| | Cb |
|---|---|
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

1. GENERAL

FS-85 is nominally columbium, solution-strengthened with 28 percent tantalum and 10 percent tungsten and dispersion strengthened with 1 percent zirconium. This alloy is commercially available in mill forms such as ingot, plate, sheet, strip, foil, welded tubing and fabricated parts. It has good secondary creep properties and strength at high temperatures and is readily fabricated at room temperature. It can be welded and coated without embrittlement and it has a very low ductile-to-brittle transition. The alloy retains its ductility at a temperature below -320F, (1).

1.01 Commercial Designation

FS-85.

1.02 Alternate Designation

Cb-28Ta-10W-1Zr.

1.03 Specifications

1.031 Fansteel Metallurgical Corporation. Product Specification No. S-82402-R-O, sheet, (2).

1.04 Composition

Table 1.04.

TABLE 1.04

| Source | Fansteel (2) | |
|---|---|---|
| | Percent | |
| | Min | Max |
| Carbon | - | 0.01 |
| Hydrogen | - | 0.001 |
| Oxygen | - | 0.03 |
| Nitrogen | - | 0.015 |
| Tantalum | 26 | 29 |
| Tungsten | 10 | 12 |
| Zirconium | 0.6 | 1.1 |
| Columbium | Balance | |

1.05 Heat Treatment

1.051 Stress relief. 1830F, 1 hour, (3).

1.052 Recrystallize. 2400F, 1 hour, (3).

1.06 Hardness

1.061 Effect of annealing temperature on room temperature hardness of 50 percent cold reduced sheet, Fig. 1.061.

1.062 Room temperature hardness DPH Scale, (2600 gms)
Stress relieved 225 DPH,
Recrystallized 180 DPH, (4).

1.07 Forms and Conditions Available

1.071 The alloy is available as ingot, plate, sheet, strip, foil, welded tubing and fabricated parts, (1).

1.072 Sheet and plate are available in the stress relieved or fully recrystallized condition, (2).

1.08 Melting and Casting Practice

1.081 Alloy is melted and cast using an electron beam furnace and then remelted and cast, using an arc furnace, (1).

1.09 Special Considerations

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting point, 4695F, (4).

2.012 Phase changes

2.0121 Time-temperature-transformation diagrams

2.0122 Crystal structure, bcc, (4).

2.013 Thermal conductivity, Fig. 2.013.

2.014 Thermal expansion, Fig. 2.014.

2.015 Specific heat

2.016 Thermal diffusivity

2.02 Other Physical Properties

2.021 Density. 0.383 lbs per cu in, 10.6 gr per cu cm, (4)(15).

2.022 Electrical properties

2.023 Magnetic properties

2.024 Emissivity

2.025 Damping capacity

2.03 Chemical Properties

2.031 At most temperatures the alloy resists oxidation appreciably better then commercially pure columbium or tantalum, although scaling due to oxidation at high temperatures presents a serious problem in the use of this alloy. Coating with silicides or aluminides is the most promising solution to the oxidation problem. FS-85 can be coated without embrittlement of the base metal, (1).

2.04 Nuclear Properties

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.011 Producer's minimum room temperature mechanical properties, Table 3.011.

TABLE 3.011

| Source | | Fansteel (2) | |
|---|---|---|---|
| Alloy | | Cb-28Ta-10W-1Zr | |
| Form | | Sheet | |
| Condition | | Stress-relief | Recrystall |
| $F_{tu}$, | min-ksi | 90.0 | 70.0 |
| $F_{ty}$, | min-ksi | 80.0 | 50.0 |
| e(2 in) | min-percent | 10.0 | 20.0 |

3.02 Mechanical Properties at Room Temperature

3.021 Tension

3.0211 Stress-strain diagrams

3.0212 Tensile properties of 0.030 inch sheet, Table 3.0212.

TABLE 3.0212

| Source | | (5, p. A-82) | | |
|---|---|---|---|---|
| Alloy | | Cb-28Ta-10W-1Zr | | |
| Form | | Sheet | | |
| Condition | | Stress relief As received | Recrystall 2300F, 1 Hr | Recrystall Cr-Ti-Si Coated |
| Thickness - in | | 0.030 | | |
| $F_{tu}$, | Avg-ksi | 120 | 85.9 | 82.8 |
| $F_{ty}$, | Avg-ksi | 107 | 69.4 | 67.6 |
| e(1 in), | Avg-percent | 10.8 | 22.2 | 17.2 |
| RA, | Avg-percent | 44.4 | 51.8 | 30.1 |

3.0213 Tensile properties of cold worked sheet, Table 3.0213.

TABLE 3.0213

| Source | | (3) | | | |
|---|---|---|---|---|---|
| Alloy | | Cb-28Ta-10W-1Zr | | | |
| Form | | Sheet (cold worked) | | | |
| Condition | | Stress-relief 1830F, 1 hr | As worked | Stress-relief 1830F, 1 hr | Recrystall 2400F, 1 hr |
| Thickness - in | | 0.04 | | 0.063 | |
| $F_{tu}$, | -ksi | 105 | 129 | 109 | 78.9 |
| $F_{ty}$, | -ksi | 95.4 | 119 | 97.6 | 66.4 |
| e(2 in) | -percent | 14 | 5 | 14 | 33 |

| | |
|---|---|
| | Cb |
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

3.0214 Effect of test direction on tensile properties of sheet, Table 3.0214.

TABLE 3.0214

| Source | | (5) | |
|---|---|---|---|
| Alloy | | Cb-28Ta-10W-1Zr | |
| Form | | Sheet | |
| Test - Direction | | L | T |
| $F_{tu}$, | Avg-ksi | 94.5 | 93.3 |
| $F_{ty}$, | Avg-ksi | 78.1 | 76.2 |
| e(1 in) | Avg-percent | 25.2 | 19.8 |

3.022 Compression
3.0221 Stress-strain diagrams
3.023 Impact
3.024 Bending
3.0241 Bend ductility and transition temperature for unwelded and welded sheet, Table 3.0241.

TABLE 3.0241

| Source | (8) | | | |
|---|---|---|---|---|
| Alloy | Cb-28Ta-10W-1Zr | | | |
| Form | 0.050 to 0.050 inch sheet | | | |
| Test | Bend ductility data | | | |
| Producer | Fansteel | | Westinghouse | |
| Condition | Bend radius | Bend transition Temp - F | Bend radius | Bend transition Temp - F |
| Stress relieved | 1t | <-320 | - | - |
| Recrystallized | 1t | <-320 | 3.2t | -280 |
| Stress relieved + TIG welded | 1t | 23 | 3.2t | 25 |
| Stress relieved + TIG welded + 1800F, 1 hr | - | - | 3.2t | -100 |
| Stress relieved + TIG welded + 2100F, 1 hr | 1t | -85 | - | - |

3.025 Torsion and shear
3.026 Bearing
3.027 Stress concentration
3.0271 Notch properties
3.02711 Edge-notched tensile strength of sheet, Table 3.02711.

TABLE 3.02711

| Source | (5) | |
|---|---|---|
| Alloy | Cb-28Ta-10W-1Zr | |
| Form | Sheet | |
| Condition | Stress-relieved | Recrystall |
| Thickness - in | 0.040 | |
| Notch radius - in | 0.00087 | 0.0013 |
| Net fracture strength - ksi | 68.7 | 53.3 |
| Rapid crack length - in | 0 | 0 |

3.0272 Fracture toughness
3.028 Combined properties

3.03 Mechanical Properties at Various Temperatures
3.031 Tension
3.0311 Stress-strain diagrams
3.0312 Effect of test temperature on tensile properties of recrystallized sheet, Fig. 3.0312.
3.0313 Effect of test temperature on tensile properties of stress relieved sheet, Fig. 3.0313.
3.0314 Effect of test temperature on tensile properties of 50 percent cold reduced sheet, Fig. 3.0314.
3.0315 Effect of test temperature on tensile properties of 94.1 percent cold reduced sheet, Fig. 3.0315.
3.0316 Effect of test temperature on tensile properties of recrystallized sheet from room temperature to 2600F, Fig. 3.0316.
3.0317 Effect of elevated temperatures on sheet, Fig. 3.0317.
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
3.0372 Fracture toughness
3.038 Combined properties

3.04 Creep and Creep Rupture Properties
For alloy, recrystallized 2600F, 1 hour, the time for total strain of 2 percent at 10 ksi stress at 2000F is 1400 hours.
3.041 Creep rupture curves at 2000F to 2600F, Fig. 3.041.
3.042 Secondary creep rate curves at 2000F to 2600F, Fig. 3.042.
3.043 Creep rupture curves at 1800F to 2600F for 94.1 percent cold reduced sheet, Fig. 3.043.
3.044 Effect of temperature on total elongation in 300 hours, stressed to 4 ksi, Fig. 3.044.
3.045 Total creep strain curves for sheet at 2000 and 2200F, Fig. 3.045.
3.046 Master parameter curve for alloy, Fig. 3.046.
3.047 Creep rupture properties of sheet at 2000 and 2400F, Fig. 3.047.
3.048 Effect of time on total creep extension, Fig. 3.048
3.049 Creep properties of recrystallized alloy, Table 3.049.

TABLE 3.049

| Source | (11) | | |
|---|---|---|---|
| Alloy | Cb-28Ta-10W-1Zr | | |
| Form | Not given | | |
| Condition | Recrystallized | | |
| Temp - F | Stress-ksi | Time-hr | Total e, % |
| 2000 | 10 | 1400 | 2 |
| 2200 | 4 | 300 | 0.26 |
| 2400 | 4 | 300 | 3.35 |

3.05 Fatigue Properties

3.06 Elastic Properties
3.061 Poisson's ratio
3.062 Modulus of elasticity
3.0621 Effect of temperature on modulus of elasticity in tension for cold reduced sheet, Fig. 3.0621.
3.063 Modulus of rigidity

4. FABRICATION

4.01 Formability
4.011 The alloy may be formed, blanked, spun and drawn readily at room temperature, (4).

4.012 The alloy retains its ductility at a temperature below -320F. Bend ductility at -320F of alloy, Table 4.012.

TABLE 4.012

| Source | (1) | | |
|---|---|---|---|
| Alloy | Cb-28Ta-10W-1Zr | | |
| Condition | As Rolled | Stress Reliev | Recrystall |
| Test Temp - F | -320 | | |
| Bend Radius | 1T | 2T | 4T |
| | Bend Angle, Degrees | | |
| Ram Speed | | | |
| 0.1 in/min | 90 | 121 | 129 |
| | 123 | - | 135 |
| | - | - | 140 |
| 1 in/min | 98 | - | 108 |
| | 105 | - | 110 |
| 10 in/min | 110 | - | 112 |

4.02 Machining and Grinding

4.021 Machining characteristics are similar to those of other columbium alloys, it has a tendency to gall and tear unless proper techniques are used. In machining, high speed steel tools with high cutting speeds have been found most satisfactory. Tools should be kept sharp and should be ground with as much protective rake as the strength of the tool will withstand. Carbon tetrachloride or tri-chloroethane is recommended as the cutting medium and the work must be kept well flooded at all times, (3).

4.03 Welding. See also 3.0241.

4.031 Good tungsten inert gas or electron beam techniques produce weldments without embrittlement or other property alterations, (1).

4.032 Bend ductility of butt-welded sheet, Table 4.032.

TABLE 4.032

| Source | (1) | | | | (3) | | | |
|---|---|---|---|---|---|---|---|---|
| Alloy | Cb-28Ta-10W-1Zr | | | | | | | |
| Condition | 1 | | 2 | | 1 | 2 | 3 | 4 |
| Ram-speed | 1 in per minute | | | | 10 in per minute | | | |
| Temp - F | >14 | <32 | >-96 <-76 | | 14 | -112 | -31 | -112 |
| Bend radius | 1t | 4t | 1t | 4t | 1t | 1t | 1t | 1t |
| Bend angle (°) | 105 | 105 | 105 | 105 | 125 | 125 | 125 | 125 |

1. Stress relieved as welded
2. Stress relieved, welded, stress relieved again
3. Recrystallized, as welded
4. Recrystallized, welded and stress relieved

4.033 Hardness data indicate that the softest portion of the alloy weldments are the heat-affected zones, while the bare material is slightly harder than the fusion zones. The Vickers hardness number (5-Kg load) average 223 VHN in base material, 199 VHN at heat affected zone and 219 VHN in the fusion zone, (7, p. 9, 11).

4.034 For 6 mil-material, slightly lower weld efficiencies were obtained at all test temperatures with electron beam welding as compared to TIG welding, (16).

4.035 Brazing

4.0351 Effect of brazing temperature and brazing cycle on tensile properties of foil, Table 4.0351.

TABLE 4.0351

| Source | (10) | | | |
|---|---|---|---|---|
| Alloy | Cb-28Ta-10W-1Zr | | | |
| Form | Foil | | | |
| Condition | (a) | | | As Received* |
| Thickness - in | 0.006 | | | |
| Brazing Temp - F | 2600 | 2800 | 3000 | Simulated Brazing Cycle |
| $F_{tu}$, -ksi (avg) | 79 | 78.5 | 79 | 94.7 |
| e(0.5 in) -percent | 23 | 24 | 20.5 | 14.5 |

* Strain rate: 0.003 in per in per minute (elastic range)

(a) Following various 5-minute vacuum-brazing cycles in the 2600 to 3000F range
Average cooling rate = 3000F/min to 1200F

4.04 Heat Treatment

4.05 Surface Treatment
See 2.031.

| | Cb |
|---|---|
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

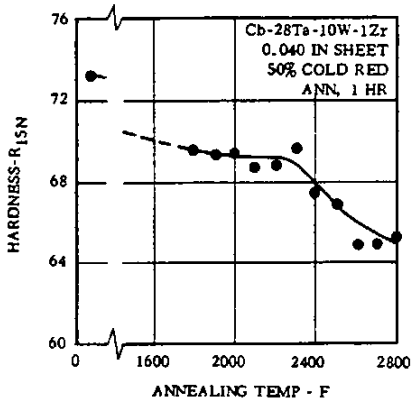


FIG. 1.061 EFFECT OF ANNEALING TEMPERATURE ON ROOM TEMPERATURE HARDNESS OF 50 PERCENT COLD REDUCED SHEET (3)

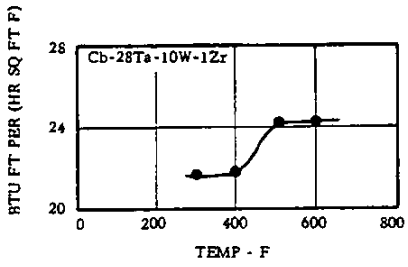


FIG. 2.013 THERMAL CONDUCTIVITY (5, p. A-79)

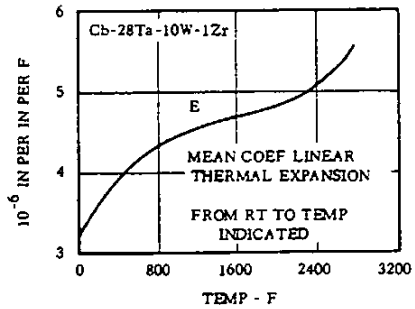


FIG. 2.014 THERMAL EXPANSION (4)

(a) Converted from total expansion data

| | |
|---|---|
| | Cb |
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

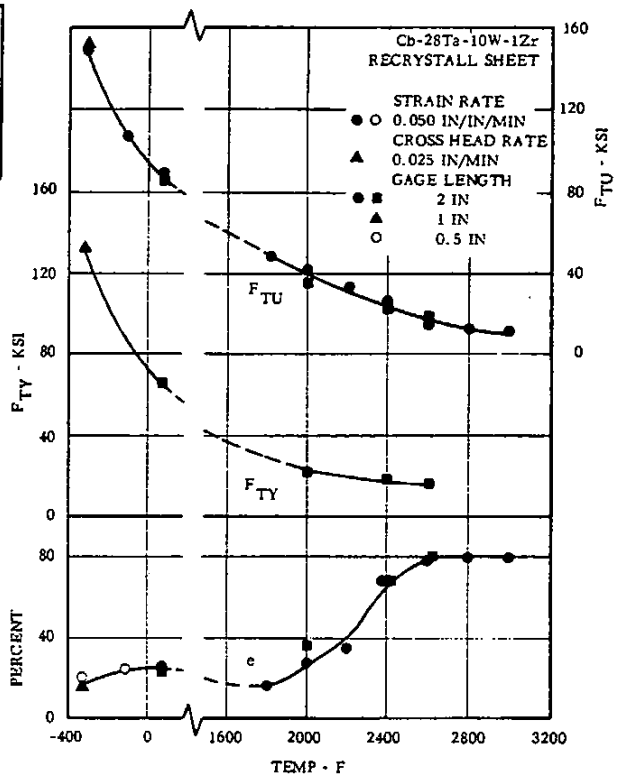


FIG. 3.0312 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF RECRYSTALLIZED SHEET (1)

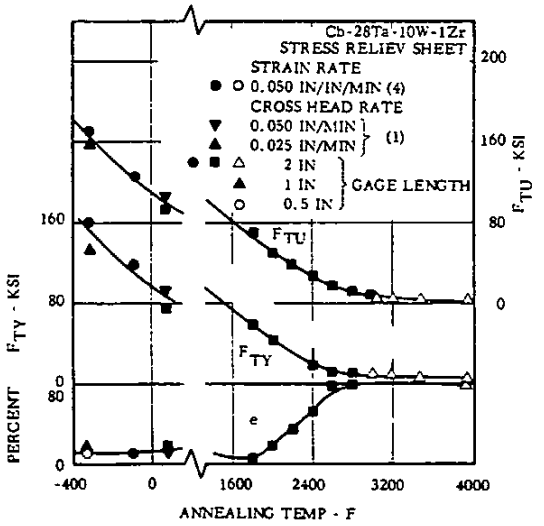


FIG. 3.0313 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF STRESS RELIEVED SHEET (1) (4)

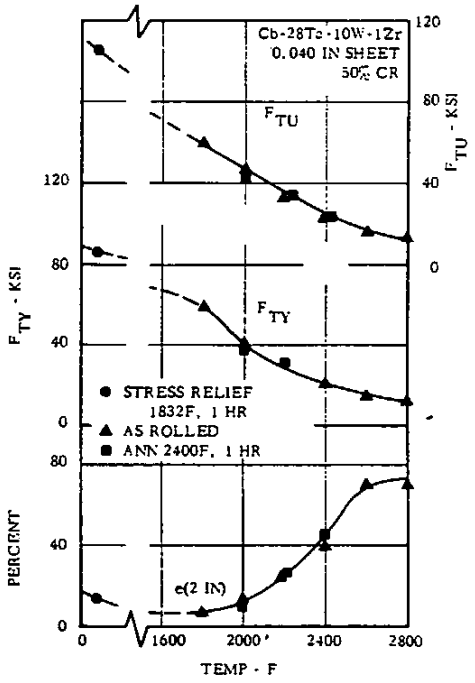


FIG. 3.0314 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF 50 PERCENT COLD REDUCED SHEET (3)

| | |
|---|---|
| | Cb |
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

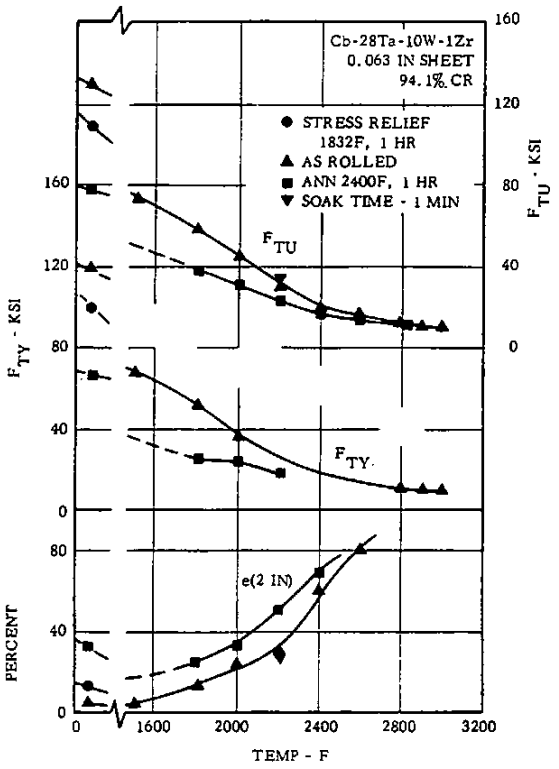


FIG. 3.0315 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF 94.1 PERCENT COLD REDUCED SHEET (3)

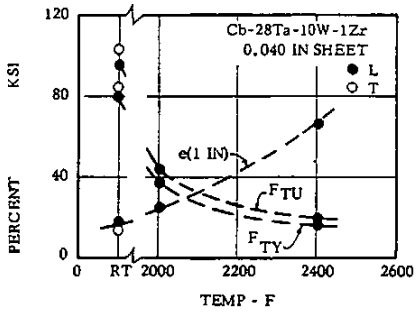


FIG. 3.0317 EFFECT OF ELEVATED TEMPERATURES ON SHEET (14)

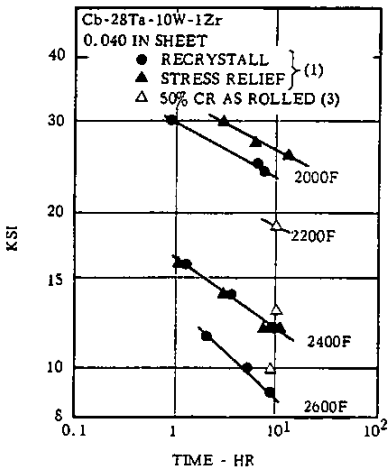


FIG. 3.041 CREEP RUPTURE CURVES AT 2000F TO 2600F (1)(3)

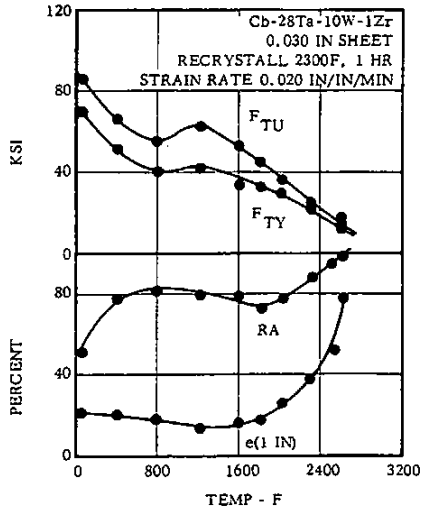


FIG. 3.0316 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF RECRYSTALLIZED SHEET FROM ROOM TEMPERATURE TO 2600F (5, p. A-83)

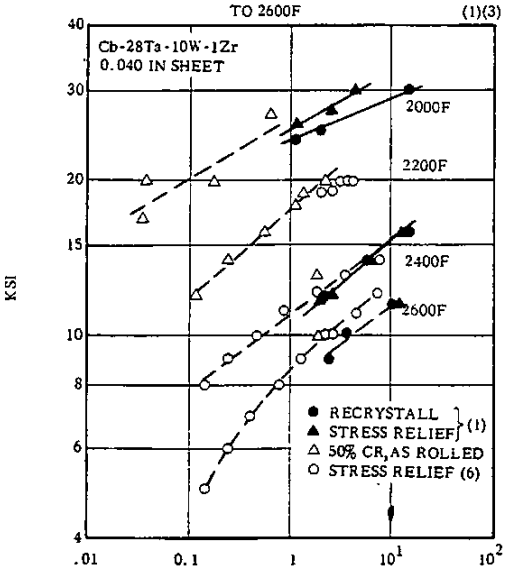


FIG. 3.042 SECONDARY CREEP RATE CURVES AT 2000F TO 2600F (1)(3)(6, p. A 74)

| | |
|---|---|
| | Cb |
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

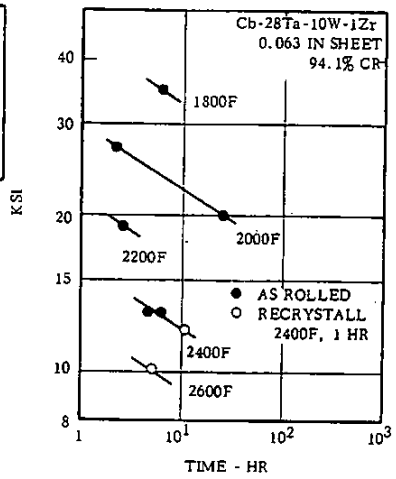


FIG. 3.043 CREEP RUPTURE CURVES AT 1800F TO 2600F FOR 94.1 PERCENT COLD REDUCED SHEET (3)

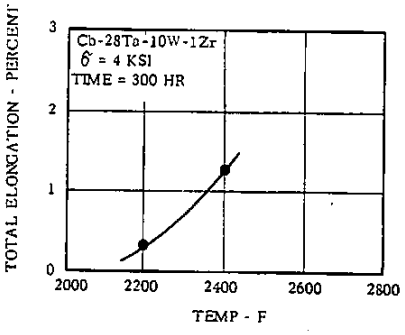


FIG. 3.044 EFFECT OF TEMPERATURE ON TOTAL ELONGATION IN 300 HOURS STRESSED TO 4 KSI (1)

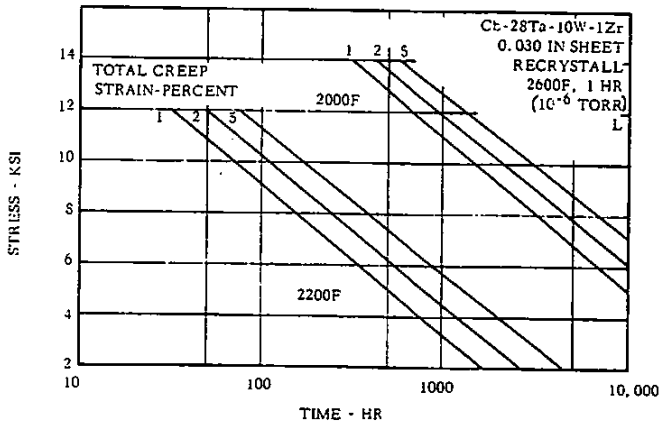


FIG. 3.045 TOTAL CREEP STRAIN CURVES FOR SHEET AT 2000 AND 2200F (Ref. 9)

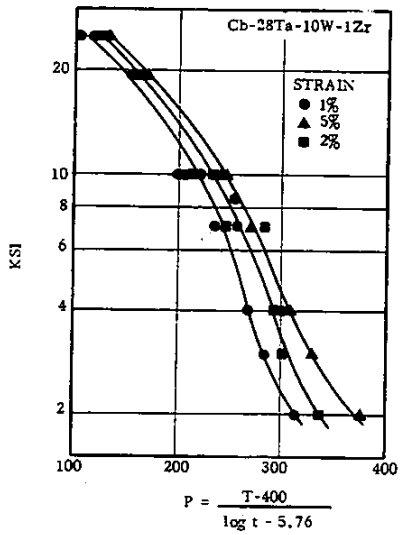


FIG. 3.046 MASTER PARAMETER CURVE FOR ALLOY (12)

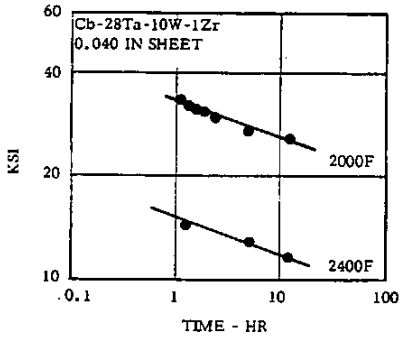


FIG. 3.047 CREEP RUPTURE PROPERTIES OF SHEET AT 2000 AND 2400F (14)

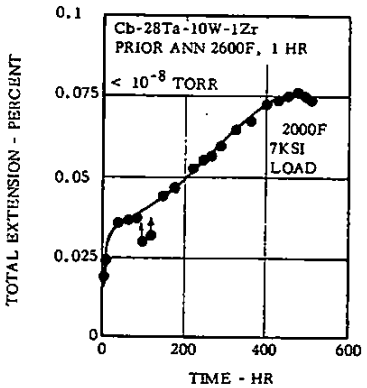


FIG. 3.048 EFFECT OF TIME ON TOTAL CREEP EXTENSION (11)

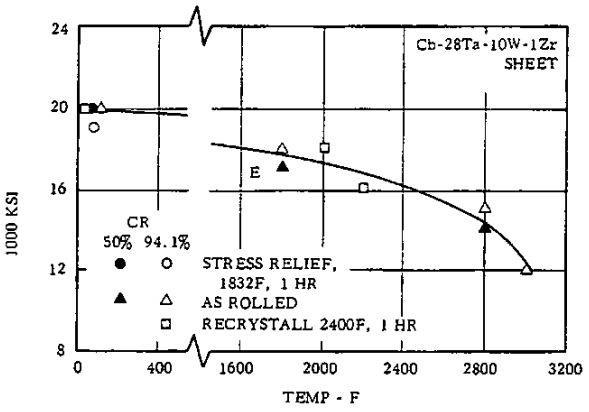


FIG. 3.0621 EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY IN TENSION FOR COLD REDUCED SHEET (3)

| | |
|---|---|
| | Cb |
| 28 | Ta |
| 10 | W |
| 1 | Zr |

FS-85

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