

Crucible 416 PLUS Data Sheet

Issue no. 9

CRUCIBLE 416 PLUS is a hardenable chromium steel with improved machinability and non-galling characteristics. Better machinability than that of standard AISI Type 416 stainless is obtained by the use of balanced chemistry and special manufacturing techniques. This grade is magnetic in all conditions. Typical applications are screw-machine products and all machined parts requiring good corrosion resistance.

Analysis

Carbon 0.15% max.

Manganese 1.25% max.

Silicon 1.00% max.

Phosphorus 0.060% max.

Chromium 12.00/14.00%

Sulfur 0.15% min.

Molybdenum 0.60% max.

Typical applications

Bolts, nuts, and
screws

Gate valve parts
Instrument parts
Shafts

Parts made in screw
machines
Valve trim

Note: These are some typical applications. Your specific application should not be undertaken without independent study and evaluation for suitability.

Forging

CRUCIBLE 416 PLUS should be forged at 2050 to 2150°F and finished above 1400°F. CRUCIBLE 416 PLUS is not adaptable to severe upset forging operations.

Annealing

CRUCIBLE 416 PLUS should be annealed for maximum softness at 1550°F followed by a furnace cool. For better machinability, a semi-anneal at 1300°F is recommended.

Hardening and tempering

CRUCIBLE 416 PLUS can be hardened by air cooling or oil quenching from 1750 to 1850°F. When air hardening small or thin sections, a temperature in the upper part of this range should be used. Tempering should be at the proper temperature to give the desired properties as shown in Figure 3. It is desirable to avoid tempering between 800 and 1100°F as there is a drop in impact strength within this range with a coincidental drop in resistance to corrosion. This condition disappears when the tempering temperature is 1100°F or higher.

Note: Temperatures shown throughout this data sheet are metal temperatures.

Attainable hardness

Attainable hardness is defined as the hardness obtained on cooling a sample approximately $\frac{1}{2}$ " in thickness in air from 1825°F. This hardness gives some idea of the mechanical properties of the material which might be expected after hardening and tempering. The attainable hardness of CRUCIBLE 416 PLUS is guaranteed to RC35 minimum.

Forming

CRUCIBLE 416 PLUS will withstand only gradual cold working. It is not adaptable to severe cold-forming operations.

Welding

CRUCIBLE 416 PLUS is not generally recommended for welding as porosity results where sulfur (or selenium) is introduced.

Resistance to scaling

CRUCIBLE 416 PLUS scales at approximately 1250°F. This temperature can vary with the type of atmosphere and application.

General corrosion resistance

The corrosion resistance of CRUCIBLE 416 PLUS was evaluated in a variety of corrosion tests normally used for this type of stainless. Comparisons were made to AISI Type 416 stainless. The corrosion resistance of CRUCIBLE 416 PLUS is comparable to that of AISI Type 416. Comparative data are given below.

Surface area showing corrosion
(In percent)

| Grade | Water Vapor Column (24 Hours) | | 100% Relative Humidity (200 Hours) CGA | | 5% Salt Spray (2 Hours) CGA | |
|---------------|-------------------------------|---------------------|--|--------------|-----------------------------|-----------|
| | CGA | Hardened & Tempered | U | P | U | P |
| Type 416 | U P 20 1 | U P 13 10 | U P 6 4 | U P 19 13 | U P 23 13 | U P 13 |
| Type 416 Plus | 20 1 | 18 4 | 5 0 | | | |

CGA — Center less-Ground-Annealed

U — Unpassivated

P — Passivated

Passivation

It is recommended that finished parts machined from stainless steel be passivated for optimum corrosion resistance.

Free-machining types are prone to dulling and discoloration in passivating treatments. It is important that correct procedures be followed when passivation is specified. The recommended treatment for CRUCIBLE 416 PLUS is shown below:

| Acid concentration by volume of concentrated nitric acid | Sodium dichromate by weight | Bath temperature (*F) | Immersion time (min.) |
|--|-----------------------------------|-----------------------------|-----------------------------|
| 40-60% | 2.0% | 110 - 140 (120 Typ.) | 15 - 30 |

Machining

The machining of all high-chromium steels is characterized by the tendency of the chip to gall or build up on the cutting edges and radii of the tool. CRUCIBLE 416 PLUS gives freer cutting properties and minimizes the tendency of the steel to form a built-up edge on the tool. The chips are short and brittle which results in relatively easy chip control. For the majority of applications material which has been heat treated to about 200 Brinell or annealed and cold drawn is preferred to materials in the annealed condition. The additional hardness obtained by either heat treating or cold drawing reduced the tendency of the chip to build up on the cutting edge, thus allowing a better machine finish.

CRUCIBLE 416 PLUS provides increased productivity through the use of higher cutting speeds or feed rates in comparison to AISI Type 416 stainless. Initial speed or feed rates may be 10 percent higher than for standard 416, but substantially greater improvements than this may be expected depending on the particular job. In addition, a significant improvement in tool life can be realized over standard Type 416 even at the increased speeds and feeds. Figures 1 and 2 demonstrate the improvement to be expected. Recommended feeds and speeds are given below.

Machining data

| Operation | Tool Width or Depth of Cut (in) | CRUCIBLE 416 PLUS High Speed Tooling * | | Carbide Tooling | |
|----------------------|---------------------------------|--|---------------|-----------------|---------------|
| | | Speed (fpm) | Feed (in/rev) | Speed (fpm) | Feed (in/rev) |
| Turning single point | 0.050 | 160 | 0.0060 | 280 | 0.015 |
| | 0.250 | 150 | 0.0055 | 220 | 0.030 |
| | 0.500 | 140 | 0.0045 | 210 | 0.045 |
| Forming | 1/2 wide | 155 | 0.0020 | 240 | 0.003 |
| | 1 wide | 150 | 0.0017 | 240 | 0.002 |
| | 1 1/2 wide | 150 | 0.0015 | 225 | 0.002 |
| | 2 wide | 140 | 0.0013 | 200 | 0.002 |
| Cutoff | 1/16 wide | 150 | 0.0017 | 240 | 0.002 |
| | 1/8 wide | 150 | 0.0020 | 240 | 0.003 |
| | 3/16 wide | 155 | 0.0020 | 225 | 0.003 |
| | 1/4 wide | 160 | 0.0025 | 200 | 0.003 |
| Drilling | 1/16 dia. | 95 | 0.0020 | | |
| | 1/8 dia. | 100 | 0.0030 | | |
| | 1/4 dia. | 100 | 0.0040 | | |
| | 1/2 dia. | 100 | 0.0045 | | |
| | 3/4 dia. | 105 | 0.0055 | | |
| | 1 dia. | 105 | 0.0065 | | |
| Threading† | | 15-40 | - | | |
| Tapping† | | 15-25 | - | | |

†Use the higher speeds for the finer threads.

Machinability

Results of drill and tool life machinability tests are shown below. These laboratory tests have been found to correlate with results in machine shops.

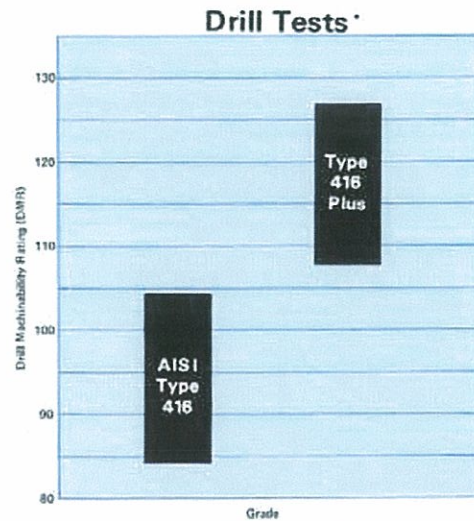


Figure 1

*Details on drill test techniques and Crucible High Speed and Tool Bit recommendations are described in the booklet, "Machining Crucible Stainless Steels."

Tool Life Test*

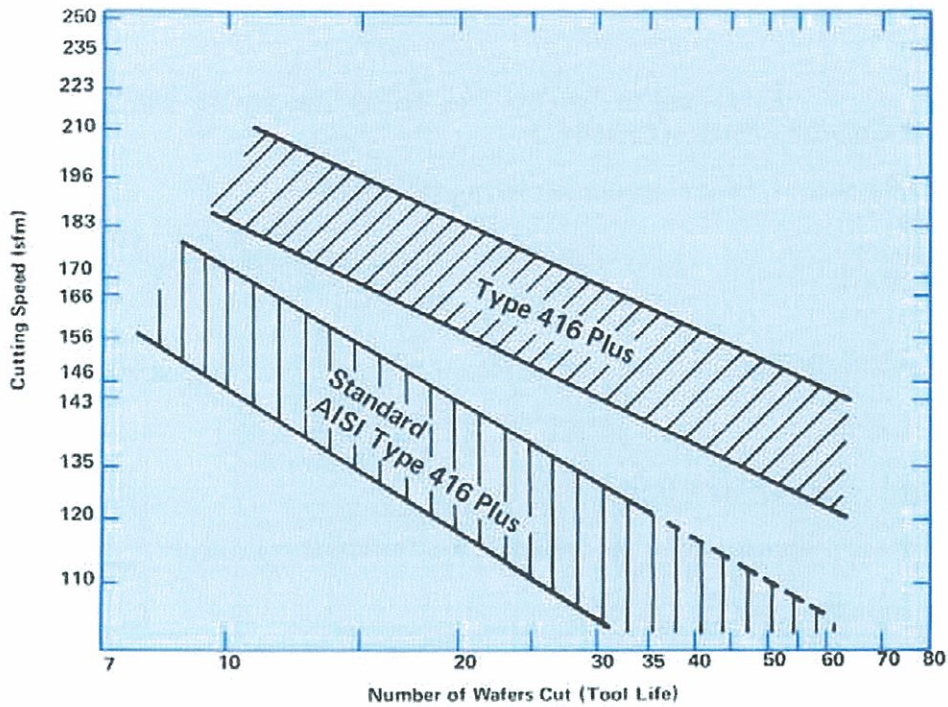


Figure 2

*Details on tool life test techniques are described in the booklet, "Machining Crucible Stainless Steels."

Specifications

CRUCIBLE 416 PLUS meets the following specifications:

| | | | | |
|-----------|-------------|----------|-----------|-----------|
| Q/Q-S-764 | MIL-W-52263 | AMS 5610 | ASTM A581 | ASTM A582 |
|-----------|-------------|----------|-----------|-----------|

Physical properties

| | |
|--|------------|
| Modulus of elasticity in tension - psi | 29,000,000 |
| Modulus of elasticity in torsion - psi | 10,500,000 |
| Electrical resistivity | |
| Room temperature (microhm - centimeters) | 56.8 |
| Specific heat (Btu/lb./°F) 32-212°F | 0.11 |
| Specific gravity | 7.75 |
| Weight (lb./ cu.in.) | 0.280 |
| Thermal conductivity (Btu/hr./sq.ft./°F/ft.) | |
| 200°F | 14.4 |
| 1000°F | 16.5 |

(Continued)

Physical properties (cont.)

| | |
|--|-----------|
| Mean coefficient of thermal expansion (in/in/°F x 10 ⁻⁶) | |
| 32-212°F | 5.5 |
| 32-600°F | 5.6 |
| 32-1000°F | 6.4 |
| 32-1200°F | 6.5 |
| Melting point range (°F) | 2700/2790 |

Mechanical properties

(All values are representative properties in the annealed condition) Bar (1 in.rd.)

| | |
|------------------------------------|--------|
| Tensile strength - psi | 75,000 |
| Yield strength (0.2% offset) - psi | 40,000 |
| Elongation in 2 in. (%) | 30 |
| Reduction of area (%) | 60 |
| Hardness (BHN) | 155 |

Short time elevated temperature tensile strength:

| Temperature °F | Tensile Strength psi |
|-------------------|-------------------------|
| 1000 | 45,000 |
| 1100 | 33,000 |
| 1200 | 22,000 |
| 1300 | 14,000 |
| 1400 | 9,000 |

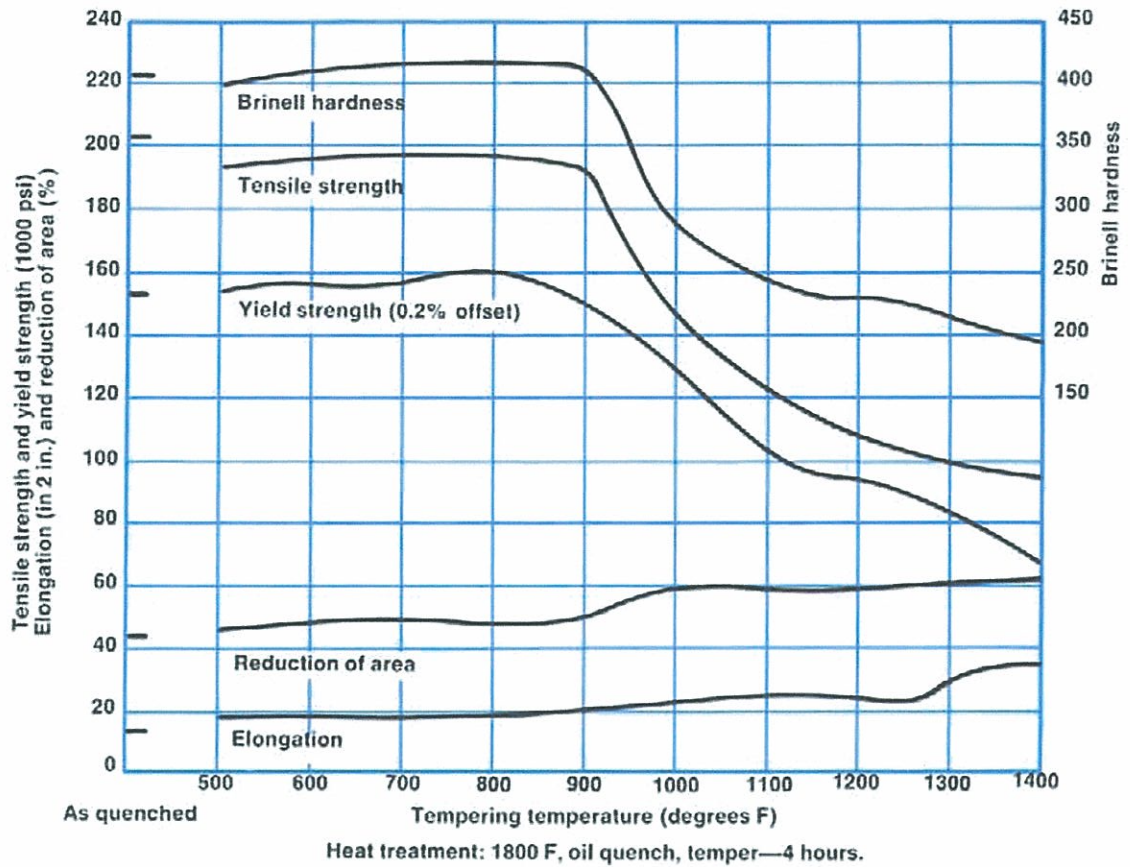
Creep Data:

| Temperature °F | Stress for creep rate of 0.0001% per hour psi |
|-------------------|---|
| 1000 | 9,200 |
| 1100 | 4,200 |
| 1200 | 2,000 |
| 1300 | 1,000 |

Mechanical properties as heat treated

Typical Values

Size 1" rd. Tensile 0.505 in. diam.



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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