204	197	6

(a) Prepared from 30 pound ingot as described in Table 3.0241.
(b) Transverse direction. Tested in as-exposed condition.
(c) 2 inch gage length.

3.02119 Effect of exposure to elevated temperature with load on room temperature tensile properties of solution treated and stabilization aged sheet, Table 3.02119.

TABLE 3.02119

Source	(3)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	0.050 Inch Sheet (a)					
Condition	1500F, 10 Min, AC + 1100F, 8 Hr, AC					
Exposure Conditions				Subsequent Room Temperature Tensile Properties (b)		
Temperature F	Stress ksi	Time hours	Permanent Deformation percent	F_{tu} ksi	F_{ty} ksi	e(1 in) percent
	None(c)			149	139	14
600	93.5	150	0.098	152	143	18
600	93.5	150	0.141	150	140	18
600	93.5	150	0.116	151	142	16
600	93.5	500	0.160	157	142	16
600	93.5	500	0.193	156	147	17
600	93.5	500	0.244	156	143	14

(a) Prepared from 30 pound ingot as described in Table 3.0241.
(b) Transverse direction. Tested in as-exposed condition.
(c) Unexposed values average five tests. Elongation for 2 inch gage length.

3.02120 Effect of 500 hour, 600F exposure at 90 percent of 600F yield strength on room temperature tensile properties of annealed, simulated hand mill sheet solution treated (50 percent recrystallized) and aged, Table 3.02120.

TABLE 3.02120

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	0.060 Inch Sheet (a)				
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC (b)+ST+Age				
500 Hr, 600F Exposure		Subsequent Room Temperature Tensile Properties(c)			
Stress ksi	Permanent Deformation Percent	Direction	F_{tu} - ksi	F_{ty} - ksi	e(1 In) Percent
1475F, 1/2 Hr, AC (d) + 900F, 8 Hr, AC					
None		Longitudinal	200	187	5.5
None		Longitudinal	201	189	6.0
None		Transverse	195	(e)	(f)
None		Transverse	204	200	2.5
138	0.781	Longitudinal	179	(e)	0
138	0.710	Transverse	219	213	2.0
138	0.676	Transverse	197	(e)	0
1475F, 1/2 Hr, AC (d) + 1100F, 16 Hr, AC					
None		Longitudinal	155	140	16.0
None		Longitudinal	156	142	13.0
None		Transverse	160	149	12.0
None		Transverse	158	147	12.0
98	0.163	Longitudinal	156	149	11.0
98	0.410	Transverse	149	142	13.0
98	0.203	Transverse	153	149	12.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(c) Tested in as-exposed condition.
(d) 50 percent recrystallized.
(e) Specimen broke before achieving 0.2 percent strain.
(f) Specimen broke outside gage length.

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

3.02121 Effect of 500 hour, 600F exposure at 90 percent of 600F yield strength on room temperature tensile properties of 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Table 3.02121.

TABLE 3.02121

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	0.060 Inch Sheet (a)				
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch)(b) + ST + Age				
500 Hr, 600F Exposure		Subsequent Room Temperature Tensile Properties (c)			
Stress ksi	Permanent Deformation percent	Direction	F_{tu} - ksi	F_{ty} - ksi	e(1 in) percent
1450F, 10 Min, AC (d) + 900F, 8 Hr, AC					
None		Longitudinal	198	-	7.0
None		Longitudinal	194	183	8.5
None		Transverse	204	198	5.5
None		Transverse	201	187	4.0
125	1.654	Longitudinal	201	(e)	0
125	1.192	Transverse	219	203	(f)
125	1.189	Transverse	178	(e)	0
1450F, 10 Min, AC (d) + 1100F, 24 Hr, AC					
None		Longitudinal	142	135	16.0
None		Longitudinal	141	135	15.0
None		Transverse	148	137	14.0
None		Transverse	149	139	18.5
93	0.316	Longitudinal	148	138	17.0
93	0.360	Transverse	146	145	16.0
93	0.105	Transverse	164	159	4.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) Tested in as-exposed condition.
(d) 50 percent recrystallized.
(e) Specimen broke before achieving 0.2 percent strain.
(f) Specimen broke outside gage length.

3.02122 Effect of 150 hour exposure to elevated temperatures on room temperature tensile properties of cold rolled plus solution treated and aged fastener stock, Figure 3.02122.
3.022 Compression.
3.0221 Stress-strain diagrams.
3.023 Impact.
3.024 Bending.
3.025 Torsion and shear.
3.0251 Shear strength of solution treated and solution treated plus stabilization aged fastener stock, Table 3.0251.

TABLE 3.0251

Source	(8)(11)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.256 Inch Diameter Wire (Fastener Stock)		
Condition	Cold Rolled 9 Percent + Heat Treat		
Heat Treatment		F_{ty}-ksi (a)	F_{su}-ksi (b)
1450F, 15 Min, AC		117	90.8
1450F, 15 Min, AC + 1200F, 8 Hr, AC		125	99.4

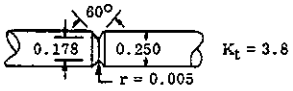
(a) See Table 3.02117 for balance of tensile properties.
(b) 0.200 inch diameter double shear specimen. Shear planes separated two diameters minimum. Shear testing clevis bushed to produce near zero clearance between specimen and holes and between adjacent surfaces of shear clevis.

3.026 Bearing.
3.027 Stress concentration.
3.0271 Notch properties.
3.02711 Mild notch tensile properties of solution treated and aged closed die forging, Table 3.02711.

TABLE 3.02711

Source	(2)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	Closed Die Forging (a)			
Condition	1475F, 1 Hr, WQ + 1000F, 8 Hr, AC (b)			
Direction	Section Size Inches	Location	F_{ty} (c) ksi	NTS(d) ksi
Longitudinal	0.5	Center	181.7	227.7
Transverse	0.5	Center	181.0	208.6
Longitudinal	2.5	Outside	177.8	131.8(e)
Longitudinal	2.5	Outside	177.8	226.9

(a) See Table 3.02115 for forging configuration and production details.
(b) Heat treated in full section size.
(c) Each value average two tests. See Table 3.02115 for balance of smooth tensile properties.
(d) Individual results.
(e) Considered by the investigator to be invalid in view of the other values obtained. However, visual and metallographic examination of broken specimen furnished no reason for this low value.



3.0272 Fracture toughness. (see Appendix C)
3.02721 Room temperature plane strain fracture toughness values of 50.4 and 54.7 ksi $\sqrt{in}$ were obtained using 3 point bend specimens from 3 inch square forged bars heat treated in full section to F_{ty} = 165 ksi (1475F, 1 hr, WQ + 1000F, 8 hr, AC)(1). Specimen orientation was RT (or RW, equivalent for symmetrical forgings) with the crack tips located at "mid-radius". Using the same specimen type, values ranging from 38.3 to 41.6 ksi $\sqrt{in}$ were obtained for 0.5 inch and 2.5 inch sections from a small, aircraft type forging heat treated in full section to F_{ty} = 177.5 to 181.0 ksi (same heat treatment as above). Specimen orientation was transverse to the long axis of the part (see drawing in Table 3.0211). These latter results are presented in Table 3.02722. For both studies the specimen, instrumentation and method of data analysis conformed in all respects to ASTM Tentative Method of Test E 399-70 T (5)(6)(7).
3.02722 Room temperature plane strain fracture toughness of solution treated and aged closed die forging, Table 3.02722.

TABLE 3.02722

Source	(2)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	Closed Die Forging (a)			
Condition	1475F, 1 Hr, WQ + 1000F, 8 Hr, AC (b)			
Direction	Section Size Inches	Location	F_{ty} (c) ksi	K_{Ic} (d)(e) ksi $\sqrt{in}$
Transverse	0.5	Center	181.0	38.3
Transverse	0.5	Center	181.0	41.6
Transverse	2.5	Center	177.5	41.1

(a) See Table 3.02115 for forging configuration and production details.
(b) Heat treated in full section size.
(c) Each value average two tests (see Table 3.02115 for balance of smooth tensile properties).
(d) Individual results.
(e) Specimens (three point bend), instrumentation and method of data analysis conformed in all respects to the ASTM Tentative Method of Test for Plane Strain Fracture Toughness of Metallic Materials (5)(6).

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures

3.031 Tension.

3.0311 Stress-strain diagrams.

3.0312 Tensile properties of solution treated and aged sheet at room temperature and 600 F, Table 3.0312.

TABLE 3.0312

Source	(3)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	0.050 Inch Sheet (a)					
Condition	1500 F, 15 Min, WQ + 900 F, 8 Hr, AC			1500 F, 15 Min, WQ + 900 F, 24 Hr, AC		
Test Temperature - F	F_{tu} ksi	F_{ty} ksi	e percent	F_{tu} ksi	F_{ty} ksi	e percent
RT	198	181	4.5(b)	204	191	5.2(b)
600	168	142	4.2(c)	170	154	3.8(c)

(a) Prepared from 30 pound ingot as described in Table 3.0241. Transverse direction tested only. Each value average two tests minimum.
(b) 2 inch gage length.
(c) 1 inch gage length.

3.0313 Tensile properties of solution treated and stabilization aged sheet at room temperature and 600 F, Table 3.0313.

TABLE 3.0313

Source	(3)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.050 Inch Sheet (a)		
Condition	1500 F, 10 Min, AC + 1100 F, 8 Hr, AC		
Test Temperature - F	Tensile Properties (b)		
	F_{tu} - ksi	F_{ty} - ksi	e(2 In) - Percent
RT	149	139	14
600	122	104	9

(a) Prepared from 30 pound ingot as described in Table 3.0241.
(b) Each value average of five tests. Transverse direction.

3.0314 Tensile properties at -65 F, room temperature, and 600 F for annealed, simulated hand mill sheet solution treated (50 percent recrystallized) and aged. Table 3.0314.

TABLE 3.0314

Source	(4)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	0.060 Inch Sheet (a)(b)					
Condition	Annealed 1285 F, 4 Hr, FC to 1000 F, AC (c) + ST + Age					
Test Temperature F	1475 F, 1/2 Hr, AC(d) + 900 F, 8 Hr, AC			1475 F, 1/2 Hr, AC(d) + 1100 F, 16 Hr, AC		
	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent
-65	204	(e)	(f)	168	148	5.0
-65	196	(e)	(f)	168	-	4.5
RT	195	(e)	(f)	160	149	12.0
RT	204	200	2.5	158	147	12.0
600	180	159	3.0	131	110	10.0
600	176	153	2.5	126	108	10.0
600	174	147	4.5	-	-	-

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Transverse direction.
(c) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(d) 50 percent recrystallized.
(e) Specimen broke before achieving 0.2 percent strain.
(f) Specimen broke outside gage length.

3.0315 Tensile properties at -65 F, room temperature and 600 F for 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Table 3.0315.

TABLE 3.0315

Source	(4)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	0.060 Inch Sheet (a)(b)					
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch)(c) + ST + Age					
Test Temperature F	1450 F, 10 Min, AC(d) + 900 F, 8 Hr, AC			1450 F, 10 Min, AC(d) + 1100 F, 24 Hr, AC		
	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent	F_{tu} ksi	F_{ty} ksi	e(2 In) Percent
-65	214	(e)	(f)	172	164	8.0
-65	198	184	1.0	169	163	13.0
RT	204	198	5.5	148	137	14.0
RT	201	187	4.0	149	139	18.5
600	162	137	6.0	122	103	9.0
600	164	140	3.5	124	103	14.5

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Transverse direction.
(c) Representative of mill strip.
(d) 50 percent recrystallized.
(e) Specimen broke before achieving 0.2 percent strain.
(f) Specimen broke outside gage length.

3.0316 Room temperature and 600 F tensile properties of solution treated and aged plate, Table 3.0316.

TABLE 3.0316

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	Plate (a)				
Condition	1500 F, 10 Min, AC + 900 F, 16 Hr, AC				
Plate Thickness Inches	Test Temperature F	Tensile Properties (b)(c)			
		F_{tu} ksi	F_{ty} ksi	RA Percent	e(1 In) Percent
1/2	RT	209-210	195-197	4.0-9.5	4-8
1/2	600	161-181	143-159	16-54	4-7
2	RT	202-212	196-204	2.5-5.5	1-2
2	600	176-183	161-167	4.0-9.0	1-4

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Range of values from three tests for 1/2 inch plate and from five tests for 2 inch plate.
(c) Center properties, longitudinal direction.

3.0317 Tensile properties at room temperature and 600 F for solution treated and aged 1 inch square forged bar, Table 3.0317.

TABLE 3.0317

Source	(1)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	1 Inch Square Forged Bar*			
Condition	1475 F, 1 Hr, WQ + 1000 F, 8 Hr, AC			
Test Temperature - F	F_{tu} - ksi	F_{ty} - ksi	e(4D)-percent	RA - percent
RT	182.6	166.6	8.2	13.6
600	156.9	133.0	15.0	41.2

* Processed from 1800 pound ingot as described in Table 4.012.

	Ti
8	Mo
8	V
2	Fe
3	Al

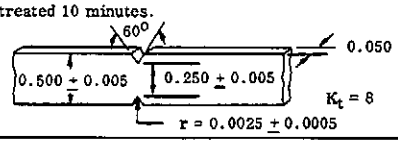
Ti - 8Mo-8V-2Fe-3Al

3.032 Compression.
3.0321 Stress-strain diagrams.
3.033 Impact.
3.034 Bending.
3.035 Torsion and shear.
3.036 Bearing.
3.037 Stress concentration.
3.0371 Notch properties.
3.03711 Mild notch tensile properties at room temperature and 600 F for solution treated and aged sheet, Table 3.03711.

TABLE 3.03711

Source	(3)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	0.050 Inch Sheet (a)			
Condition	1500 F, 10 to 15 Min (b), WQ + 900 F, 8 hr, AC		1500 F, 10 to 15 Min (b), WQ + 900 F, 24 hr, AC	
Test Temperature - F	F_{ty} - ksi	NTS - ksi	F_{ty} - ksi	NTS - ksi
RT	181	172	191	164
600	142	184	154	188

(a) Prepared from 30 pound ingot as described in Table 3.0241. Transverse direction tested only. Mild notch strength values average five tests. Yield strength values average two tests minimum.
(b) Sheet from which smooth specimens extracted solution treated 15 minutes. Sheet from which mild notch specimens extracted solution treated 10 minutes.

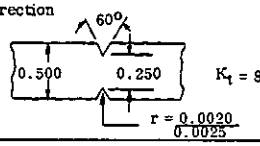


3.03712 Mild notch tensile properties at room temperature and 600 F for solution treated and stabilization aged sheet, Table 3.03712.

TABLE 3.03712

Source	(3)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.050 Inch Sheet (a)	
Condition	1500 F, 10 Min, AC + 1100 F, 8 Hr, AC	
Test Temperature F	F_{ty} - ksi (b)(d)	NTS - ksi (c)(d)
RT	139	174
600	104	136

(a) Prepared from 30 pound ingot as described in Table 3.0241.
(b) Balance of smooth tensile properties reported in Table 3.0313.
(c) Each value average of five tests.
(d) Transverse direction

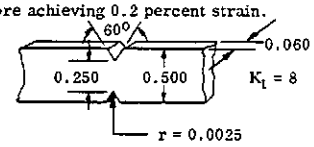


3.03713 Mild notch tensile properties at -65 F, room temperature and 600 F for annealed, simulated hand mill sheet solution treated (50 percent recrystallized) and aged, Table 3.03713.

TABLE 3.03713

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	0.060 Inch Sheet (a)				
Condition	Annealed 1235 F, 4 Hr, FC to 1000 F, AC(b)+ST+Age				
Test Temperature F	Direction	1475 F, 1/2 Hr, AC(c) + 900 F, 8 Hr, AC		1475 F, 1/2 Hr, AC(c) + 1100 F, 16 Hr, AC	
		F_{ty} - ksi	NTS - ksi	F_{ty} - ksi	NTS - ksi
-65	Transverse	(d)	137	148	175
-65	Transverse	(d)	144	148	165
RT	Longitudinal	188	140	141	162
RT	Longitudinal	188	135	141	168
RT	Transverse	200	154	148	169
RT	Transverse	200	151	148	170
600	Transverse	153	172	109	135
600	Transverse	153	172	109	134

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(c) 50 percent recrystallized.
(d) Specimen broke before achieving 0.2 percent strain.

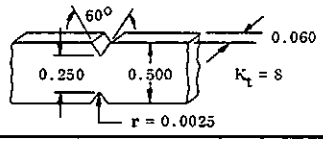


3.03714 Mild notch tensile properties at -65 F, room temperature and 600 F for 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Table 3.03714.

TABLE 3.03714

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	0.060 Inch Sheet (a)				
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch)(b) + ST + Age				
Test Temperature F	Direction	1450 F, 10 Min, AC(c) + 900 F, 8 Hr, AC		1450 F, 10 Min, AC (c) + 1100 F, 24 Hr, AC	
		F_{ty} - ksi	NTS - ksi	F_{ty} - ksi	NTS - ksi
-65	Transverse	184	145	164	182
-65	Transverse	184	153	164	166
RT	Longitudinal	183	162	135	164
RT	Longitudinal	183	140	135	165
RT	Transverse	192	164	138	170
RT	Transverse	192	153	138	170
600	Transverse	138	175	103	134
600	Transverse	138	169	103	133

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) 50 percent recrystallized.



Ti	
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

3.03715 Mild notch tensile properties at room temperature and 600F for solution treated and aged plate, Table 3.03715.

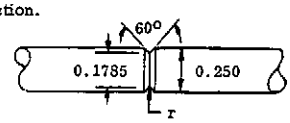
TABLE 3.03715

Source	(4)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	Plate*					
Condition	1500F, 10 Min, AC + Age					
Test Temperature - F			RT		600	
Plate Thickness Inches	K_t	Age Treatment	F_{ty}-ksi	NTS-ksi	F_{ty}-ksi	NTS-ksi
2	2.8	900F, 16 Hr, AC	200	216	162	230
1/2	2.8	900F, 16 Hr, AC	196	263	153	241
1/2	8.0	900F, 8 Hr, AC	-	226	-	230
1/2	8.0	900F, 16 Hr, AC	196	229	153	235

* Prepared from 500 pound ingot mill processed as described in Table 4.011.

All values average three tests minimum. Center properties, longitudinal direction.

r	K_t
0.010	2.8
0.001	8.2



3.042 500 hour, 600F creep behavior of 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Table 3.042.

TABLE 3.042

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.060 Inch Sheet (a)		
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch) (b) + ST + Age		
	500 hr Deformation at 600F		
Stress (c) ksi	Initial Deformation Percent	Creep Deformation Percent	Total Deformation Percent
1450F, 10 Min, AC (d) + 900F, 8 Hr, AC			
125	1.234	1.301	2.535
125	1.041	1.012	2.053
125	1.496	0.942	2.438
1450F, 10 Min, AC (d) + 1100F, 24 Hr, AC			
93	0.646	0.128	0.774
93	0.743	0.342	1.085
93	0.878	0.238	1.116

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) 90 percent of 600F yield strength.
(d) 50 percent recrystallized.

3.0372 Fracture toughness. (see Appendix C)
3.038 Combined properties.

3.04 Creep and Creep Rupture Properties

3.041 500 hour, 600F creep behavior of annealed, simulated hand mill sheet solution treated (50 percent recrystallized) and aged, Table 3.041.

TABLE 3.041

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.060 Inch Sheet (a)		
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC (b) + ST + Age		
	500 Hr Deformation at 600F		
Stress (c) ksi	Initial Deformation Percent	Creep Deformation Percent	Total Deformation Percent
1475F, 30 Min, AC (d) + 900F, 8 Hr, AC			
138	1.033	0.662	1.695
138	0.964	0.531	1.495
138	1.068	0.645	1.713
1475F, 30 Min, AC (d) + 1100F, 16 Hr, AC			
98	0.670	0.135	0.805
98	0.954	0.221	1.175
98	0.797	0.122	0.919

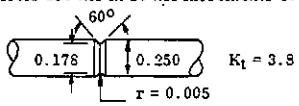
(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(c) 90 percent of 600F yield strength.
(d) 50 percent recrystallized.

3.043 Room temperature mild notch stress rupture properties of solution treated and aged closed die forging, Table 3.043.

TABLE 3.043

Source	(2)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	Closed Die Forging (a)			
Condition	1475F, 1 Hr, WQ + 1000F, 8 Hr, AC (b)			
			RT Mild Notch Stress Rupture Properties (c)	
Direction	Section Size Inches	Location	Stress at Failure ksi	Time to Failure min
Longitudinal	2.5	Outside	220	0
Longitudinal	2.5	Outside	200	10

(a) See Table 3.02115 for forging configuration and production details and corresponding smooth tensile properties.
(b) Heat treated in full section size.
(c) Stress increased from 150 ksi in 10 ksi increments every 5 hours.



3.05 Fatigue Properties

3.051 Room temperature rotating beam fatigue strength of solution treated and aged closed die forging, Figure 3.051.

3.052 Room temperature mild notch fatigue strength of 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Figure 3.052.

Ti
8 Mo
8 V
2 Fe
3 Al

Ti - 8Mo-8V-2Fe-3Al

3.06 Elastic Properties

3.061 Poisson's ratio.

3.062 Modulus of elasticity.

3.0621 Effect of variation in iron content on room temperature tensile elastic modulus of solution treated and solution treated plus aged sheet, Table 3.0621.

TABLE 3.0621

Source	(3)	
Form	0.050 Inch Sheet (a)	
Condition	1500 F, 15 Min, WQ	1500 F, 15 Min, WQ + 900 F, 8 Hr, AC
Alloy	E - 10^3 ksi	E - 10^3 ksi
Ti-3Mo-8V-1Fe-3Al (b)	9.43	14.35
Ti-3Mo-8V-2Fe-3Al (c)	10.15	15.0
Ti-3Mo-8V-3Fe-3Al (b)	11.05	15.0

(a) Transverse Direction.
(b) Prepared from 1/2 pound ingot as described in Figure 1.061.
(c) Prepared from 30 pound ingot as described in Table 3.0241.
(see Table 3.0212 for balance of tensile properties)

3.0622 Effect of variation in total alloy composition on room temperature tensile elastic modulus of solution treated and solution treated plus aged sheet, Table 3.0622.

TABLE 3.0622

Source	(4)	
Form	0.050 Inch Sheet*	
Condition	1500 F, 15Min, WQ	1500 F, 15 Min, WQ+900 F, 8 Hr, AC
Alloy	E - 10^3 ksi	E - 10^3 ksi
Ti-8.5Mo-8.5V-2.25Fe-3.5Al-0.18O (Normal maximum alloy content)	11.4	14.2
Ti-7.5Mo-7.5V-1.75Fe-2.5Al-0.10O (Normal minimum alloy content)	9.4	15.4
Ti-8.5Mo-8.5V-2.25Fe-2.5Al-0.10O (Composition corresponding to lowest alpha-beta ratio)	10.7	15.3
Ti-7.5Mo-7.5V-1.75Fe-3.5Al-0.18O (Composition corresponding to highest alpha-beta ratio)	9.8	15.7

* Prepared from 10 pound ingot in same manner as described in Table 3.0241 for 30 pound ingot.
Values average of duplicate tests. Transverse Direction.
(see Table 3.0213 for balance of tensile properties.

3.0623 Effect of aging time and temperature on room temperature tensile elastic modulus of solution treated sheet, Figure 3.0623.

3.0624 Effect of aging time at 900 and 1100 F on room temperature tensile elastic modulus of annealed, simulated hand mill sheet 50 percent recrystallized, Figure 3.0624.

3.0625 Effect of aging time at 800, 900, and 1100 F on room temperature tensile elastic modulus of 25 percent cold rolled, simulated mill strip 50 percent recrystallized, Figure 3.0625.

3.0626 Room temperature tensile elastic modulus of solution treated and solution treated plus aged plate, Table 3.0626.

TABLE 3.0626

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	Plate (a)	
Condition	1500 F, 10 Min, AC	1500 F, 10 Min, AC + 900 F, 16 Hr, AC
Plate Thickness Inches	E - 10^3 ksi (b)(c)(d)	
1/2	12.2-14.1	16.0-16.3
2	12.2-13.2	15.6-16.1

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Range of values from three tests for 1/2 inch plate and from five tests for 2 inch plate.
(c) Center location, longitudinal direction.
(d) For balance of tensile properties, see Tables 3.02111 and 3.02112.

3.0627 Effect of heat treated section size on room temperature tensile elastic modulus of forged bars, Figure 3.0627.

3.0628 Tensile elastic modulus at -65 F, room temperature and 600 F for annealed, simulated hand mill sheet solution treated (50 percent recrystallized) and aged, Table 3.0628.

TABLE 3.0628

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.060 Inch Sheet (a)(b)	
Condition	Annealed 1285 F, 4 Hr, FC to 1000 F, AC (c) + ST + Age	
Test Temperature- F	1475 F, 1/2 Hr, AC (d) + 900 F, 8 Hr, AC	1475 F, 1/2 Hr, AC (d) + 1100 F, 16 Hr, AC
	E - 10^3 ksi (e)	
-65	16.3	14.8
-65	15.2	15.1
RT	16.9	16.6
RT	-	15.9
600	15.8	14.1
600	15.1	15.6
600	16.5	-

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Transverse direction.
(c) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(d) 50 percent recrystallized.
(e) See Table 3.0314 for balance of tensile properties.

3.0629 Tensile elastic modulus at -65 F, room temperature and 600 F for 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Table 3.0629.

TABLE 3.0629

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.060 Inch Sheet (a)(b)	
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch) (c) + ST + Age	
Test Temperature- F	1450 F, 10 Min, AC (d) + 900 F, 8 Hr, AC	1450 F, 10 Min, AC (d) + 1100 F, 24 Hr, AC
	E - 10^3 ksi (e)	
-65	15.0	15.9
-65	15.6	15.5
RT	17.2	15.7
RT	-	16.2
600	14.7	13.0
600	13.6	14.6

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Transverse direction.
(c) Representative of mill strip.
(d) 50 percent recrystallized.
(e) See Table 3.0315 for balance of tensile properties.

3.06210 Effect of 500 hour, 600 F exposure at 90 percent of 600 F yield strength on room temperature tensile elastic modulus of annealed, simulated hand mill sheet solution treated (50 percent recrystallized) and aged, Table 3.06210.

TABLE 3.06210

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.060 Inch Sheet (a)		
Condition	Annealed 1285 F, 4 Hr, FC to 1000 F, AC (b) + ST + Age		
500 Hr, 600 F Exposure		Subsequent RT Elastic Modulus	
Stress ksi	Deformation Percent	Direction	E (c) 10^3 ksi
1475 F, 1/2 Hr, AC (d) + 900 F, 8 Hr, AC			
None		Longitudinal	16.3
None		Longitudinal	16.0
None		Transverse	16.9
138	0.781	Longitudinal	16.0
138	0.710	Transverse	16.0
138	0.676	Transverse	15.9
1475 F, 1/2 Hr, AC (d) + 1100 F, 16 Hr, AC			
None		Longitudinal	16.3
None		Longitudinal	18.0
None		Transverse	15.7
None		Transverse	16.8
98	0.163	Longitudinal	15.3
98	0.410	Transverse	15.0
98	0.203	Transverse	15.6

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(c) Tested in as-exposed condition.
(d) 50 percent recrystallized.
(see Table 3.02120 for corresponding tensile properties)

3.06211 Effect of 500 hour, 600 F exposure at 90 percent of 600 F yield strength on room temperature tensile elastic modulus of 25 percent cold rolled, simulated mill strip solution treated (50 percent recrystallized) and aged, Table 3.06211.

TABLE 3.06211

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.060 Inch Sheet (a)		
Condition	Cold Rolled 25 Percent (0.080 Inch to 0.060 Inch)(b) +ST + Age		
500 Hr, 600 F Exposure		Subsequent RT Elastic Modulus	
Stress ksi	Deformation Percent	Direction	E (c) 10^3 ksi
1450 F, 10 Min, AC (d) + 900 F, 8 Hr, AC			
None		Longitudinal	16.7
None		Transverse	17.2
125	1.654	Longitudinal	15.3
125	1.192	Transverse	15.2
125	1.189	Transverse	15.1
1450 F, 10 Min, AC (d) + 1100 F, 24 Hr, AC			
None		Longitudinal	16.0
None		Longitudinal	15.9
None		Transverse	15.7
None		Transverse	16.2
93	0.316	Longitudinal	14.5
93	0.360	Transverse	15.1
93	0.105	Transverse	14.6

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip.
(c) Tested in as-exposed condition.
(d) 50 percent recrystallized.
(see Table 3.02121 for corresponding tensile properties)

3.063 Modulus of rigidity.

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

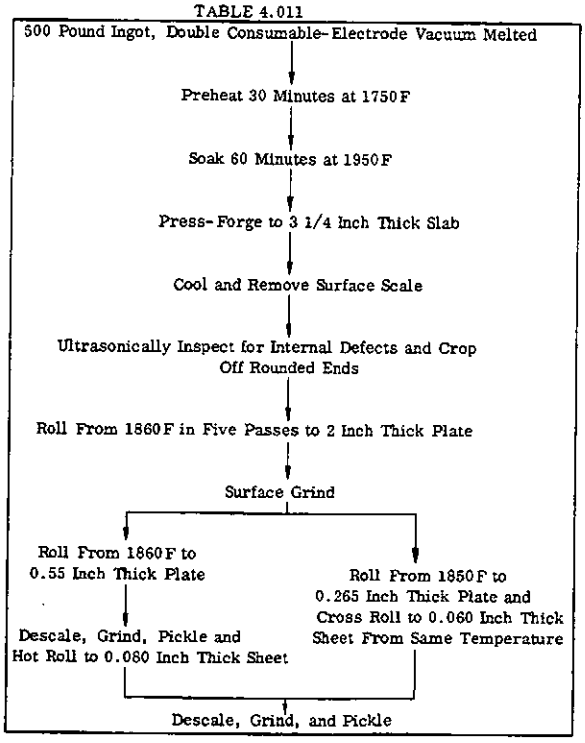
4. FABRICATION

4.01 Formability

General. As a class of alloys, the metastable beta compositions are considerably more formable than alpha + beta types, primarily because of the very high ductility of the body centered cubic beta phase (8). The data reported in this chapter were obtained on product forms processed from ingots ranging from 1/2 pound laboratory size to small commercial ingots of 500 pound and 1800 pound. No difficulties were encountered in scaling up from the smallest to largest ingot sizes. Forging and hot rolling characteristics of this alloy are judged similar to those of Ti-13V-11Cr-3Al; these include ease of deformation and surface condition after processing (4). Commercial processing schedules are outlined for the production of plate and sheet in Table 4.011, for forged bars in Table 4.012, and for a typical, small closed die aircraft type forging in Table 3.02115.

4.011 Processing of plate and sheet from 500 pound ingot, Table 4.011.

TABLE 4.011

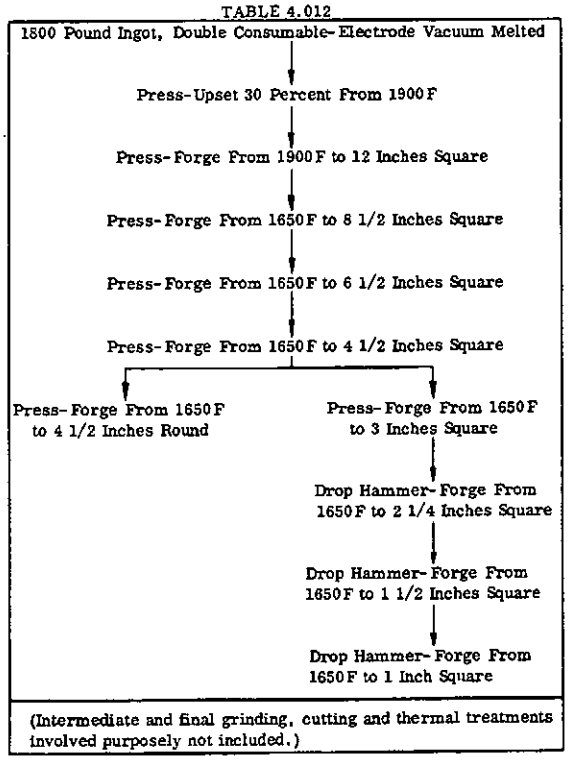


	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

4.012 Processing of forged bar from 1800 pound ingot, Table 4.012.

TABLE 4.012



(Intermediate and final grinding, cutting and thermal treatments involved purposely not included.)

4.013 Forging. The processing of bar from an 1800 pound ingot described in Table 4.012 involved initial pressing and forging at beta + 475F and finish forging at beta + 225F. The investigators were apparently dissatisfied with the ductility of these forged bars and suggested that beta grain size refinement be sought by using higher breakdown temperatures and lower finishing temperatures (1). Cross forging may not raise the level of ductility but can lessen directionality of elongation and reduction of area values as shown in Table 3.02114. Surprisingly this beneficial effect does not appear to depend on whether the cross forging temperature was either 1700F or 1400F.

The Wyman-Gordon Company produced a small, airframe-type closed die forging as a vehicle for evaluating the tensile (see Table 3.02115), fatigue (see Figure 3.051), notch stress rupture (see Table 3.043) and notch toughness (see Tables 3.02711 and 3.02722) of a typical forged part. All forging was done at 1700F as described in Table 3.02115. The part was given the same heat treatment as the bars produced in the foregoing study. Similar to the bars, the closed die forging possessed relatively low ductility (see Table 3.02115) even though the fracture toughness (see Table 3.02722) was quite high. The investigators state that additional evaluation of the alloy will undoubtedly suggest modifying processing cycles or heat treatments to produce improved strength ductility combinations.

4.014 Hot rolling. The production of hot rolled plate from a 500 pound ingot is described in Table 4.011. The first half of processing part of a 2 inch slab to 0.265 inch gage was performed at 1850F, or 40F lower than that normally used for reduction of Ti-13V-11Cr-3Al employing similar rolling pressures. Ti-8Mo-8V-2Fe-3Al may thus be slightly easier to roll than Ti-13V-11Cr-3Al.

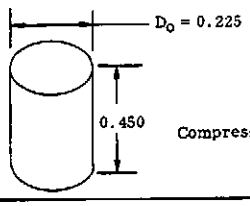
4.015 Cold upsettability. To be suitable for rivet stock, an alloy must be cold upsettable. Some consider a D_f/D_o of 1.7 when driven an acceptable minimum (8). This alloy meets this criterion in the solution treated condition.

4.016 Room temperature compressibility of solution treated and solution treated plus stabilization aged fastener stock, Table 4.016.

TABLE 4.016

Source	(8)(11)			
Alloy	Ti-8Mo-8Fe-2Fe-3Al			
Form	0.256 Inch Diameter Wire (Fastener Stock)			
Condition	Cold Rolled 9 Percent + Heat Treat			
Heat Treatment	F_{ty}-ksi(a)	Cold Upsettability D_f/D_o		
		Passed	Failed	
1450F, 15 Min, AC	117	1.96	2.13	
1450F, 15 Min, AC + 1200F, 8 Hr, AC	125	1.41	1.70	

(a) See Table 3.02117 for balance of tensile properties.
(b) After compression, puck inspected for cracks at 10x magnification: "Passed" - no cracks, "Failed" - cracked.



4.02 Machining and Grinding

4.03 Welding

This alloy is more weldable than Ti-13V-11Cr-3Al(10).

4.031 Room temperature tensile properties of welded sheet, Table 4.031.

TABLE 4.031

Source	(3)			
Alloy	Ti-8Mo-8Fe-2Fe-3Al			
Form	Welded 0.060 Inch Sheet			
Condition	1500F, 10 Min, AC + 900F, 16 Hr, AC + Weld (a)			
RT Tensile Properties	F_{tu} - ksi(c)	F_{ty} - ksi (c)	e(1/2 in) Percent(c)	e(2 in) Percent(c)
Range (b)	121-129	121-127	2-18	0.4-4.5
Average (b)	126	124	14.5	3.5

(a) Machine weld, without filler, using 3/32 inch diameter 2 percent thoriated tungsten electrode. Welded at 20 in/min in argon atmosphere. Welding current was 100-150 amps at 9 volts.
(b) Eight tests.
(c) Weld bead approximately 0.2 inch wide, perpendicular to specimen axis and ground flush with specimen surface. Gage length symmetrical about weld bead centerline.

4.032 Room temperature tensile elastic modulus of welded sheet, Table 4.032.

TABLE 4.032

Source	(3)
Alloy	Ti-8Mo-8V-2Fe-3Al
Form	Welded 0.060 Inch Sheet
Condition	1500F, 10 Min, AC + 900F, 16 Hr, AC + Weld (a)
E - 10^3 ksi	
Range (b)(c)	Average (b)(c)
14.2-15.7	15.0

(a) Machine weld, without filler, using 3/32 inch diameter 2 percent thoriated tungsten electrode. Welded at 20 in/min in argon atmosphere. Welding current was 100-150 amps at 9 volts.
(b) Eight tests.
(c) Weld bead approximately 0.2 inch wide, perpendicular to specimen axis and ground flush with specimen surface. Gage length symmetrical about weld bead centerline.
(see Table 4.031 for balance of tensile properties)

4.033 Room temperature tensile properties of welded simulated hand mill sheet, Table 4.033.

TABLE 4.033

Source	(4)
Alloy	Ti-8Mo-8V-2Fe-3Al
Form	0.060 Inch Sheet (a)(b)
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC (c) + Heat Treat/Weld

Heat Treat/Weld Sequence	No. of Tests	Room Temperature Tensile Properties (d) (Range of Values) Ftu ksi	Fty (e) ksi	e(2 in)(f) percent	e(1/2 in)(f) percent
1475F, 30 Min, AC + Weld	3	124-126	123-124	2.0-5.0	8.0-18.0
1475F, 30 Min, AC + 900F, 8Hr, AC + Weld	3	118-124	116-122	3.0-3.5	10.0-14.0
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC	2(g)	201	191 and 198	0.5 and 1.5	2.0 and 4.0
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	3	126-129	122-127	2.0-3.0	8.0
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	3	152-156	145-149	1.25	5.0
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld + 900F, 3 Hr, AC	6	185-193	180-188	2.0-3.0	2.0-4.0
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld (h) + 900F, 2 Hr, AC	10	126-153	125-151	1.0-2.0	4.0-6.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded, without filler, using automatic welding machine (except where noted) with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.
(d) All specimens broke in weld.
(e) 2 inch gage length.
(f) Weld bead width, 0.2 inch; width of weld bead plus heat affected zone, 0.5 inch.
(g) One specimen, result for which not included, broke without yielding.
(h) Hand welded.

4.034 Room temperature tensile elastic modulus of welded simulated hand mill sheet, Table 4.034.

TABLE 4.034

Source	(4)
Alloy	Ti-8Mo-8V-2Fe-3Al
Form	0.060 Inch Sheet (a)(b)
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC (c) + Heat Treat/Weld

Heat Treat/Weld Sequence	Number of Tests	E (d) (Range) 10^3 ksi
1475F, 30 Min, AC + Weld	3	13.1-13.5
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld	3	14.5-15.3
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC	2(e)	15.4 and 16.0
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	3	15.3-15.9
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	3	14.9-15.3
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld + 900F, 3 Hr, AC	6	14.7-15.5
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld (f) + 900F, Hr, AC	10	13.2-15.7

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded, without filler, using automatic welding machine (except where noted) with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.
(d) 2 inch gage length. Weld bead width, 0.2 inch; width of weld bead plus heat affected zone, 0.5 inch.
(e) One specimen, the result for which is not included, broke before yielding and had an elastic modulus of 13.9 x 10^3 ksi.
(f) Hand welded.
(see Table 4.033 for balance of tensile properties)

Ti
8 Mo
8 V
2 Fe
3 Al

Ti - 8Mo-8V-2Fe-3Al

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

4.035 600 F tensile properties of welded simulated hand mill sheet, Table 4.035.

TABLE 4.035

Source	(4)					
Alloy	Ti-8Mo-8V-2Fe-3Al					
Form	0.060 Inch Sheet (a)(b)					
Condition	Annealed 1285 F, 4 Hr, FC to 1000 F, AC (c) + Heat Treat/Weld					
Heat Treat/Weld Sequence		No. of Tests	600 F Tensile Properties (d) F_{tu} ksi	F_{ty}(e) ksi	e(2 in)(f) percent	e(1/2 in)(f) percent
1475 F, 30 Min, AC + 900 F, 8 Hr, AC + Weld		3	86-88	84-87	1.5-5.0	12.0-18.0
1475 F, 30 Min, AC + Weld + 900 F, 8 Hr, AC		3	182-185	173(g)	1.0-2.0	2.0-6.0
1475 F, 30 Min, AC + 1100 F, 16 Hr, AC + Weld		3	86-89	84-87	4.0-5.5	10.0-16.0
1475 F, 30 Min, AC + Weld + 1100 F, 16 Hr, AC		3	118-123	98-116	3.5-4.5	2.5-8.5
1475 F, 30 Min, AC + 900 F, 8 Hr, AC + Weld + 900 F, 3 Hr, AC		6	159-167	147-157	2.0-3.0	2.5-4.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded, without filler, using automatic welding machine with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.
(d) All specimens broke in weld.
(e) 2 inch gage length.
(f) Weld bead width, 0.2 inch; width of weld bead plus heat affected zone, 0.5 inch.
(g) Two specimens, the results for which are not included, broke without yielding.
(see Table 4.033 for corresponding room temperature properties)

4.036 600 F tensile elastic modulus of welded simulated hand mill sheet, Table 4.036.

TABLE 4.036

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.060 Inch Sheet (a)(b)		
Condition	Annealed 1285 F, 4 Hr, FC to 1000 F, AC (c) + Heat Treat/Weld		
Heat Treat/Weld Sequence		Number of Tests	Elastic Modulus at 600 F E(d) (Range) 10^3 ksi
1475 F, 30 Min, AC + 900 F, 8 Hr, AC + Weld		3	14.7-15.4
1475 F, 30 Min, AC + Weld + 900 F, 8 Hr, AC		3	15.2-17.0
1475 F, 30 Min, AC + 1100 F, 16 Hr, AC + Weld		3	10.0-15.1
1475 F, 30 Min, AC + Weld + 1100 F, 16 Hr, AC		3	13.1-14.8
1475 F, 30 Min, AC + 900 F, 8 Hr, AC + Weld + 900 F, 3 Hr, AC		6	13.7-15.9

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded, without filler, using automatic welding machine with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.
(d) 2 inch gage length. Weld bead width, 0.2 inch; weld bead plus heat affected zone width, 0.5 inch.
(see Table 4.035 for balance of tensile properties)

4.037 Effect of exposure to elevated temperature without load on room temperature tensile properties of welded simulated hand mill sheet, Table 4.037.

TABLE 4.037

Source	(4)				
Alloy	Ti-8Mo-8V-2Fe-3Al				
Form	0.060 Inch Sheet (a)(b)				
Condition	Annealed 1285 F, 4 Hr, FC to 1000 F, AC(c) + Heat Treat/Weld				
Exposure Conditions		Subsequent RT Tensile Properties (d)			
Temperature F	Time Hours	F_{tu} ksi	F_{ty}(e) ksi	e(2 In)(f) Percent	e(1/2 In)(f) Percent
1475 F, 30 Min, AC + Weld + 900 F, 8 Hr, AC					
None		(g)	(g)	0	2.0
None		201	191	1.5	4.0
None		201	198	0.5	2.0
650	500	189	180	2.0	2.0
650	500	193	187	2.0	2.0
1475 F, 30 Min, AC + Weld + 1100 F, 16 Hr, AC					
None		156	149	2.0	5.0
None		153	146	2.0	5.0
None		152	145	3.5	5.0
650	500	146	139	2.0	4.0
650	500	151	145	2.0	4.0

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded, without filler, using automatic welding machine with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.
(d) All specimens broke in weld. Specimens tested in as-exposed condition.
(e) 2 inch gage length.
(f) Weld bead width, 0.2 inch; weld bead plus heat affected zone width, 0.5 inch.
(g) Specimen broke before yielding.

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

4.038 Effect of exposure to elevated temperature without load on room temperature tensile elastic modulus of welded simulated hand mill sheet, Table 4.038.

TABLE 4.038

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.060 Inch Sheet (a)(b)	
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC (c) + Heat Treat/Weld	
Exposure Conditions		Subsequent RT Elastic Modulus(d)
Temperature F	Time Hours	E 10^3 ksi
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC		
	None	13.9(e)
	None	15.4
	None	16.0
650	500	14.4
650	500	15.2
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC		
	None	15.2
	None	14.9
	None	15.3
650	500	15.5
650	500	15.8

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded without filler, using automatic welding machine with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.
(d) Specimens tested in as-exposed condition. 2 inch gage length. Weld bead width, 0.2 inch; width of weld bead plus heat affected zone, 0.5 inch.
(e) Specimen broke before yielding.
(see Table 4.037 for balance of tensile properties.

4.039 Effect of temperature on bend properties of welded simulated hand mill sheet, Table 4.039.

TABLE 4.039

Source	(4)			
Alloy	Ti-8Mo-8V-2Fe-3Al			
Form	0.060 Inch Sheet (a)(b)			
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC (c) + Heat Treat/Weld			
Heat Treat/Weld Sequence	Test Temperature F	Orientation of Weld Bead to Bend Axis	Bend Radius	
			Passed	Failed
1475F, 30 Min, AC + Weld	RT	No weld	2.2t	1.8t
1475F, 30 Min, AC + Weld	RT	Transverse	2.1t	1.8t
1475F, 30 Min, AC + Weld	RT	Parallel	3.0t	2.4t
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld	RT	No weld	7.4t	6.6t
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld	RT	Transverse	2.4t	2.1t
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld	RT	Parallel	2.5t	2.4t
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC	RT	No weld	9.1t	8.0t
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC	RT	Transverse	-	≥9.5t
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC	RT	Parallel	-	≥8.3t
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	RT	No weld	4.2t	3.6t
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	RT	Transverse	2.3t	2.0t
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	RT	Parallel	1.6t	1.0t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	RT	No weld	4.1t	3.6t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	RT	Transverse	4.3t	3.7t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	RT	Parallel	11.9t	11.0t
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld	400	Transverse	0.9t	-
1475F, 30 Min, AC + 900F, 8 Hr, AC + Weld	400	Parallel	2.0t	1.5t
1475F, 30 Min, AC + Weld + 900F, 8 Hr, AC	400	Transverse	-	≥6.5t
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	400	Transverse	2.6t	1.6t
1475F, 30 Min, AC + 1100F, 16 Hr, AC + Weld	400	Parallel	3.0t	2.5t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	400	Transverse	3.0t	2.5t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	400	Parallel	7.8t	7.3t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	1100	Transverse	-	≥2.0t
1475F, 30 Min, AC + Weld + 1100F, 16 Hr, AC	1100	Parallel	-	≥8.0t

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) GTA welded, without filler, using automatic welding machine with 3/32 inch diameter, 2 percent thoriated tungsten electrode and argon shielding, at 20 inches per minute with 100-150 amp current at 9 volts. Weld bead ground flush with base metal surfaces.
(c) Simulated hand mill product. Sheet descaled, ground and pickled after annealing.

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

4.04 Heat Treatment

Recrystallization. Recrystallization parameters were determined for sheet in three conditions: 0.060 inch gage annealed 1285F, 4 hr, FC to 1000F (simulated hand mill product), hot rolled sheet cold rolled 25 percent from 0.080 inch to 0.060 inch gage (simulates mill strip), and hot rolled sheet cold rolled 50 percent from 0.080 inch to 0.040 inch gage (also simulated mill strip). Samples from each condition were solution treated at temperatures ranging from 1350F to 1525F in 25F increments for 15, 30 and 60 minutes. Ten minute solution times were also used where required. After solution treatment, all samples were partially aged for 4 hours at 900F to permit metallographic distinction between recrystallized and uncrystallized material (when partially aged, recrystallized grains are darker etching). Following this, aging response was determined for both 50 percent and 100 percent recrystallized material. Aging temperatures ranged from 800F to 1200F in 100F increments for times ranging from 2 to 24 hours. Aging was most pronounced at 900F for 8 hours or more and partially recrystallized material aged faster than fully recrystallized material. The aging curves established by Vickers hardness measurements are presented in Figures 1.066 through 1.0611.

4.041 Recrystallization characteristics of annealed sheet (simulated hand mill product), Table 4.041.

TABLE 4.041

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.060 Inch Sheet (a)		
Condition	Annealed 1285F, 4 Hr, FC to 1000F, AC(b)		
Solution Temperature F	Solution Time		
	15 Minutes	30 Minutes	1 Hour
	Percent	Percent	Percent
1350	0	0	0
1375	0	0	0
1400	0	0	0
1425	0	T(c)	T(c)
1450	5	50	75
1475	10	50	90
1500	30	80	100
1525	50	100(d)	100(d)

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) This condition representative of hand mill sheet. Sheet descaled, ground and pickled after annealing.
(c) Traces of recrystallization.
(d) Few small scattered areas of unrecrystallized material.

4.042 Recrystallization characteristics of 25 percent cold rolled sheet (simulated mill strip), Table 4.042.

TABLE 4.042

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form and Condition	Hot Rolled 0.080 Inch Sheet(a) Cold Rolled 25 Percent to 0.060 Inch Sheet (b)		
Solution Temperature F	Solution Time		
	15 Minutes	30 Minutes	1 Hour
	Percent	Percent	Percent
1350	0	0	0
1375	10	10	20
1400	40	75	95
1425	70	90	100
1450	70	100	100
1475	70	100	100
1500	100	100	100 with grain growth
1525	100	100	100 with grain growth

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip. Sheet descaled, ground and pickled after cold rolling.

4.043 Recrystallization characteristics of 50 percent cold rolled sheet (simulated mill strip), Table 4.043.

TABLE 4.043

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form and Condition	Hot Rolled 0.080 Inch Sheet (a) Cold Rolled 50 Percent to 0.040 Inch Sheet (b)		
Solution Temperature F	Solution Time		
	15 Minutes	30 Minutes	1 Hour
	Percent	Percent	Percent
1350	0	0	0
1375	T(c)	20	80
1400	85	90	100
1425	100	100	100
1450	100	100	100
1475	100	100	100 with grain growth
1500	100	100	100 with grain growth
1525	100	100 with grain growth	100 with grain growth

(a) Prepared from 500 pound ingot mill processed as described in Table 4.011.
(b) Representative of mill strip. Sheet descaled, ground and pickled after cold rolling.
(c) Traces of recrystallization.

4.044 Oxidation (see 2.0313 and 2.0314).

4.045 Cooling rate. Cooling rate from the solution temperature ranging from water quenching to plate cooling has no measurable influence on the room temperature smooth tensile properties of this alloy.

4.046 Effect of cooling rate from the solution temperature on room temperature tensile properties of solution treated and aged sheet, Table 4.046.

TABLE 4.046

Source	(4)		
Alloy	Ti-8Mo-8V-2Fe-3Al		
Form	0.050 Inch Sheet (a)		
Condition	F_{tu} ksi	F_{ty} ksi	e(2 in) Percent
1500F, 10 Min, WQ + 900F, 16 Hr, AC	204	192	5.0
1500F, 10 Min, AC + 900F, 16 Hr, AC	202	193	6.2
1500F, 10 Min, Plate Cool (b)+900F, 16 Hr, AC	203	193	5.2

(a) Prepared from 30 pound ingot as described in Table 3.0241. Transverse direction.
(b) Specimen blanks held between two 1 inch thick titanium plates; assemblage removed from furnace and allowed to cool in still air. Specimen blanks cooled to 700F in about 20 minutes, simulating the cooling rate expected in the production of 2 inch plate.

4.047 Effect of cooling rate from the solution temperature on room temperature tensile elastic modulus of solution treated and aged sheet, Table 4.047.

TABLE 4.047

Source	(4)	
Alloy	Ti-8Mo-8V-2Fe-3Al	
Form	0.050 Inch Sheet (a)	
Condition		E - 10^3 ksi
1500F, 10 Min, WQ + 900F, 16 Hr, AC		15.1
1500F, 10 Min, AC + 900F, 16 Hr, AC		15.3
1500F, 10 Min, Plate Cool (b), + 900F, 16 Hr, AC		15.7

(a) Prepared from 30 pound ingot as described in Table 3.0241. Transverse direction.
(b) Specimen blanks held between two 1 inch thick titanium plates; assemblage removed from furnace and allowed to cool in still air. Specimen blanks cooled to 700F in about 20 minutes, simulating the cooling rate expected in the production of 2 inch plate.
(see Table 4.046 for balance of tensile properties)

4.05 Surface Treatment

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

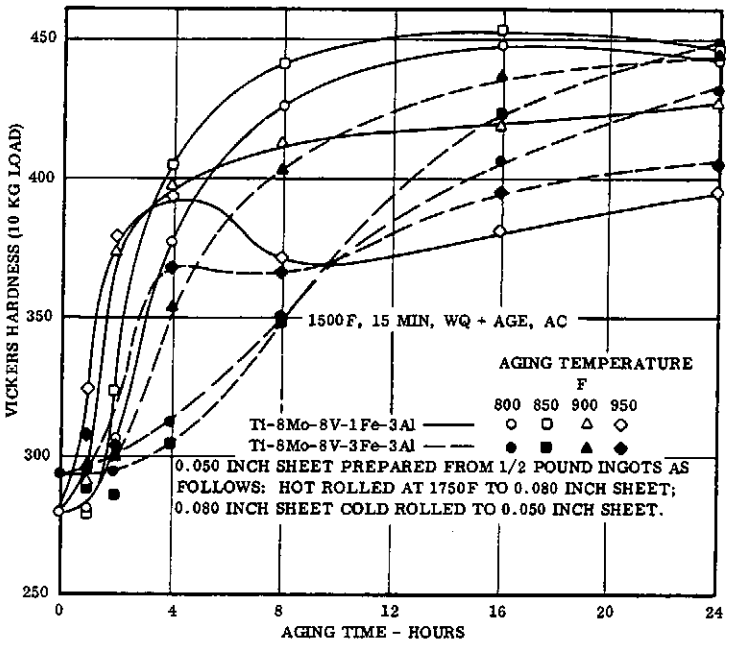


FIG. 1.061 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF SOLUTION TREATED SHEET OF TWO IRON CONTENTS. (3)

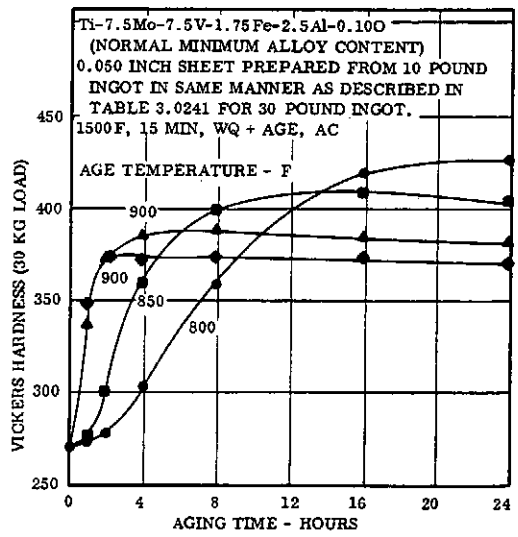


FIG. 1.062 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF SOLUTION TREATED SHEET OF NORMAL MINIMUM ALLOY CONTENT. (4)

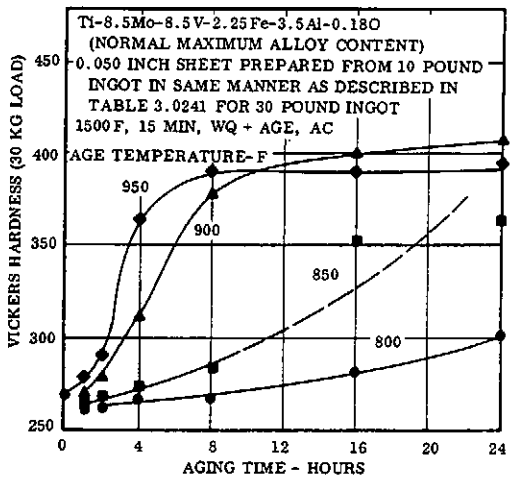


FIG. 1.063 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF SOLUTION TREATED SHEET OF NORMAL MAXIMUM ALLOY CONTENT. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

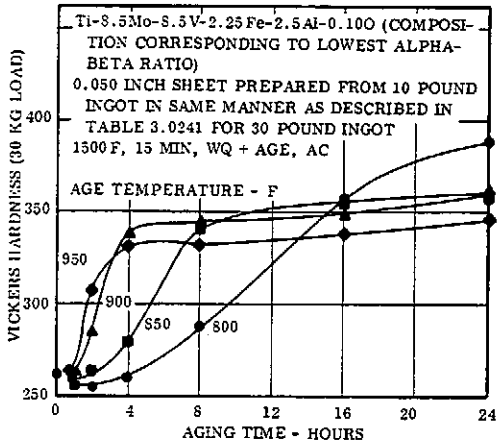


FIG. 1.064 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF SOLUTION TREATED SHEET OF COMPOSITION CORRESPONDING TO LOWEST ALPHA-BETA RATIO. (4)

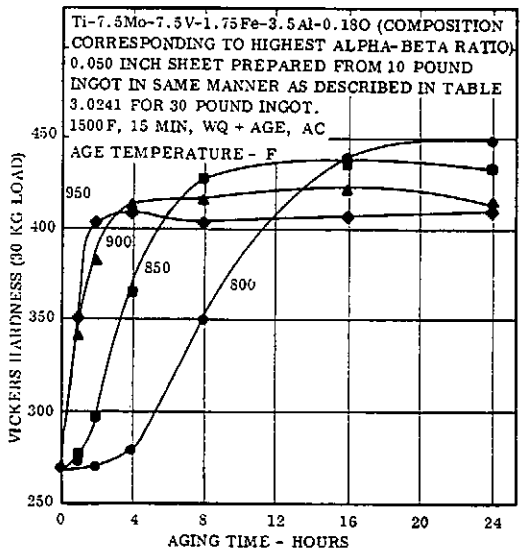


FIG. 1.065 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF SOLUTION TREATED SHEET OF COMPOSITION CORRESPONDING TO HIGHEST ALPHA-BETA RATIO. (4)

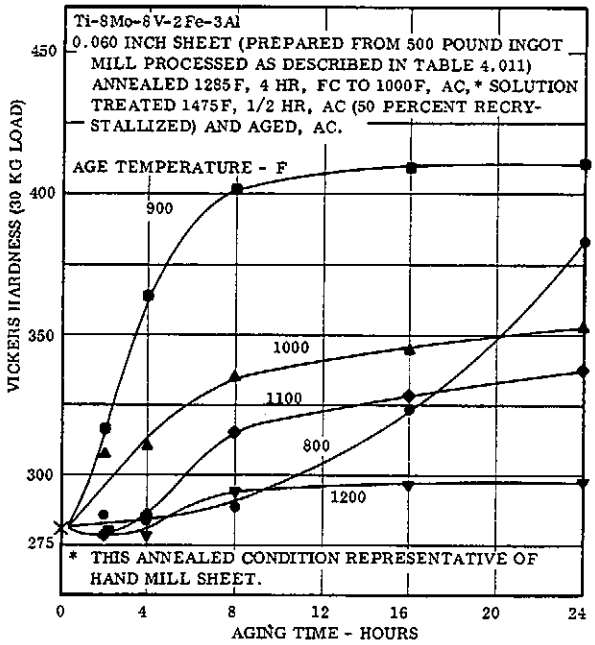


FIG. 1.066 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF ANNEALED SHEET 50 PERCENT RECRYSTALLIZED. (4)

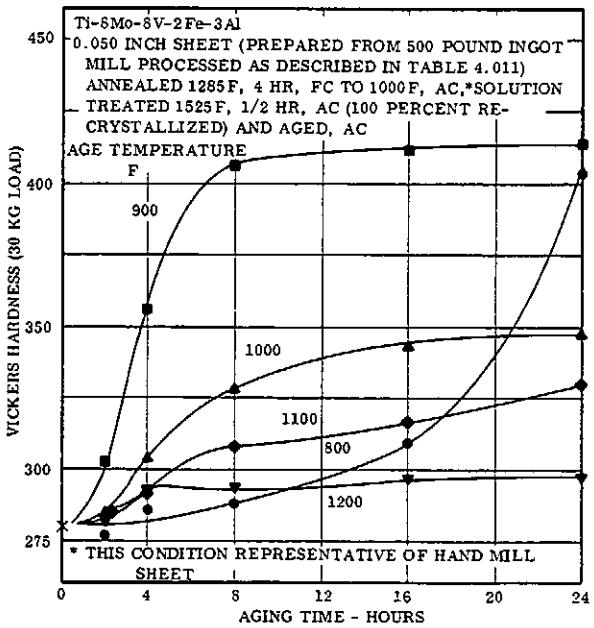


FIG. 1.067 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF ANNEALED SHEET 100 PERCENT RECRYSTALLIZED. (4)

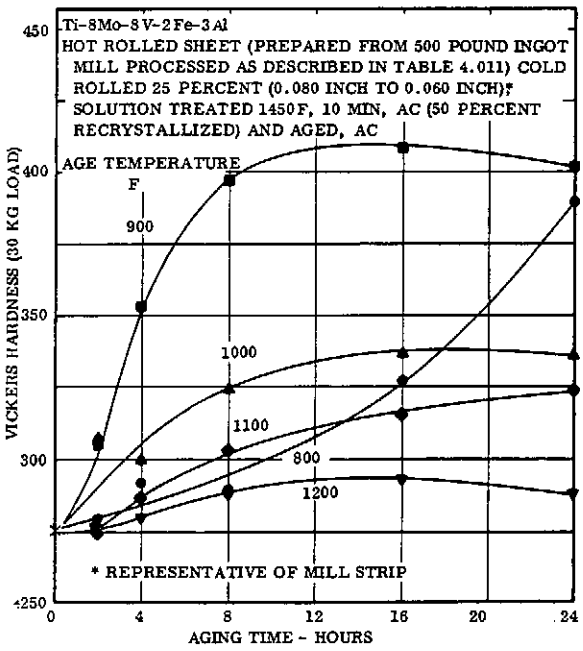


FIG. 1.068 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF 25 PERCENT COLD ROLLED SHEET 50 PERCENT RECRYSTALLIZED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

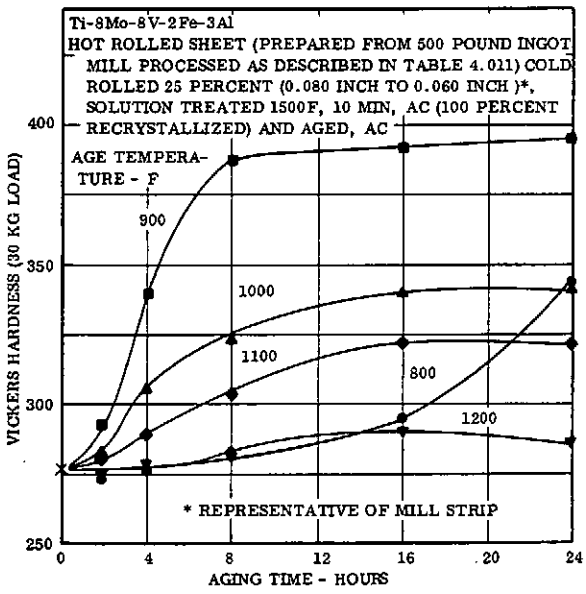


FIG. 1.069 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF 25 PERCENT COLD ROLLED SHEET 100 PERCENT RECRYSTALLIZED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

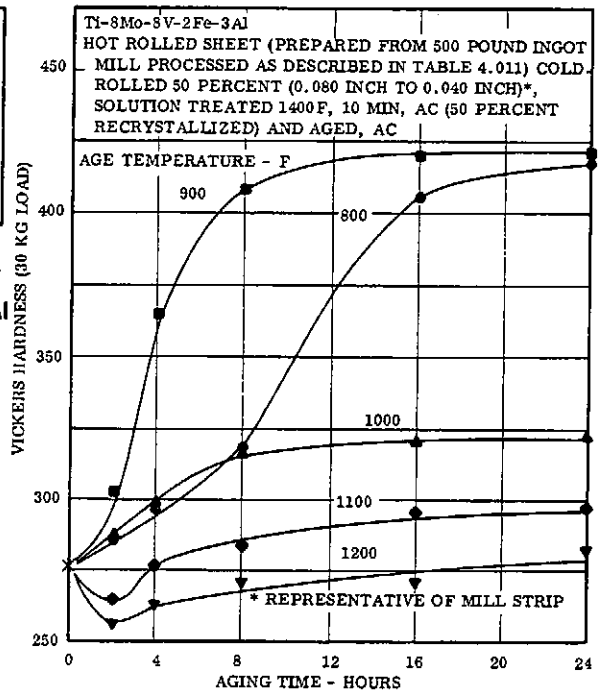


FIG. 1.0610 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF 50 PERCENT COLD ROLLED SHEET 50 PERCENT RECRYSTALLIZED. (4)

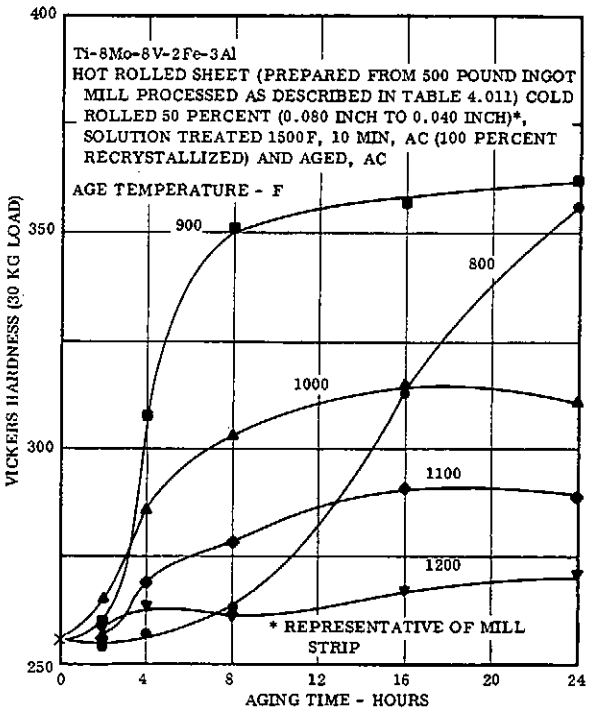


FIG. 1.0611 EFFECT OF AGING TIME AND TEMPERATURE ON HARDNESS OF 50 PERCENT COLD ROLLED SHEET 100 PERCENT RECRYSTALLIZED. (4)

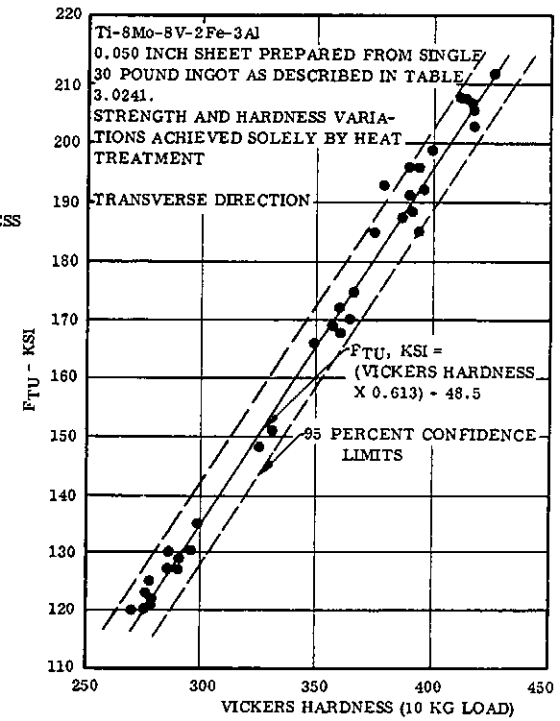


FIG. 1.0612 STATISTICAL RELATIONSHIP BETWEEN HARDNESS AND STRENGTH FOR SHEET. (3)

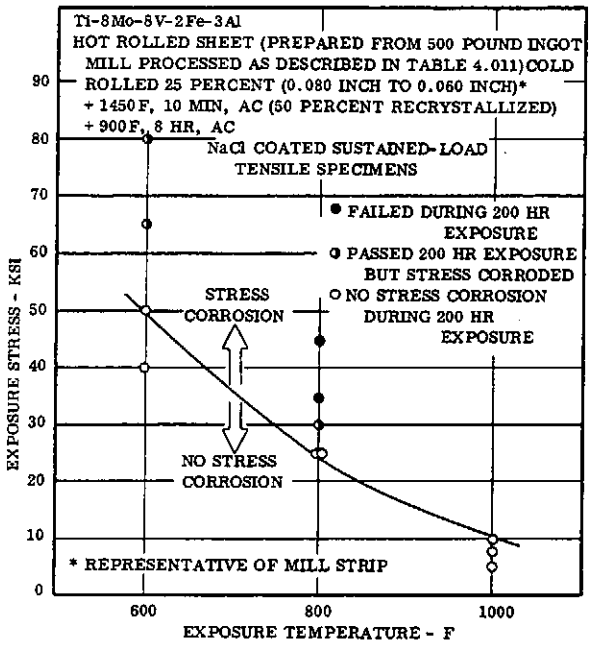


FIG. 2.033 HOT SALT STRESS CORROSION BEHAVIOR OF SIMULATED MILL STRIP SOLUTION TREATED (50 PERCENT RECRYSTALLIZED) AND AGED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

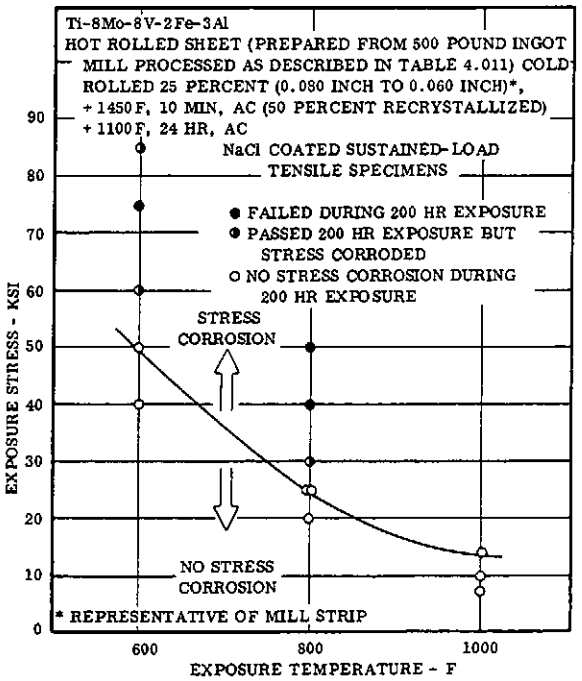


FIG. 2.034 HOT SALT STRESS CORROSION BEHAVIOR OF SIMULATED MILL STRIP SOLUTION TREATED (50 PERCENT RECRYSTALLIZED) AND STABILIZATION AGED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-
8V-2Fe-3Al

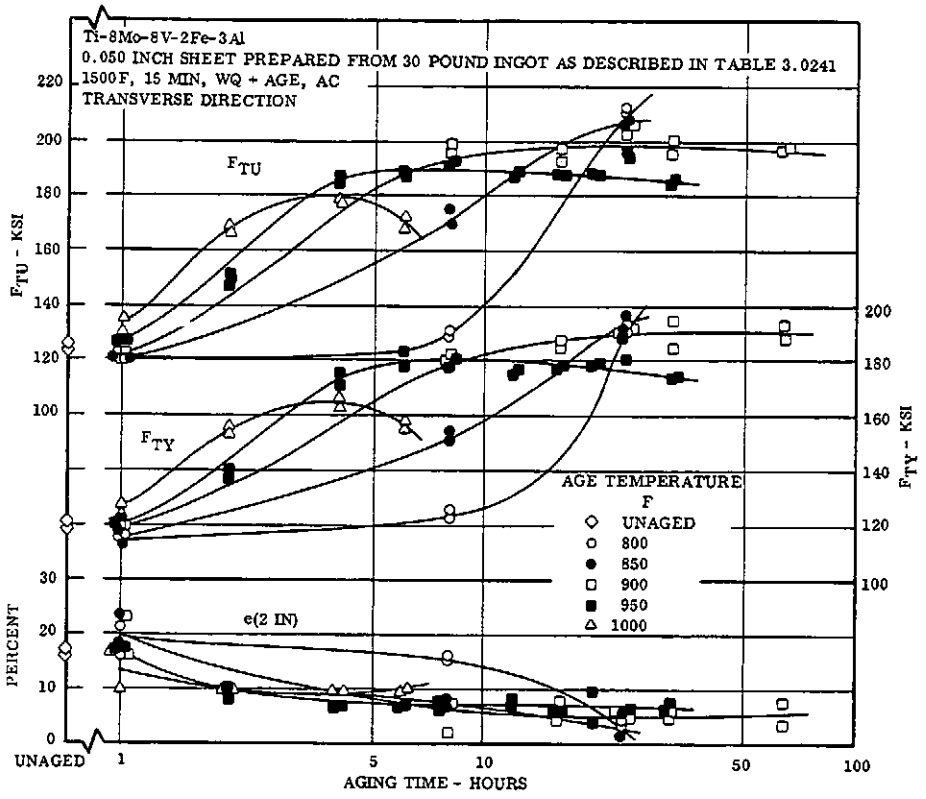


FIG. 3.0214 EFFECT OF AGING TIME AND TEMPERATURE ON TENSILE PROPERTIES OF SOLUTION TREATED SHEET. (3)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

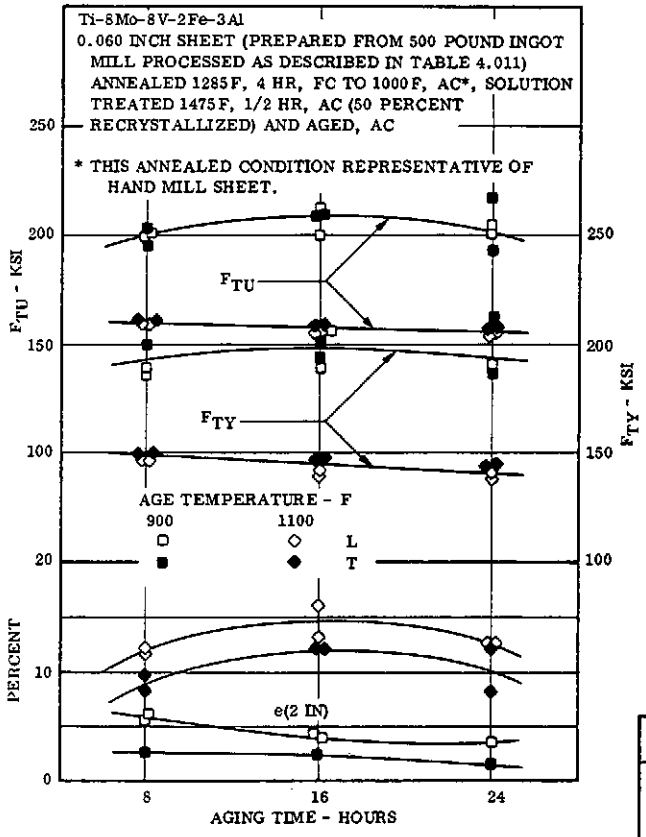


FIG. 3.0215 EFFECT OF AGING TIME AT 900 AND 1100F ON TENSILE PROPERTIES OF ANNEALED, SIMULATED HAND MILL SHEET 50 PERCENT RECRYSTALLIZED. (4)

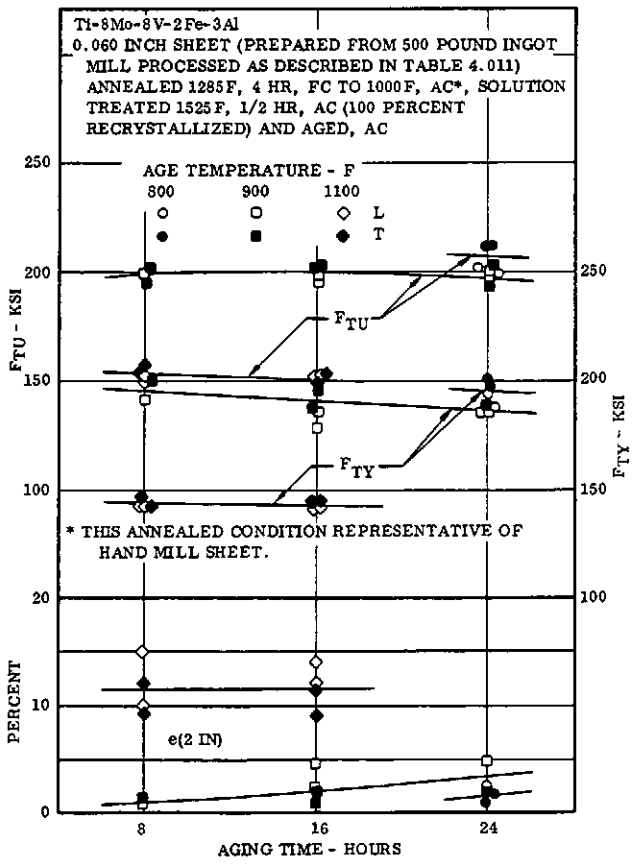


FIG. 3.0216 EFFECT OF AGING TIME AT 800, 900, AND 1100F ON TENSILE PROPERTIES OF ANNEALED, SIMULATED HAND MILL SHEET 100 PERCENT RECRYSTALLIZED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

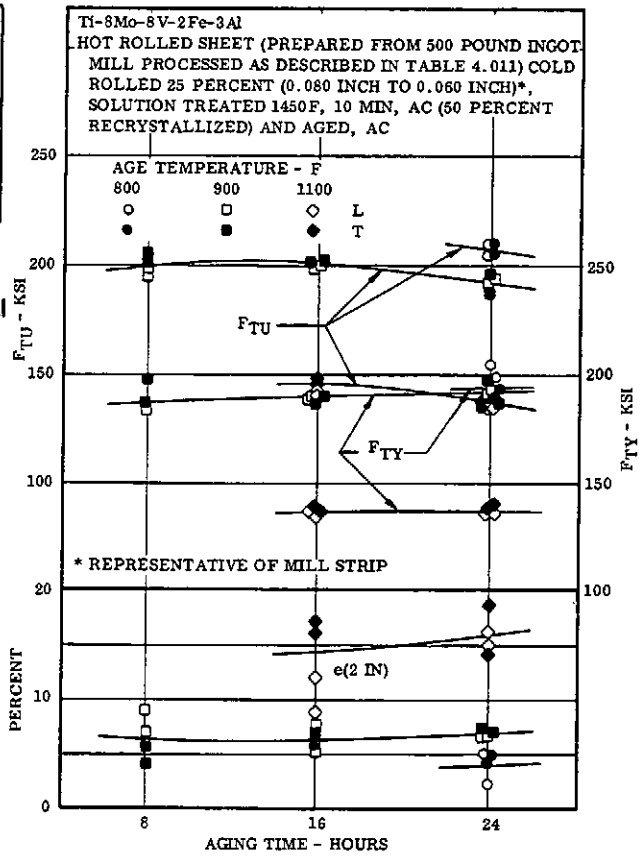


FIG. 3.0217 EFFECT OF AGING TIME AT 800, 900, AND 1100F ON TENSILE PROPERTIES OF 25 PERCENT COLD ROLLED, SIMULATED MILL STRIP 50 PERCENT RECRYSTALLIZED. (4)

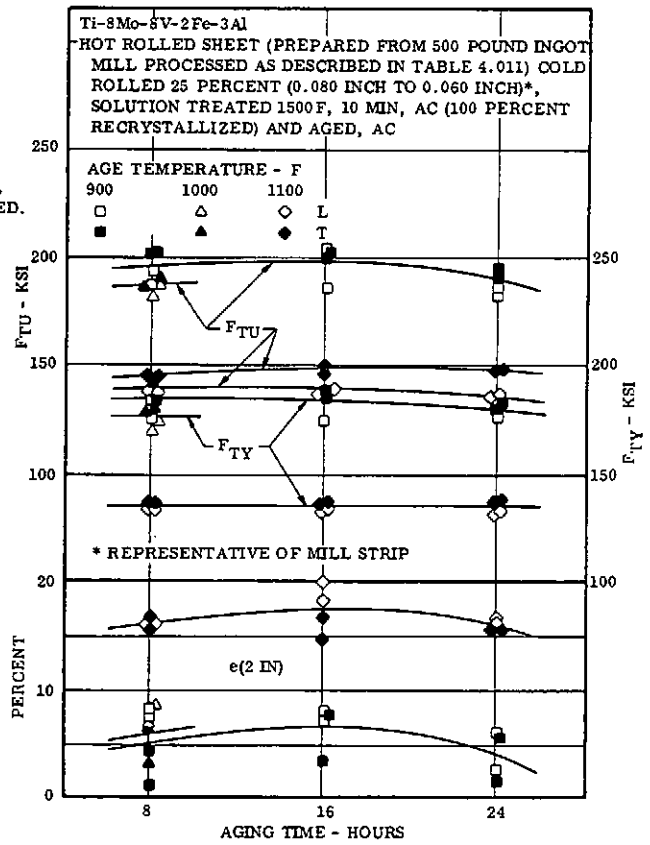


FIG. 3.0218 EFFECT OF AGING TIME AT 900, 1000, AND 1100F ON TENSILE PROPERTIES OF 25 PERCENT COLD ROLLED, SIMULATED MILL STRIP 100 PERCENT RECRYSTALLIZED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

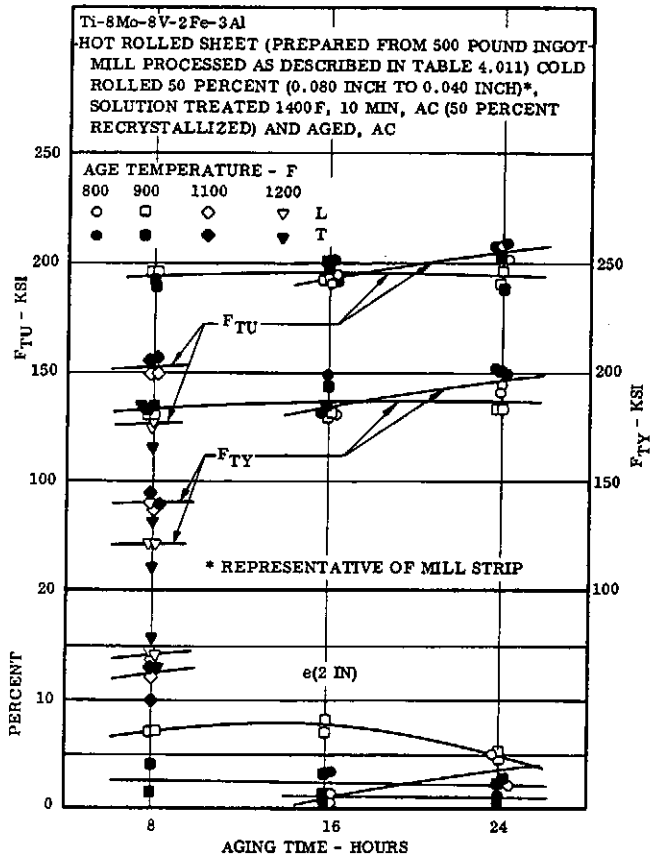


FIG. 3.0219 EFFECT OF AGING TIME AT 800, 900, 1100, AND 1200F ON TENSILE PROPERTIES OF 50 PERCENT COLD ROLLED, SIMULATED MILL STRIP 50 PERCENT RECRYSTALLIZED. (4)

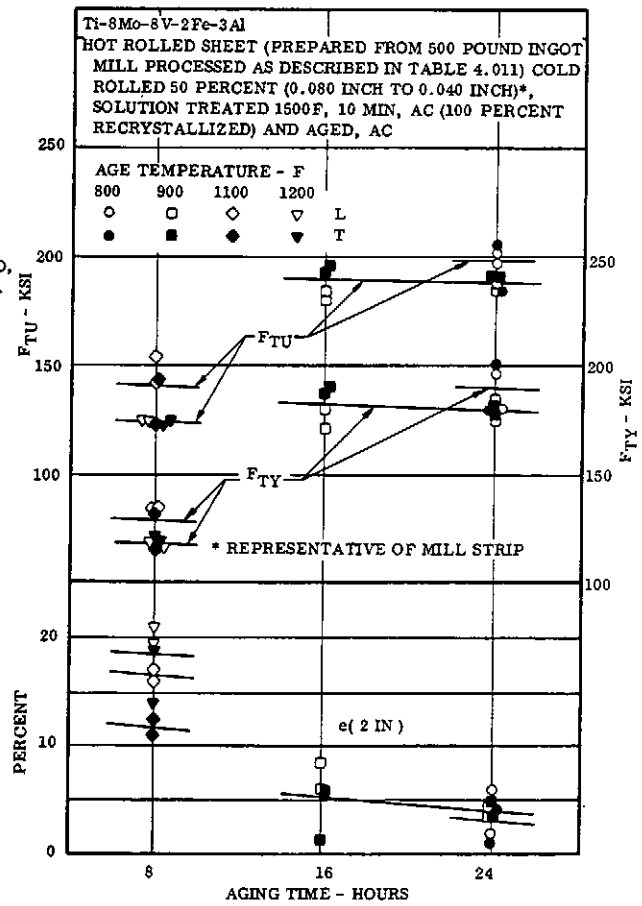


FIG. 3.02110 EFFECT OF AGING TIME AT 800, 900, 1100, AND 1200F ON TENSILE PROPERTIES OF 50 PERCENT COLD ROLLED, SIMULATED MILL STRIP 100 PERCENT RECRYSTALLIZED. (4)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

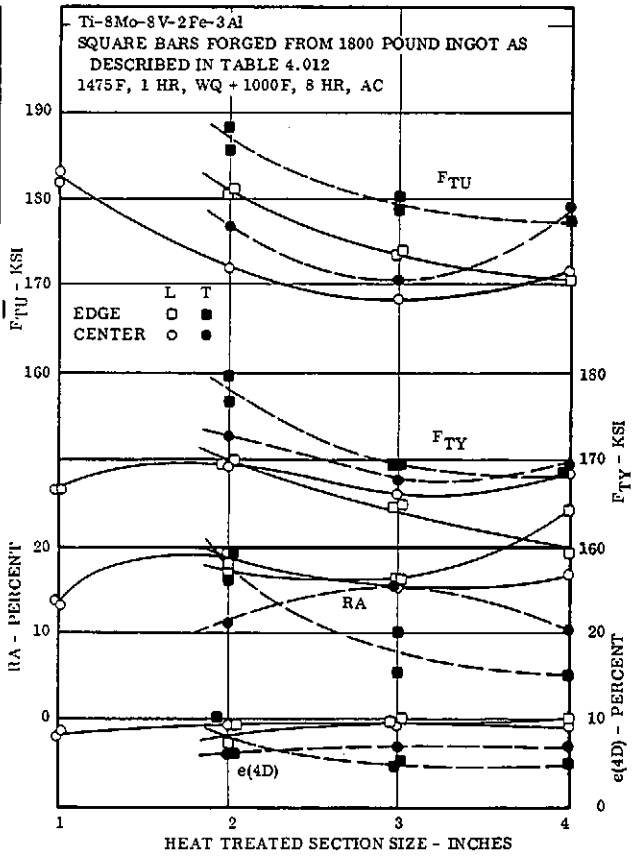


FIG. 3.02113 EFFECT OF HEAT TREATED SECTION SIZE ON TENSILE PROPERTIES OF UNDIRECTIONALLY FORGED BARS. (1)

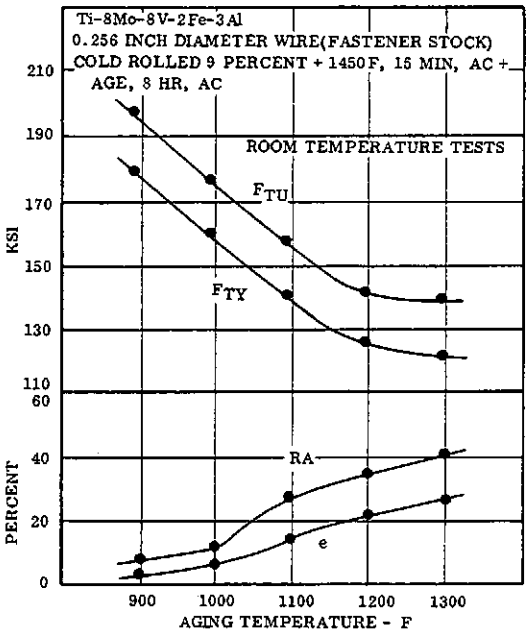


FIG. 3.02116 EFFECT OF AGING TEMPERATURE ON ROOM TEMPERATURE TENSILE PROPERTIES OF COLD ROLLED PLUS SOLUTION TREATED AND AGED FASTENER STOCK. (8)

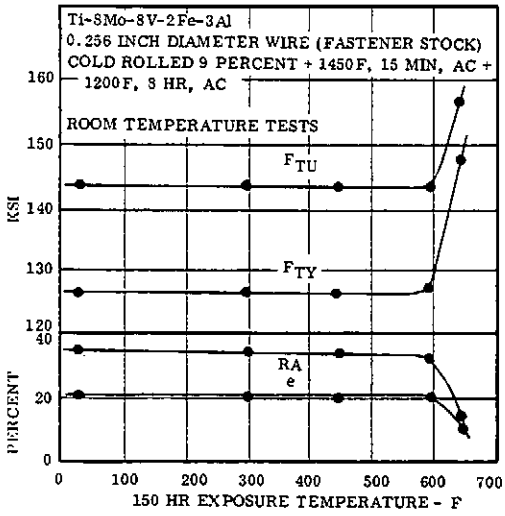


FIG. 3.02122 EFFECT OF 150 HOUR EXPOSURE TO ELEVATED TEMPERATURES ON ROOM TEMPERATURE TENSILE PROPERTIES OF COLD ROLLED PLUS SOLUTION TREATED AND AGED FASTENER STOCK. (8)

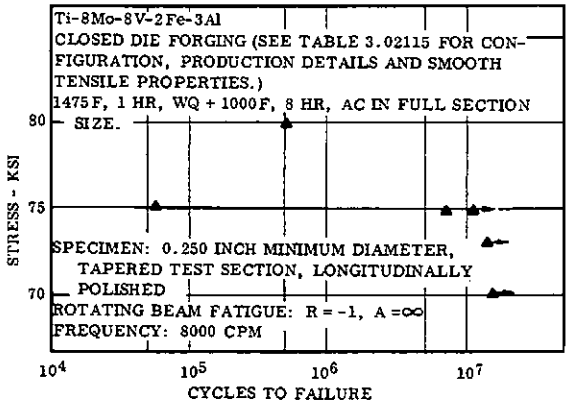


FIG. 3.051 ROOM TEMPERATURE ROTATING BEAM FATIGUE STRENGTH OF SOLUTION TREATED AND AGED CLOSED DIE FORGING. (2)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-8V-2Fe-3Al

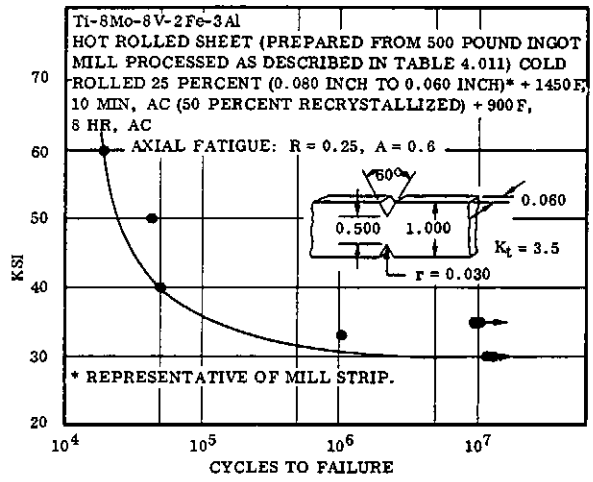


FIG. 3.052 ROOM TEMPERATURE MILD NOTCH FATIGUE STRENGTH OF 25 PERCENT COLD ROLLED, SIMULATED MILL STRIP SOLUTION TREATED (50 PERCENT RECRYSTALLIZED) AND AGED. (4)

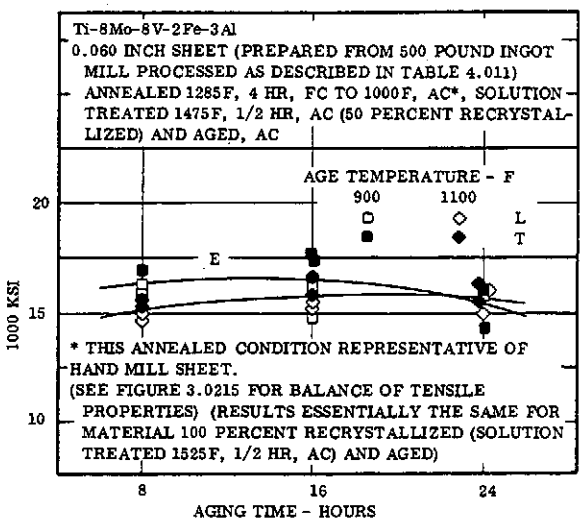


FIG. 3.0624 EFFECT OF AGING TIME AT 900 AND 1100F ON ROOM TEMPERATURE TENSILE ELASTIC MODULUS OF ANNEALED, SIMULATED HAND MILL SHEET 50 PERCENT RECRYSTALLIZED. (4)

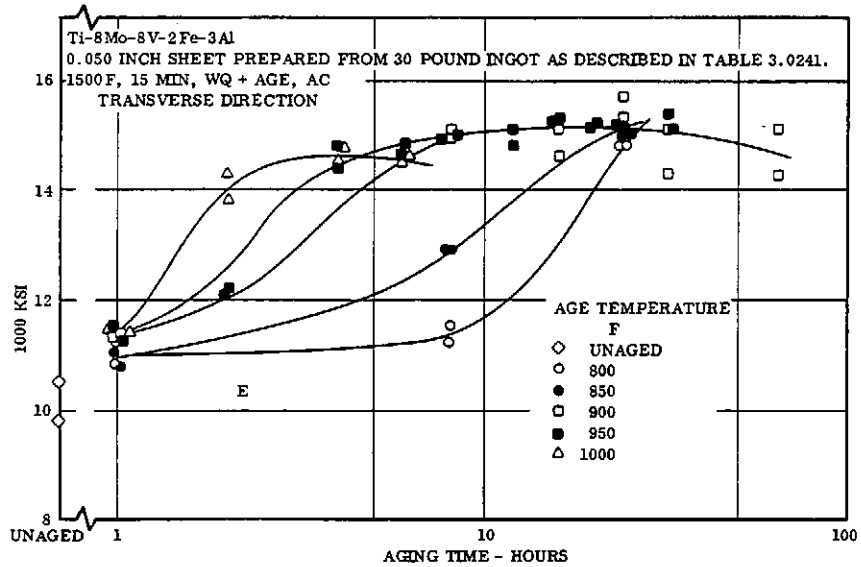


FIG. 3.0623 EFFECT OF AGING TIME AND TEMPERATURE ON ROOM TEMPERATURE TENSILE ELASTIC MODULUS OF SOLUTION TREATED SHEET. (3)

	Ti
8	Mo
8	V
2	Fe
3	Al

Ti - 8Mo-
8V-2Fe-3Al

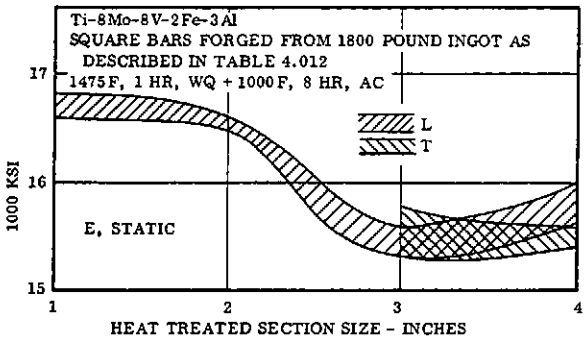


FIG. 3.0627 EFFECT OF HEAT TREATED SECTION SIZE ON ROOM TEMPERATURE TENSILE ELASTIC MODULUS OF FORGED BARS. (1)

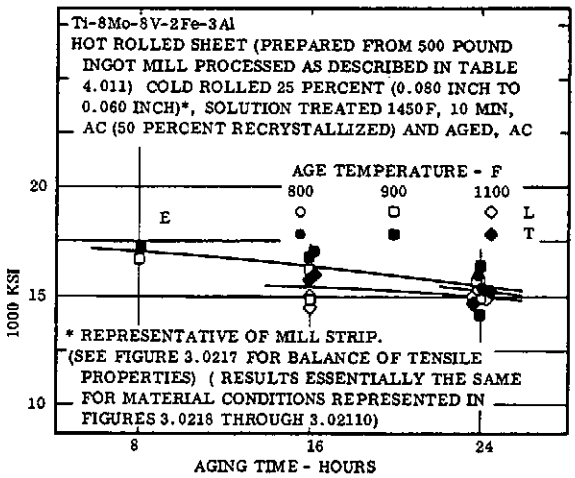


FIG. 3.0625 EFFECT OF AGING TIME AT 800, 900, AND 1100F ON ROOM TEMPERATURE TENSILE ELASTIC MODULUS OF 25 PERCENT COLD ROLLED, SIMULATED MILL STRIP 50 PERCENT RECRYSTALLIZED. (4)

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7. Private communication with J. Partidge of TMCA, Toronto, Ohio.
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11. Private communication with E. von Tiesenhausen of TMCA, Henderson, Nevada.