Crucible® Data Sheet

Issue #6

STEEL SERVICE CENTER INSTITUTE

CRUCIBLE 422 STAINLESS STEEL

Carbon	0.23%	Manganese	0.75%	Silicon	0.35%
Chromium	11.50%	Nickel	0.80%	Vanadium	0.25%
Tungsten	1.00%			Molybdenum	1.00%

CRUCIBLE 422 is a hardenable martensitic stainless steel which is being widely used for high temperatures up to 1200F. It has excellent creep-rupture properties in the range of 600/1200F and is capable of being heat treated to various high strength levels depending on section, form, and application involved. CRUCIBLE 422 offers designers in the aircraft and power industries high strength/weight ratios from room temperature to 1200F. The composition is carefully balanced to provide a microstructure which is virtually all tempered martensite after heat treatment. This structure assures uniformity of mechanical properties with a minimum of directionality.

Typical Applications:

Compressor and turbine blades (aircraft, gas or steam turbines)
Compressor and turbine wheels
Rotors
High temperature bolting
Valve trim and other valve applications
Structural components for aircraft and missile applications

Forging:

CRUCIBLE 422 should be forged at 1950-2025F and finished not lower than 1550-1600F. It is recommended that large sections be pre-heated at 1200-1400F equalized, and then heated to forging temperature.

Annealing:

CRUCIBLE 422 may be annealed by one of the following procedures:

1. Maximum ductility: Heat to 1600F and hold at temperature 1½ hours per inch of cross-section, cool slowly to 1300F (maximum cooling rate of 25F per hour), hold 6 hours, then slow cool (50F per hour) in the furnace to 1000F.

2. General machining of bar stock: When general machining of CRUCIBLE 422 bar stock is required following mechanical work, a sub-critical anneal at 1400-1425F (held 6-8 hours at temperature) followed by furnace cooling to 1200F, is recommended.

3. Large sizes (12-inch diameter or larger) should be cooled slowly to 150F in an insulating material such as vermiculite, lime, or ashes in order to prevent strain cracking.

Recommended Heat Treatment:

The heat treatment of CRUCIBLE 422 is generally accomplished by austenitizing at 1900F followed by oil quenching and tempering for at least 2 hours. Double tempering is desirable and recommended for heavy sections. Sections up to 4 inches thick may be air cooled if desired. Tempering temperatures will vary depending upon the product form and the desired mechanical properties. A tempering temperature of 980F is generally used when highest strength is of primary concern, whereas, 1200F or higher is used for long-time, elevated temperature service.

Machining:

The machining of CRUCIBLE 422 is similar to other standard martensitic stainless grades such as Type 420 and is characterized by the tendency of the chip to gall or build up on the cutting edges and radii of the tool. This results in high tool pressures and temperatures on the cutting point of the tool and the tearing of the machined finish of the work. The chips formed in machining are brittle and stringy. Material in the fully annealed condition (Rb 92) is preferred for the majority of applications. Because of the abrasive action of the large amount of chromium carbide in the structure of the steel, it is necessary that this grade be machined at slower speeds than lower carbon chromium grades. In general, machining speeds are approximately 40% of those for mild steel.

Welding:

CRUCIBLE 422 may be satisfactorily welded by gas tungsten-arc welding or gas metal-arc welding processes. Type 422 filler metal should be used to obtain optimum properties.

Because CRUCIBLE 422 is air hardening, it is essential to use a minimum preheating temperature of 350F. If the weldment is not immediately hardened and tempered, it should be stress relieved by post heating at 1200 to 1250F and air cooling.

Tension tests at room and elevated temperature show that weldments made with 422 filler metal and then heat treated have mechanical properties equal to those of the base material.

Heat treatment before welding produces joint strengths of approximately 75% of the strength of the base material. Because untempered martensitic 422 weld metal has low ductility, a tempering treatment should be employed after welding.

When standard welding procedures are used, more scale is formed on the 422 weld surface than normally is the case with other stainless steels. Therefore, the surfaces of all weld beads should be removed prior to deposition of the succeeding weld bead. Use of a gas trailing shield, similar to that used for welding titanium, reduces scale formation sufficiently to permit successive passes without grinding.

Resistance To Scaling:

CRUCIBLE 422 has good resistance to destructive scaling or oxidation for continuous service at temperatures up to 1250F. This temperature will vary with the type of atmosphere, type of construction, and cycle of operation.

General Corrosion Resistance:

CRUCIBLE 422 is adaptable to applications where maximum resistance to corrosion is not required. It is resistant to the corrosive action of the atmosphere, fresh water, steam, and a variety of the milder acids and alkalies.

Physical Properties:

Specific gravity	7.78
Density lb./cu. in.	0.280
Mean linear coefficient of thermal expansion in./in./°F x 10^{-6}	
70- 500F	5.9
70- 750	6.3
70-1000	6.4
70-1200	6.7
Thermal conductivity BTU hr./sq. ft./°F/ft. at 212F	14.5
Specific heat BTU/lb./°F (32-212F)	0.11

Elastic Constants

Temp. (°F)	Modulus of elasticity (10^6 psi)	Shear modulus (10^6 psi)	Poisson's ratio
75	29.8	12.0	0.23
500	27.5	11.5	0.21
800	24.2	10.5	0.20
1100	20.5	9.0	0.16

Mechanical Properties:

(Bar data)

Effect of tempering temperature on room temperature tensile properties

Tempering* temperature (°F)	0.2% yield strength (1000 psi)	Tensile strength (1000 psi)	Elongation in 1.4 in. (%)	Reduction of area (%)
600	145	229	16	56
800	168	237	16	53
900	177	243	16	50
980	145	265	18	55
1200	125	149	19	52

Short-time elevated temperature tensile properties

Test temperature (°F)	Tempering* temperature (°F)	0.2% yield strength (1000 psi)	Tensile strength (1000 psi)	Elongation in 1.4 in. (%)	Reduction of area (%)
600	800	153	230	16	13
800	800	138	216	14	10-24
800	850	142	216	19	55
800	980	157	219	16	52
900	980	151	209	14	46
1000	980	131	177	12	43
1200	1200	46	57	21	85

* Specimens were austenitized at 1900 for 1 hour, oil quenched, and tempered 2 hours at indicated.

Effect of tempering on room temperature impact properties

Tempering temperature (°F)	Hardness (Rc)	Charpy V-Notch impact value (ft.-lb.)
700	48	9
800	48	7
900	50	5
980	49	6
1200	34	15
1200*	34	19
1250*	33	24
1300*	29	56
1350*	25	89
1400	26	38

Specimens were austenitized at 1900F for 1 hour, oil quenched, and tempered 2 hours as indicated.

* Double tempered.

Low and elevated temperature impact properties

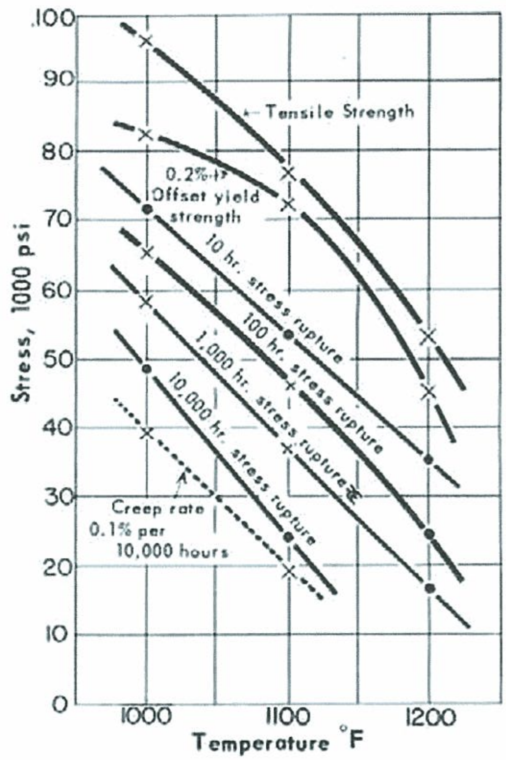
Test temperature (°F)	Charpy V-Notch* impact value (ft.-lb.)	Test temperature (°F)	Charpy V-Notch* impact value (ft.-lb.)
−100	3	260	16
	4		17
0	4	280	21
	5		—
RT	6	300	23
	7		27
160	10	340	28
	11		29
212	13	400	32
	15		38

* Specimens were austenitized at 1900F for 1 hour, oil quenched, and tempered at 980F for 2 hours, air cooled.

Impact properties after static exposure at elevated temperatures

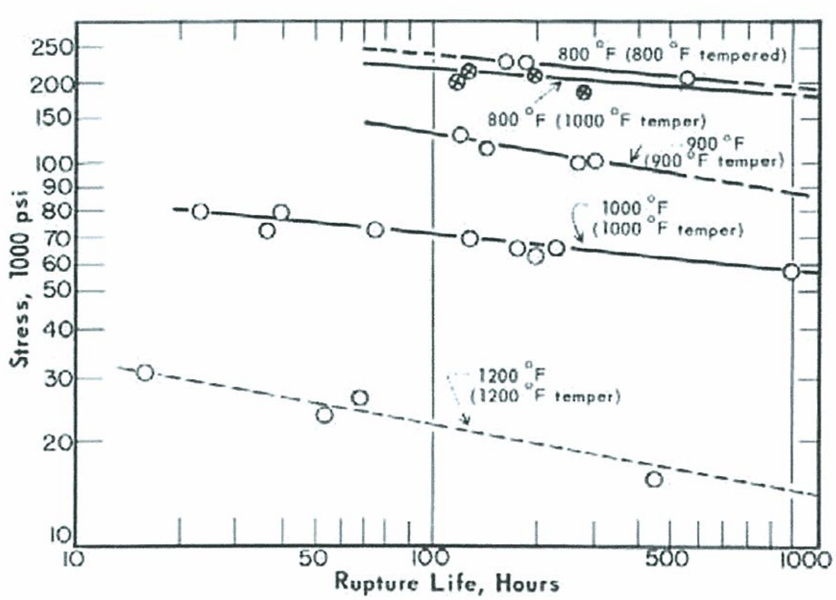
	Charpy V-Notch impact values (ft.-lb.) at				
Exposure time at 1000°F, hrs.	−105°F	−18°F	R.T.	150°F	212°F
Specimens tempered at 1200°F for 2 hours (Rc 34)					
0	5	10	15	25	43
25	6	11	14	26	42
100	5	10	15	25	42
500	5	10	12	16	28
1000	6	10	10	—	21
Specimens tempered at 1400°F for 2 hours (Rc 26)					
0	13	19	38	68	71
25	14	21	36	62	64
100	12	20	40	58	64
300	8	20	39	65	65
500	9	14	23	51	55
700	9	13	21	46	53
1000	7	12	17	37	48

Note: Specimens austenitized at 1900°F for 1 hour, oil quenched, tempered at 1200°F or 1400°F, and then heated to 1000°F for the indicated times.



High temperature strength of quenched and tempered CRUCIBLE 422. Bars were tempered at 1200°F for a room temperautre tensile strength of 150,000 psi.

Note: Values plotted are representative. A slight degree of scatter should be expected with variations in heat treatment.

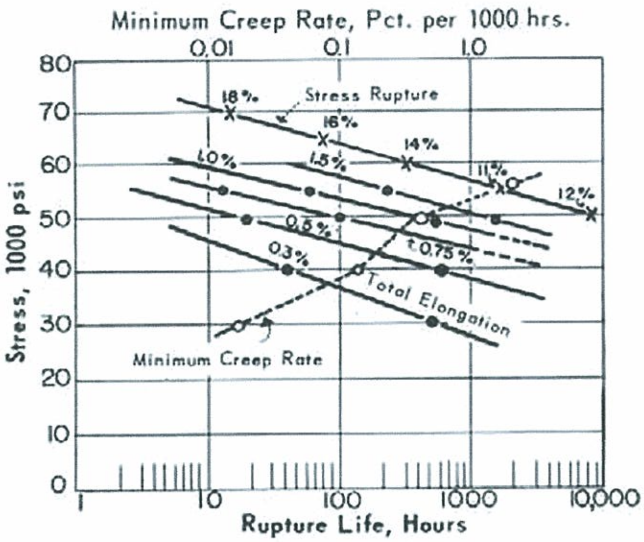


Creep-Rupture strength of 0.025-inch-thick CRUCIBLE 422 sheet at the indicated temperature.

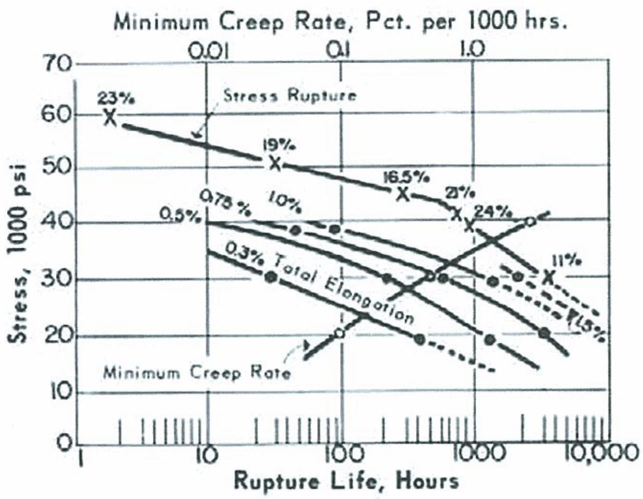
Additional Design Data:

Since much of an airframe is loaded in compression, stiffness of a steel assumes considerable importance as an airframe design parameter. The ability of CRUCIBLE 422 to develop its compressive yield strength without buckling is shown. Column action is dependent upon the modulus of elasticity and density of the steel. The high compressive moduli and yield/density ratio are noteworthy in this connection.

Creep rate curves at 1000F and 1100F allow the designer to determine the stress to produce a given amount of strain in a given time. The following data have been used to qualify CRUCIBLE 422 for both stationary and aircraft turbine applications.



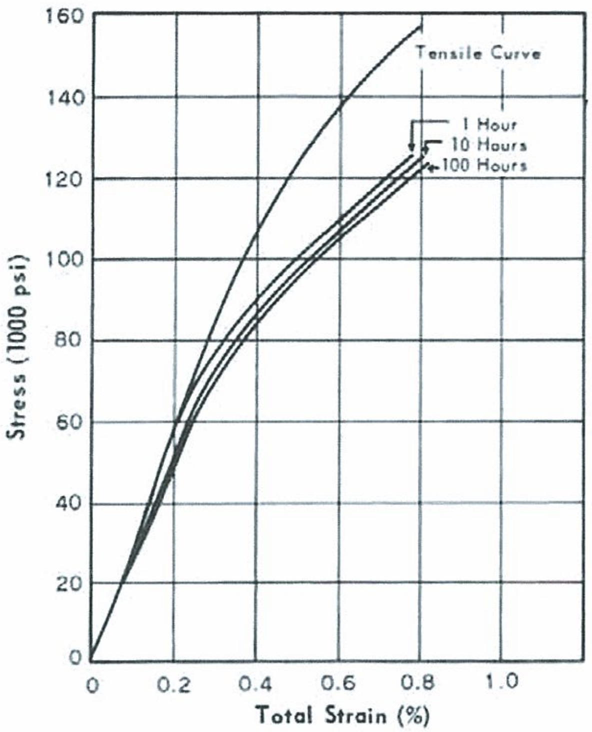
Design curves, CRUCIBLE 422, 1000 °F. Heat treatment: Oil quenched from 1900 °F, tempered at 1200 °F–2 hours.



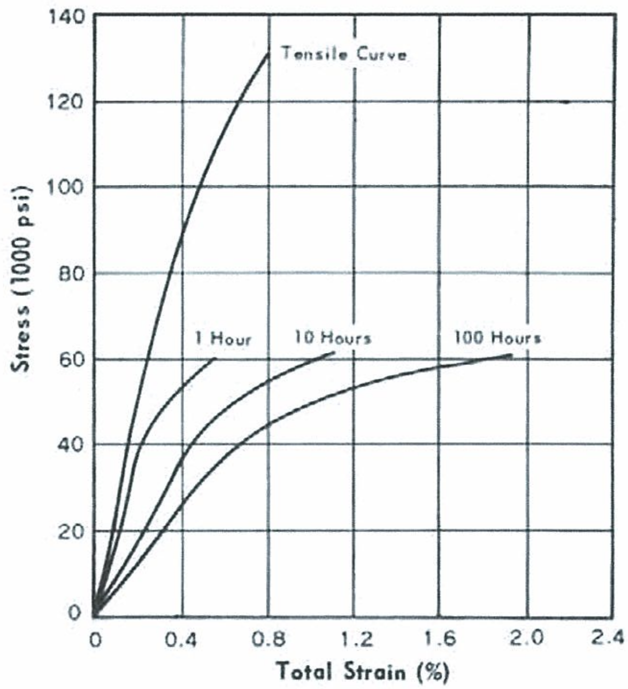
Design curves of CRUCIBLE 422 at 1100 °F. Heat treatment is the same as that shown at left.

Isochronous Curves:

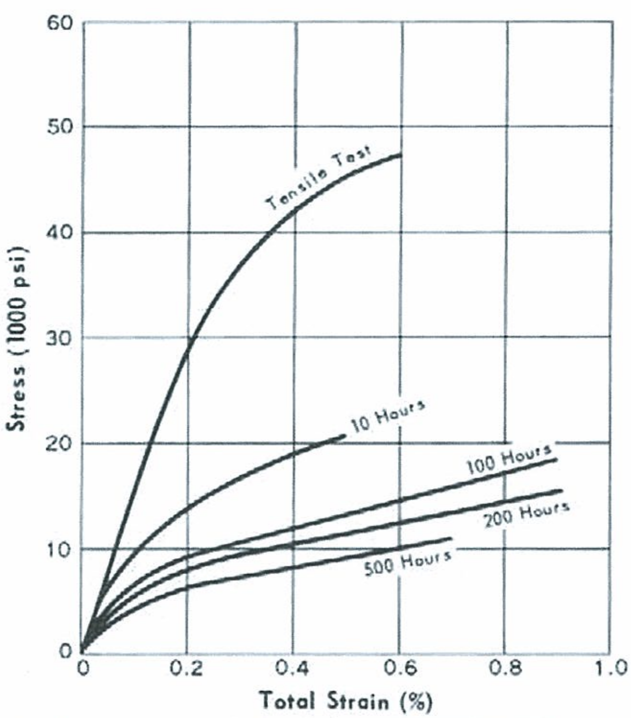
To simplify the task of evaluating airframe design for creep, isochronous (constant time) stress-strain curves are required. The isochronous curves are constructed from creep curves, plotting the strain produced by different stresses at constant times. The relationship of isochronous curves to a regular stress-strain curve is such that the points at which the isochronous curves deviate from the stress-strain curves indicate the stress at which creep becomes an important factor under the conditions of time and temperature for which the curves were prepared.



Ioschronous stress-strain curves for CRUCIBLE 422 sheet at 800 °F. Heat treatment: 1900 °F for 15 minutes, air cool plus 980 °F for 1 hour (Rc 51).



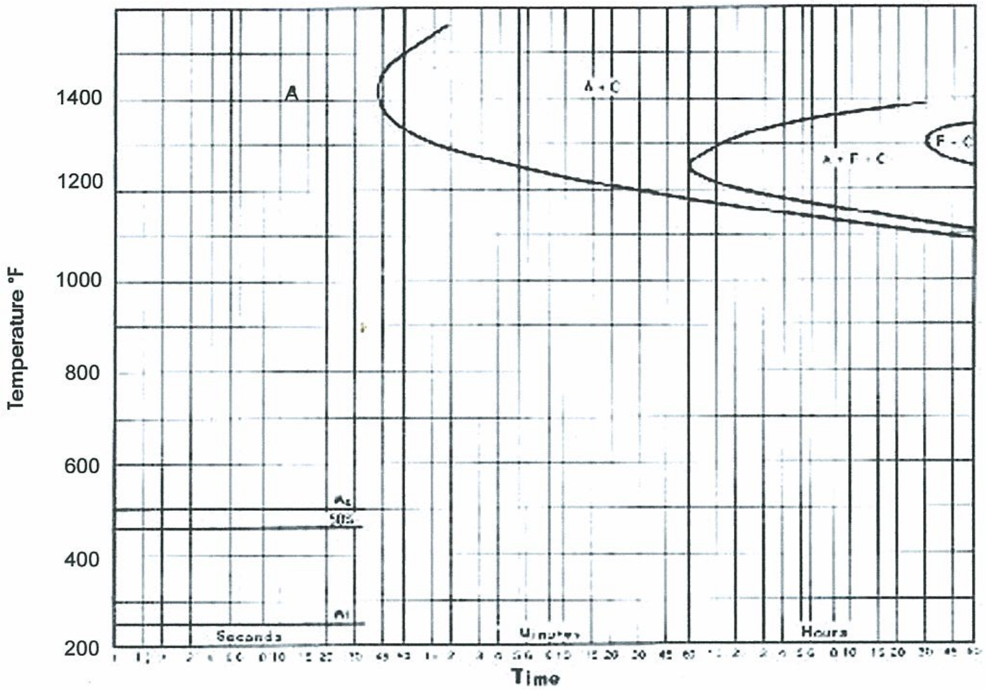
Isochronous stress-strain curves for CRUCIBLE 422 sheet at 1000 °F. Heat treatment: 1900 °F for 15 minutes, air cool plus 980 °F for 1 hours (Rc 51).



Isochronous stress-strain curves for CRUCIBLE 422 bar at 1200 °F. Heat treatment: 1900 °F for 1 hour, oil quench, plus 1200 °F for 2 hours (Rc 32).

Grade: CRUCIBLE 422
Austenizing temperature: 1900° F

Critical (Ac_1) temperature: 1475° F
Prior condition: Annealed



The TTT curve shows the times required for the austenite of the steel to start and to complete transformation at each temperature. It summarizes the reactions which may take place when the steel cools from above its Ae_1 critical temperature. It is useful in predicting the approximate structures to be obtained when the steel is cooled at different rates. It indicates holding temperatures and times, and suitable cooling rates for annealing; necessary quenching speeds for hardening; and correct hot quenching procedures for austempering and martempering.

Note: Properties shown throughout this data sheet are typical values. Normal variations in chemistry, size, and conditions of heat treatment may cause deviations from these values.

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