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NONFERROUS ALLOYS

	Cb
10	W
10	Hf
0.1	Y

Cb-129 Y

1. GENERAL
This columbium base alloy was developed to have good fabricability and ductility. Its suggested upper operating limit is approximately 3000F but, as with all such alloys, must be protected to prevent oxidation. Welding and coating cycles are much less detrimental to the strength and ductility of Cb-129Y than such age-strengthened alloys as D-43. It is available in commercial forms and quantities (1).

1.01 Commercial Designation
Cb-129Y

1.02 Alternate Designations
WC-129Y, C-129Y.

1.03 Specifications
AGC-44141-Alloy B (Aerojet General); BMS 7-130 (Boeing); MT 1-5A, Mt 2-13 - Type II (TRW Space Systems).

1.04 Composition
Table 1.04.

1.05 Heat Treatment
Typical mill product is furnished in the fully recrystallized condition achieved by a one hour heat treatment at 2400F (1). This same cycle is used as a post weld anneal (3). An ASTM grain size No. 6 or less is achieved by this cycle (1)(3). In process annealing is carried out at 1800F (1)(3).

1.06 Hardness
The hardness of recrystallized sheet and plate is usually DPH 220 (1)(3)(4).

1.07 Forms and Conditions Available
All common mill product forms are available as a product of 13 inch diameter ingots (1).

1.08 Melting and Casting Practice
Conventional practice uses an electron beam melted master alloy of Cb + 10 percent W followed by double arc melting of the master alloy with 10 percent HF and Y addition. The arc cast ingot is then extruded at 2225F to sheet bar followed by warm rolling, conditioning and cold rolling to sheet (1)(5).

1.09 Special Considerations
1.091 Heating of Cb-129Y to incandescent temperatures for short times results in a contaminated surface. All testing and heat treatments should be in a vacuum better than 10^{-5} torr, or in ultra pure He or H and wrapped in Ta foil. High dew point (≥-40F) environments must be avoided.
1.092 Creep testing for periods over 100 hours at 1800F or above must be conducted in a vacuum of 10^{-8} torr or less.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties
2.011 Melting range - 4350 ± 90F (1).
2.012 Phase changes.
2.013 Thermal conductivity, Figure 2.013 (1).
2.014 Thermal expansion.
Thermal coefficient of expansion is 3.82×10^6 in/in/F from 72 to 2010F and 4.47×10^6 in/in/F from 72 to 4015F (1).
2.015 Specific heat. Figure 2.015.
2.016 Thermal diffusivity.
2.017 Enthalpy, Figure 2.017.

2.02 Other Physical Properties
2.021 Density, 0.343 lbs/cu in (1).
2.022 Electrical properties.
2.023 Magnetic properties.
2.024 Emittance.
2.025 Damping capacity.

2.03 Chemical Properties
2.031 Exposure of Cb-129Y to potassium in a refluxing capsule test for 5000 hrs at 2215F indicated a slight weight gain comparable to Cb-1Zr (6).
2.032 Activation energy (ΔH) for the diffusion of interstitials into Cb-129Y has been measured as 39,000 ± 7380 cal/mole (5).

2.04 Nuclear Properties

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.02 Mechanical Properties at Room Temperature
3.021 Tension.
3.0211 Effect of tensile prestrain and stress relief on the mechanical properties, Table 3.0211.
3.022 Compression.
3.023 Impact.
3.024 Bending.
3.0241 Bend tests on recrystallized sheet material, Table 3.0241.
3.0242 Bend test on stress relieved 0.035 in sheet (1800F, 1 hr) gives less than 1t bend through 90° at room temperature (1).
3.025 Torsion and shear.
3.026 Bearing.
3.027 Stress concentration.
3.0271 Notch properties.
3.0272 Fracture toughness.
3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures
3.031 Tension.
3.0311 Tensile properties from room temperature to 3500F, Figure 3.0311.
3.0312 Elevated temperature tensile properties of annealed base metal and GTA welds, Figure 3.0312.
3.032 Compression.
3.033 Impact. (See 4.042 for ballistic/oxidation data).
3.034 Bending.
3.0341 In the recrystallized condition (2400F for 1 hour) 0.035 inch sheet has a 1t bend through 105° at room temperature and -320F (1)(3)(8).
3.0342 Ductile-to-brittle transition curves for base metal and welded sheet, Figure 3.0342.
3.0343 Base metal Cb-129Y 0.025 in sheet coated with an aluminide ceramic successfully passed a 2t bend through 105° at RT while welded (GTA) and coated sheet passed the same test at RT.
3.035 Torsion and shear.
3.036 Bearing.
3.037 Stress concentration.
3.038 Combined properties.

3.04 Creep and Creep Rupture Properties
3.041 Creep curves for sheet at 2000 and 2200F, Figure 3.041.
3.042 Creep curves for sheet at 2500 and 3000F, Figure 3.042.
3.043 Creep rupture properties of cold worked sheet at 2227F, Figure 3.043.
3.044 Creep rupture properties of cold worked sheet at 2020F, Figure 3.044.
3.045 Creep rupture properties of cold worked sheet at 1822F, Figure 3.045.
3.046 Effect of annealing temperature on the creep rupture properties of sheet, Figure 3.046.
3.047 Effect of annealing temperature on rupture ductility, Figure 3.047.
3.048 Secondary creep rate versus stress, Figure 3.048.

3.05 Fatigue Properties
3.051 In a thermal fatigue test TRW TiCr-Si coated gas turbine vane specimens were subjected to a JP-5 burner test cycle of one minute at the temperatures indicated below, followed by a 30 second air blast to reduce the vane temperature to about 200F. The vanes were rotated at 1850 RPM during thermal exposure. These specimens

did not show oxidation after:
600 cycles at 2200F, followed by
400 cycles at 2400F, followed by
400 cycles at 2500F (4).
Specimens were cold formed from 0.050 in sheet with a leading edge radius of 2.5t. The trailing edges were joined by manual GTA (Argon at -40 dew point or lower).

3.06 Elastic Properties
3.061 Poisson's ratio.
3.062 Modulus of elasticity.
3.0621 Static modulus of elasticity, Figure 3.0621.
3.0622 Dynamic modulus as percent of static modulus, Figure 3.0622.
3.063 Modulus of rigidity.

4. FABRICATION

4.01 Formability
4.011 Shear spin. Both 30 inch and 60 inch conical preform cones were satisfactorily shear spun from a blank 8 inch diameter by 0.125 inch thick. Total wall reductions of 75 percent were reported, however, it is recommended initial breakdown be limited to 30 to 40 percent reduction (1).
4.012 Beaded panel forming. Using a Verson-Wheelon press employing hydraulic fluid for the approximately 4000 psig pressure medium, 0.012 inch sheet was formed into heat shield panels with bead heights in the range of 0.35 to 0.37 inch. A stress relief of 1.5 hours at 2400F after 10 to 12 percent strain is recommended. Maximum stretch achieved was 17 percent in one inch before cracking. Oxygen contamination from heat treating will cause loss of ductility (2)(7).

4.02 Machining and Grinding
4.021 The machining and grinding of this alloy is similar to D-43, Code 5204.

4.03 Welding
4.031 General. The importance of a low vacuum (10^{-5} Torr) or high purity He or A atmosphere (less than -40F dew point) in the welding of this alloy, as well as all Cb base alloys cannot be overemphasized. However, the yttrium addition does allow more tolerance for contamination than other high strength Cb alloys (1). Non-chamber GTA welds have been made with 1t room temperature bend ductility, provided that adequate gas coverage was used during welding. Representative mechanical properties of these weldments is given in Table 4.031. Tolerance for oxygen contamination is demonstrated by the fact that samples with up to 600 ppm oxygen were found to have 2t bend ductility at room temperature in the as-welded condition.
4.032 GTA weld parameters of 30 inches per minute, 3/8 inch clamp spacing, and 110 amperes followed by a 2400F for 1 hour post weld anneal produced optimum weldments in 0.035 inch sheet. Such weldments had a -200F and -225F longitudinal and transverse bend ductile brittle transition temperature, respectively, at a 1t bend radius and a weld width of 0.180 to 0.130 (top to bottom) (3)(8).
4.033 Plate, measuring to 0.375 inch in thickness was welded using manual helium shielded GTA and U-joint preparation. This plate was warm reduced 75 percent and recrystallized at 2400 F for one hour. Specimens measuring 1.5 inches by 6 inches were subjected to 16t, 8t, and 3t bends. As welded longitudinal specimens exhibited full ductile bends at all three radii. As welded transverse specimens exhibited full section cleavage at 8t bends (40 - 60°), however a post weld anneal (2400F for 1 hr) provided full bend ductility up to 3t bend (3)(8).
4.034 Effect of annealing on GTA weld-bend ductility. Figure 4.034.
4.035 Nitrogen contamination of 1.6 percent in the helium shield reduced the ductile bend transition temperature from -235F to 15F when GTA welding at 8 IPM. The fusion zone of the weldment contained 300 to 400 ppm N_2 (11).

4.04 Surface Treatment
4.041 Oxidation data for the Boeing Disil coated sheet, Table 4.041.
4.042 Ballistic impact test data of coated sheet, Table 4.042.
4.043 Specimens coated with modified TRW TiCr-Si exhibited resistance to failure after 100 hrs at 2200F plus 40 hours at 2400F (4) using test sequence described in 3.051. Other data using the same coating but different test conditions showed lives of 218 hours at 2400F before edge failure and 24 - 120 hours at 1600F (12).

Source	(1)		(2)(a)	(3)(b)
	percent		percent	percent
	min	max		
Hafnium	9	11	10.0	10.1
Tungsten	9	11	9.7	10.85
Yttrium	0.05	0.3	0.07	0.105
Tantalum		0.5	0.37	-
Zirconium		0.7	0.24	-
Carbon		0.02	0.005	0.008
Oxygen		0.022	0.005	0.011
Hydrogen		0.002	0.0003	-
Nitrogen		0.015	0.004	0.005
Columbium	Balance		Balance	Balance

(a) Heat WC 572027
(b) Heat 610-57204

TABLE 1.04 COMPOSITION.

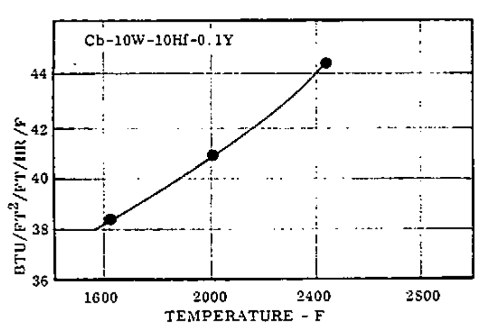

FIG. 2.013 THERMAL CONDUCTIVITY. (1)

	Cb
10	W
10	Hf
0.1	Y

Cb-129 Y

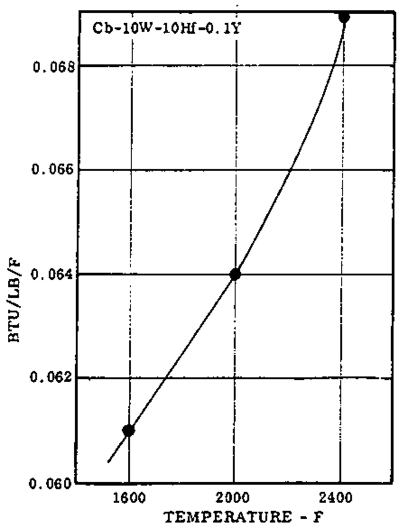

FIG. 2.015 SPECIFIC HEAT. (1)

Source	(4)	
Alloy	Cb-10W-10Hf-0.1Y	
Form	0.050 inch sheet	
Condition	Recrystallized, 2400F for 1 hour	
Mandrel axis relative to sheet roll direction	Normal	Parallel
Bend radius		
3t(a)	Passed(b)	Passed
2t	Passed	Passed
1t	Passed	Passed
(a) t represents sheet thickness.		
(b) Passed test if bent 105° without failure.		

TABLE 3.0241 BEND TESTS ON RECRYSTALLIZED SHEET MATERIAL.

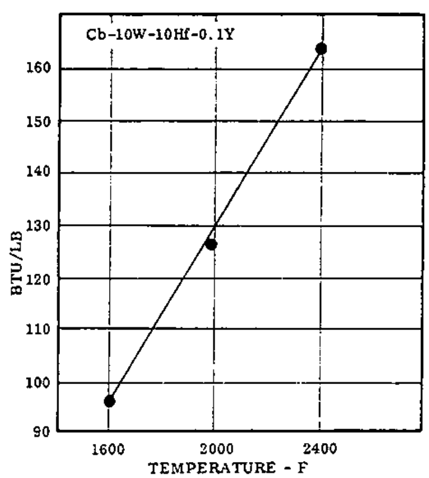

FIG. 2.017 ENTHALPY. (1)

Source	(2) (7)		
Alloy	Cb-10W-10Hf-0.1Y		
Form	0.012 inch sheet		
Condition	Recrystallized, 2400F for 1 hour		
Average prestrain, percent	10	10	5
Stress relief after prestrain	None	1.5 hrs/2400F	1.5 hrs/2400F
F_{tu} - ksi	87	81	87
F_{ty} - ksi	85	69	71
e (1 inch) - percent	44	46	43

TABLE 3.0211 EFFECT OF TENSILE PRESTRAIN AND STRESS RELIEF ON THE MECHANICAL PROPERTIES.

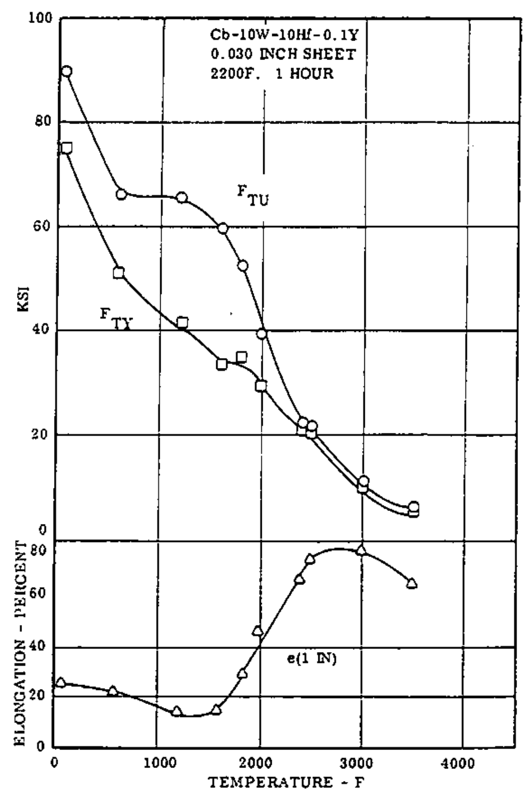

FIG. 3.0311 TENSILE PROPERTIES FROM ROOM TEMPERATURE TO 3500F. (1)

	Cb
10	W
10	Hf
0.1	Y

Cb-129 Y

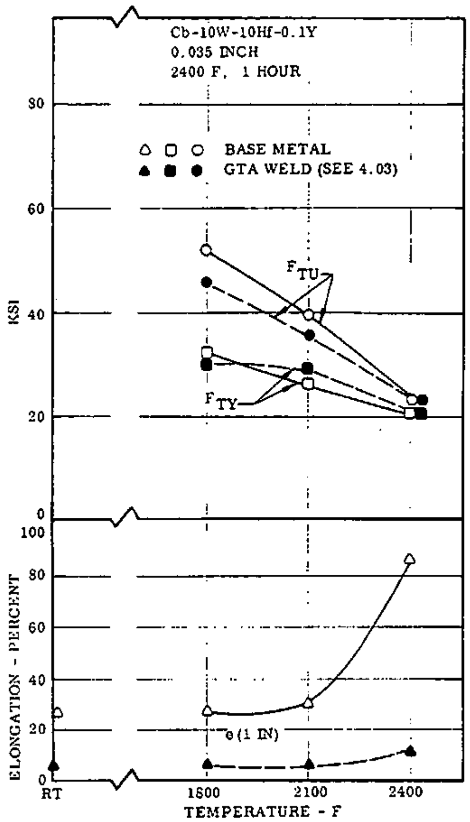

FIG. 3.0312 ELEVATED TEMPERATURE TENSILE PROPERTIES OF ANNEALED BASE METAL AND GTA WELDS. (3)(8)

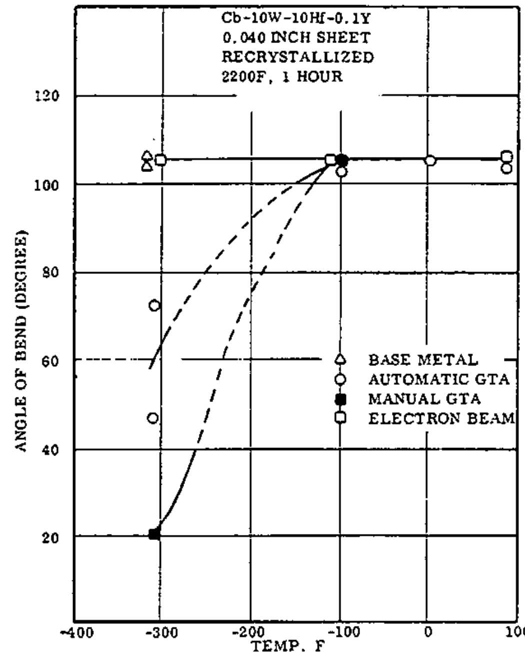

FIG 3.0342 DUCTILE-TO-BRITTLE TRANSITION CURVES FOR BASE METAL AND WELDED SHEET. (9)

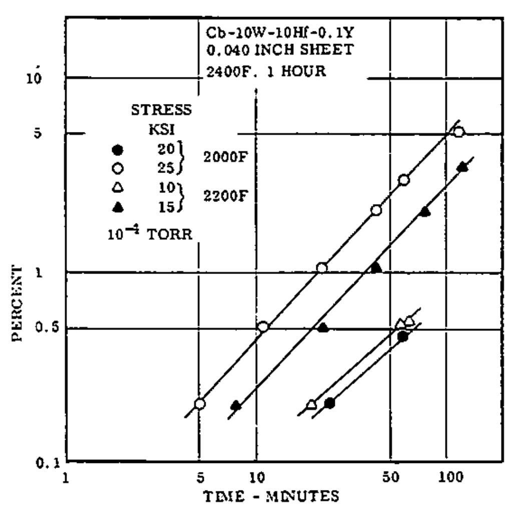

FIG. 3.041 CREEP CURVES FOR SHEET AT 2000 AND 2200F. (1)

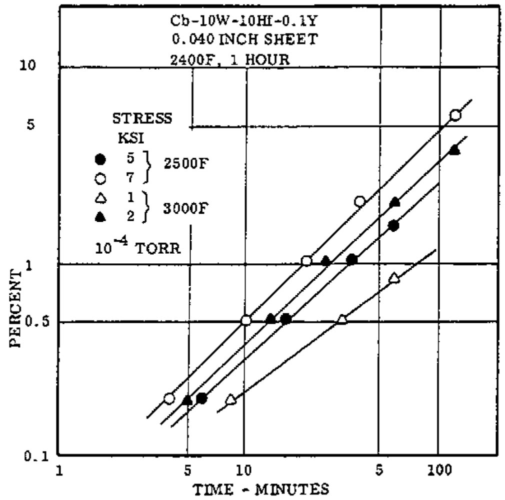

FIG. 3.042 CREEP CURVES FOR SHEET AT 2500 AND 3000F. (1)

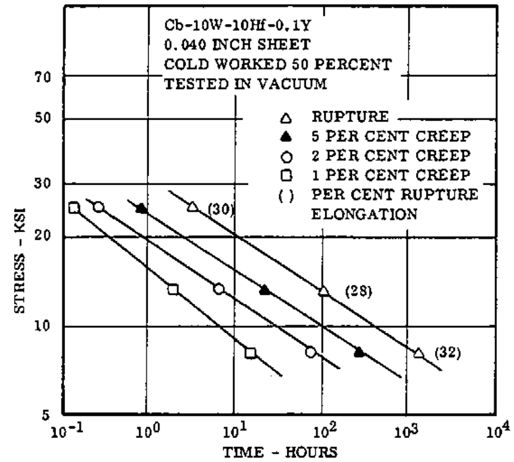

FIG. 3.044 CREEP RUPTURE PROPERTIES OF COLD WORKED SHEET AT 2020 F. (5)

	Cb
10	W
10	Hf
0.1	Y

Cb-129 Y

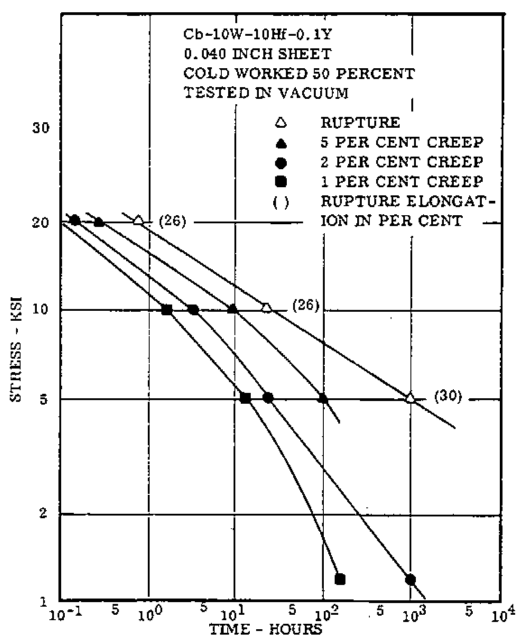

FIG. 3.043 CREEP RUPTURE PROPERTIES OF COLD WORKED SHEET AT 2227F. (5)

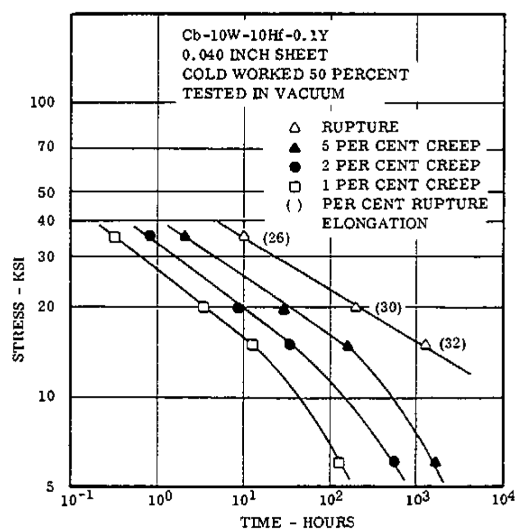

FIG. 3.045 CREEP RUPTURE PROPERTIES OF COLD WORKED SHEET AT 1822 F. (5)

	Cb
10	W
10	Hf
0.1	Y

Cb-129 Y

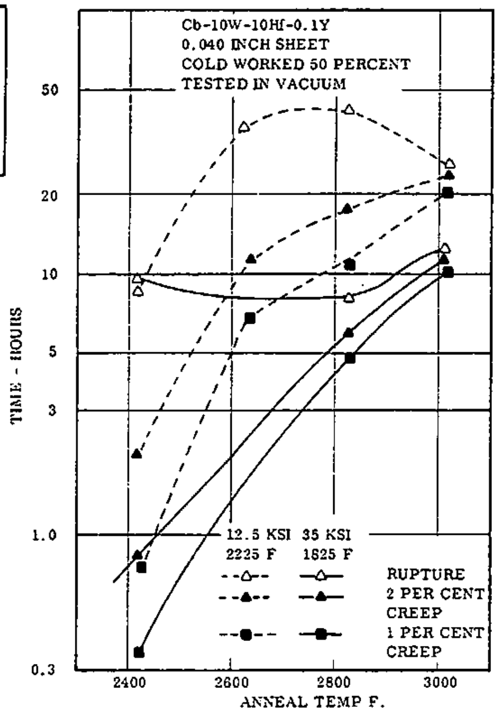

FIG. 3.046 EFFECT OF ANNEALING TEMPERATURE ON THE CREEP RUPTURE PROPERTIES OF SHEET. (5)

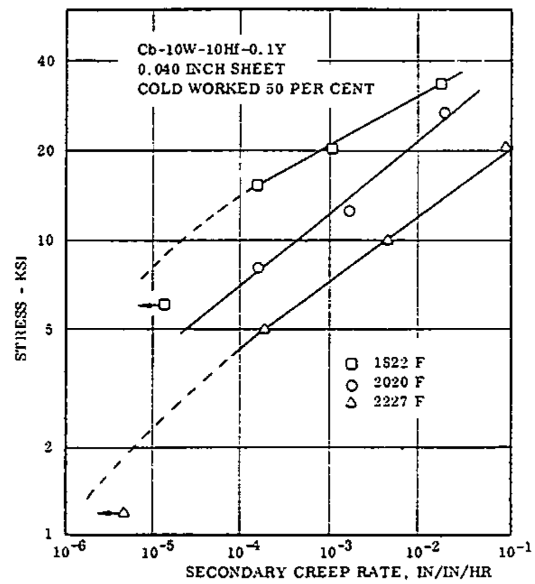

FIG. 3.048 SECONDARY CREEP RATE VERSUS STRESS. (5)

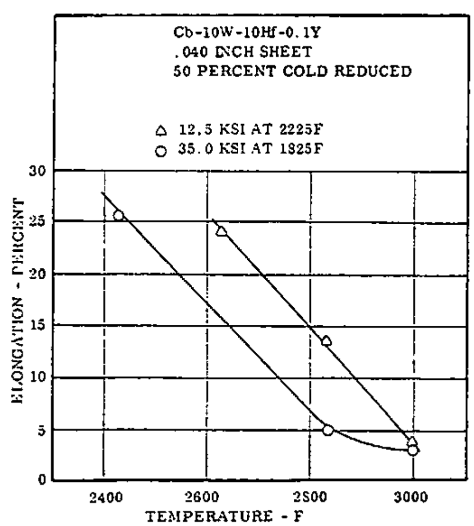

FIG. 3.047 EFFECT OF ANNEALING TEMPERATURE ON RUPTURE DUCTILITY. (5)

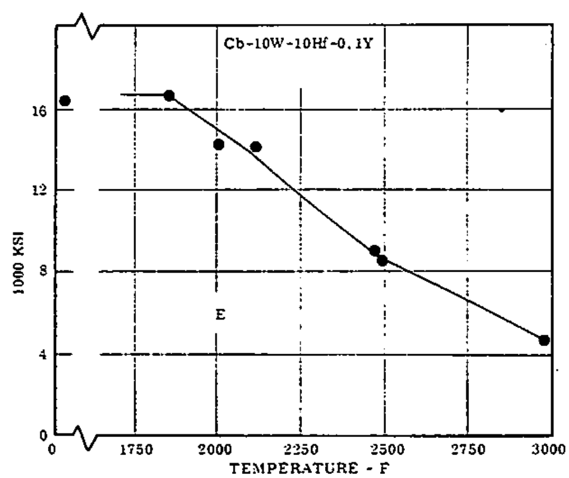

FIG. 3.0621 STATIC MODULUS OF ELASTICITY. (1)

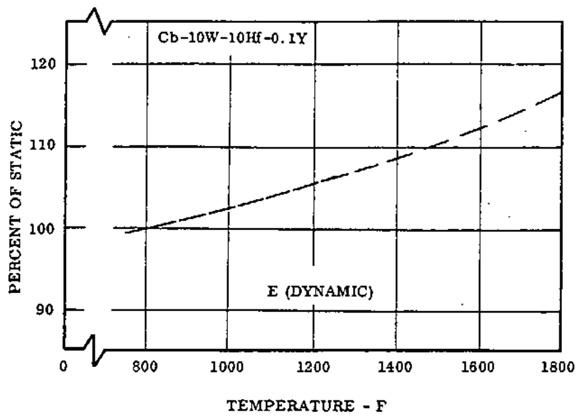

FIG. 3.0622 DYNAMIC MODULUS AS PERCENT OF STATIC MODULUS. (1)

Source	(1)	
Alloy	Cb-10W-10Hf-0.1Y	
Form	0.020inch sheet	
Condition	Recrystallized	
Weld Type	GTA butt, non-chamber	
Post weld H.T.	2200F - 1 hour	None
F_{tu} - ksi*	86.5	87.0
F_{ty} - ksi	65.0	65.5
e (1 in) - percent	19.5	15.0
e (.25 in) - percent	36.0	29.5
* All failures in parent metal.		

TABLE 4.031 REPRESENTATIVE MECHANICAL PROPERTIES OF NON-CHAMBER GTA WELDS.

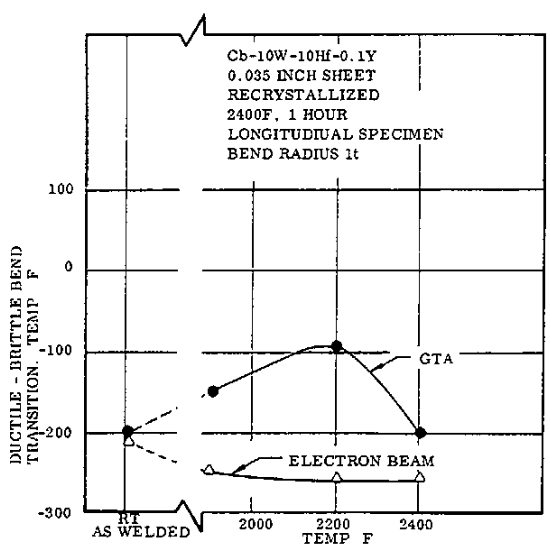

FIG 4.034 EFFECT OF ANNEALING TEMPERATURE ON WELD-BEND DUCTILITY. (10)

Source	(1)				
Alloy	Cb-10W-10Hf-0.1Y				
Coating	Disil				
Test Condition	Oxyacetylene flame adjusted for 10 percent excess O_2				
Coating Process					
Time hrs	Temp F	Coating thickness mils per side	Test temp F	Time to failure min	Remarks*
8	1850	1.0	2700	> 240	No failure
8	1850	1.0	3000	78-133	Localized failure
8 plus TiC overlay	1850	1.0 0.5	3000	127	Localized failure
8	1950	1.5	3000	157-182	Localized failure
* Failure is defined as any oxidation by visual appearance.					

TABLE 4.041 OXIDATION DATA FOR THE BOEING DISIL COATED SHEET.

Source	(4)			
Alloy	Cb-10W-10Hf-0.1Y			
Condition	Recrystallized 2400F for 1 hour			
Form	0.050 inch sheet			
Coating	Modified TRW TiCr-Si			
Specimen temp at impact F	Impact velocity ft/sec*	Oxidation life after impact		Remarks
		Temp F	Time min	
70	200	2200	60	Oxidation of surface
2200	200	2200	120	No oxide noted
70	500	2200	60	Oxidation of surface
2200	500	2200	120	Oxidation of surface
* Weight of pellet: 0.75 grams.				

TABLE 4.042 BALLISTIC IMPACT TEST DATA OF COATED SHEET.

REFERENCES

1. Wah Chang Corporation, "Columbium and Tantalum Alloys, Technical Information", Vol. II (August 1966).
2. Carpenter, S.R., "Forming and Joining Developments for Cb and TD NiCr Radiative Heat Shields", GDC-ERR-1344, General Dynamics (Convair) (December 1968).
3. Lessmann, G.G., "The Comparative Weldability of Refractory Metal Alloys", Westinghouse, Welding Journal Supplement (December 1966).
4. Hauser, H.A. and Holloway, J.F., "Evaluation and Improvement of Coatings for Cb Alloy Gas Turbine Engine Components", Pratt & Whitney Aircraft Company, AFML-TR-66-186, Pt. 1 (July 1966).
5. Stephenson, R.L., "Creep-Rupture Properties of C-129Y In Vacuum", ORNL, Jnl. of Vac. Science and Technology, Vol. 7, No. 6 (November/December 1970).
6. Stefano, J.R., "Refluxing Capsule Experiments With Refractory Metals in Boiling Alkali Metals", ORNL-4323 (January 1969).
7. Carpenter, S.R., "Fabrication Developments of High Temperature Materials: Cb and TD NiCr", GDC-ERR-1458, General Dynamics (Convair) (December 1969).
8. Lessmann, G.G. and Stoner, D.R., "Welding Refractory Metal Alloys for Space Power System Application", WANL Sp-009, 9th National SAMPE Symposium (November 1965).
9. Donnelly, R.G., "Weldability of Niobium Alloy C-129Y", ORNL-TM-929 (September 1964).
10. Lessmann, G.G. and Stoner, D.R., Report WANL PR(P)-007, NASA, Lewis Research Center, NAS 3-2540.
11. R.M. Evans, DMIC - Metals Joining Memo, (December 10, 1965).
12. Nejedlik, J.F. and Gadd, J.D., "Coatings for Long-Term Intermediate Temperature Protection of Cb Alloys", Final Report, AFML-TR-68-170, TRW Inc., Contract AF 33(615)-5121 (October 1968).