

---

# PRODUCT DATA

---



S-29d

## Armco 17-7 PH Precipitation-Hardening Stainless Steel Bar And Wire

Armco 17-7 PH is a precipitation-hardening stainless steel that provides excellent fatigue properties, good corrosion resistance and minimum distortion on heat treatment. Hard-drawn 17-7 PH wire is an excellent spring material. When heat treated at 900 F (482 C), it exhibits elastic properties like those of the best music wire and alloy spring steels. Solution treated (annealed) 17-7 PH wire can be readily cold formed before heat treating to high tensile strengths and high hardness. At service temperatures up to about 600 F (316 C), 17-7 PH has higher strength than nickel-chromium, nickel-copper, nickel-aluminum and copper-beryllium alloys.

Armco 17-7 PH bar, wire and forgings are used primarily in components also utilizing Armco 17-7 PH sheets and plate. When these components are subjected to transverse stresses Armco PH 13-8 Mo should be used. For most machined or forged parts not used in conjunction with 17-7 PH sheet or plate, a different precipitation-hardening stainless steel, Armco 17-4 PH\*, Armco 15-5 PH VAC CE\*\*, or Armco PH 13-8 Mo\*\*\* is generally specified. Similar mechanical properties, higher impact strength, and comparable corrosion resistance can be obtained with Armco 17-4 PH or 15-5 PH VAC CE stainless steels. Higher tensile strength, higher impact strength and better corrosion resistance are obtained with Armco PH 13-8 Mo stainless steel.

The information and data in this Product Data Bulletin are accurate to the best of our knowledge and belief, but are intended for general information only. Applications suggested for the materials described herein are made solely to permit the reader to make his own evaluation and decision, and are not to be construed as either express or implied warranties of fitness for these or other applications. The data reported herein have been developed through tests conducted by or for Armco. They are not guarantees. Data referring to minimum and maximum mechanical properties are the result of tests performed on specimens obtained from specific locations of the product in accordance with prescribed sampling procedures, and any warranty thereof obviously is limited to the values obtained at such locations and by such procedures.

*\*Armco 17-4 PH Bar and Wire are described in Armco Product Data Bulletin S-6.*

*\*\*Armco 15-5 PH VAC CE Bar and Wire are described in Armco Product Data Bulletin S-21.*

*\*\*\*Armco PH 13-8 Mo Bar and Wire are described in Armco Product Data Bulletin S-33.*

Armco, the Armco Triangle, 17-4 PH, 15-5 PH, 17-7 PH and NITRONIC<sup>®</sup> trademarks of Armco Inc., Middletown, Ohio.  
PH 13-8 Mo trademark of Armco Inc.

## COMPOSITION

The following composition is acceptable in specifications for Armco 17-7 PH:

	%		%
Carbon	.09 max	Silicon	1.00 max
Manganese	1.00 max	Chromium	16.00-18.00
Phosphorus	.04 max	Nickel	6.50-7.75
Sulfur	.04 max	Aluminum	0.75-1.50

## AVAILABLE FORMS

Armco 17-7 PH stainless steel is available in bar, wire and billets as well as sheet, strip and plate\*. Bars, billets and wire are normally supplied in the solution treated (annealed) Condition A. Wire is also produced in the cold drawn Condition C, that requires only a single heat treatment or cold drawn and hardened in Condition CH 900.

\*Flat-rolled forms of Armco 17-7 PH stainless steel are described in Armco Product Data Bulletin S-30.

## APPLICATIONS

Armco 17-7 PH stainless steel is widely used for applications requiring good corrosion resistance combined with high strength. Bars and forgings are used primarily in aircraft structural parts. With excellent spring properties at temperatures up to 600 F (316 C) and good corrosion resistance, 17-7 PH wire is used for a wide variety of springs. These include springs made of flat and round wire for appliances, aircraft controls and instruments, automotive components, and processing equipment.

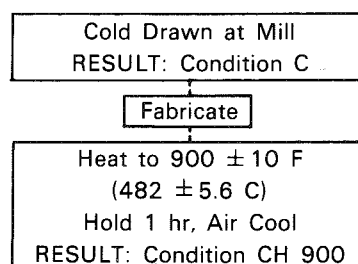
## METRIC PRACTICE

The values shown in this bulletin were established in U.S. customary units. The metric equivalents of U.S. customary units shown may be approximate. Conversion to the metric system, known as the International System of Units (SI), has been accomplished in accordance with the American Iron and Steel Institute Metric Practice Guide, 1978.

The newton (N) has been adopted by the SI as the metric standard unit of force as discussed in the AISI Metric Practice Guide. The term for force per unit of area (stress) is the newton per square metre (N/m<sup>2</sup>). Since this can be a large number, the prefix mega is used to indicate 1,000,000 units and the term meganewton per square metre (MN/m<sup>2</sup>) is used. The unit (N/m<sup>2</sup>) has been designated a pascal (Pa). The relationship between the U.S. and the SI units for stress is: 1000 pounds/in<sup>2</sup> (psi) = 1 kip/in<sup>2</sup> (ksi) = 6.8948 meganewtons/m<sup>2</sup> (MN/m<sup>2</sup>) = 6.8948 megapascals (MPa). Other units are discussed in the Metric Practice Guide.

## STANDARD HEAT TREATMENTS

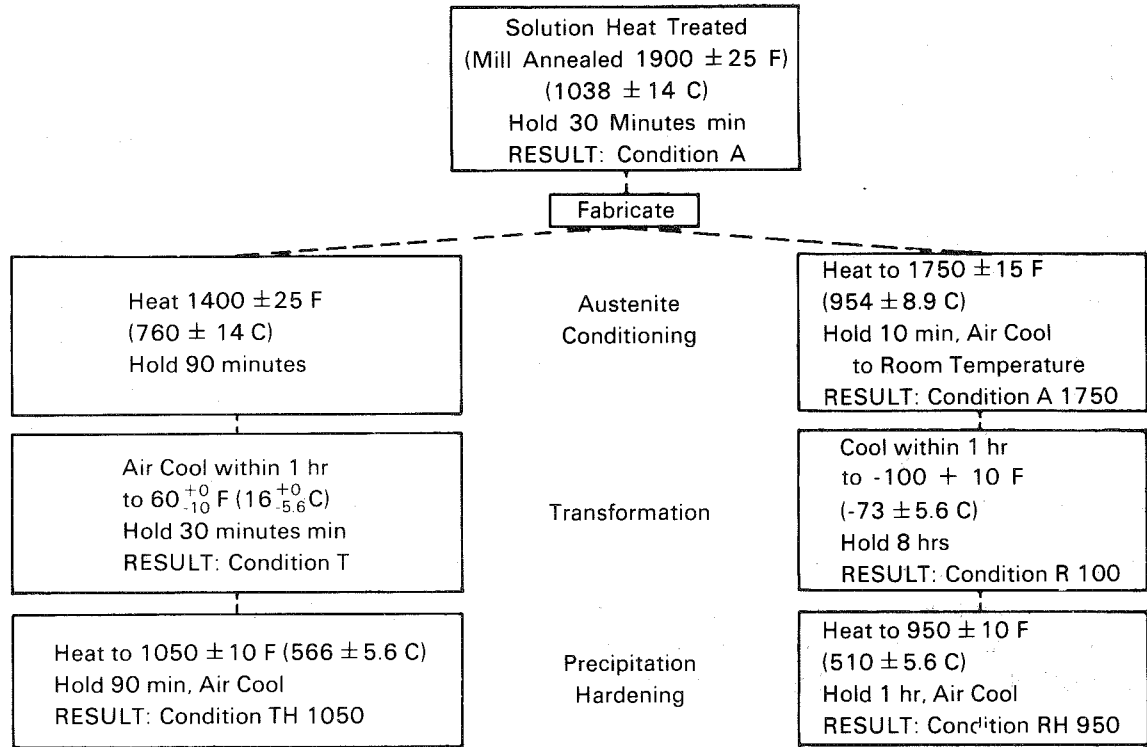
The highest mechanical properties obtainable from 17-7 PH stainless steel are found in wire treated to Condition CH 900. To obtain these properties, Condition A material is transformed to martensite at the mill by cold reduction. This is designated as Condition C. Hardening to Condition CH 900 is accomplished with a single low-temperature heat treatment.



For the heat treatment of 17-7 PH Condition A products, the following three essential steps are required to develop the high strengths of Conditions TH 1050 and RH 950:

1. Austenite conditioning
2. Cooling to effect transformation of austenite to martensite
3. Precipitation hardening

Material purchased in Condition A can be heat treated to develop these high strengths by one of the following procedures:



## MECHANICAL PROPERTIES

### Properties Acceptable for Material Specifications

Tables I and II list properties acceptable for material specifications

Table I  
Properties Acceptable For Material Specification  
Bar and Wire

Condition	UTS psi (MPa)	0.2% YS. psi (MPa)	Elong % in 2" (50.8 mm) or 4 x D	Red. of Area %	Hardness	
					BHN	Rockwell
Condition A	150,000 max (1034)	—	—	—	229 max	B98 max
Condition TH 1050 up to 3" (76.2 mm) incl	170,000 min (1172)	140,000 min (965)	6 min	25 min	363 min	C38 min
Condition RH 950 up to 3" (76.2 mm) incl	185,000 min (1276)	150,000 min (1034)	6 min	10 min	387 min	C41 min

**Table II**  
**Properties Acceptable For Material Specification**  
**Cold Drawn Wire**

Wire Diameter inches (mm)	Ultimate Tensile Strength, ksi (MPa)	
	Condition C range	Condition CH 900 range
*.030-.041 (.762-1.041)	260-290 (1793-1999)	320-350 (2206-2413)
*.042-.051 (1.067-1.295)	255-285 (1758-1965)	310-340 (2137-2344)
*.052-.061 (1.321-1.549)	250-280 (1724-1931)	305-335 (2102-2309)
.062-.071 (1.575-1.803)	242-272 (1669-1875)	297-327 (2048-2254)
.072-.086 (1.829-2.184)	240-270 (1655-1862)	292-322 (2013-2220)
.087-.090 (2.210-2.286)	230-260 (1586-1793)	282-312 (1944-2151)
.091-.100 (2.311-2.540)	227-257 (1565-1772)	279-309 (1924-2130)
.101-.106 (2.565-2.692)	223-253 (1538-1744)	274-304 (1889-2096)
.107-.130 (2.718-3.302)	221-251 (1524-1731)	272-302 (1875-2082)
.131-.138 (3.327-3.505)	215-245 (1482-1689)	260-290 (1793-1999)
.139-.146 (3.531-3.708)	213-243 (1469-1675)	258-288 (1779-1986)
.147-.162 (3.734-4.115)	211-241 (1455-1662)	256-286 (1765-1972)
.163-.180 (4.140-4.572)	209-239 (1441-1648)	254-284 (1751-1958)
.181-.207 (4.597-5.258)	207-237 (1427-1634)	252-282 (1737-1944)
.208-.225 (5.283-5.715)	203-233 (1400-1606)	248-278 (1710-1917)
.226-.306 (5.740-7.772)	198-228 (1365-1572)	242-272 (1669-1875)
.307-.331 (7.798-8.40)	192-222 (1324-1531)	235-265 (1620-1827)

\* Produced in coils only.

Note: Tensile strength of Condition C wire in straight lengths may be slightly less than minimum value shown. However, tensile strengths after aging will be within the range shown for Condition CH 900. Hardness of Condition C material will be Rockwell C44 min, while Condition CH 900 material will have a minimum hardness of Rockwell C48.

### Typical Mechanical Properties

**Table III**  
**Room Temperature Properties**

Property	Condition				
	A	T	R 100	TH 1050	RH 950
UTS, psi (MPa)-Tension	—	—	—	175,000 (1207)	200,000 (1379)
0.2% YS, psi (MPa)-Tension	—	—	—	155,000 (1069)	175,000 (1207)
Elong, % in 2" (50.8 mm) or 4 x D	—	—	—	12.0	10.0
Reduction of Area, %	—	—	—	34.0	30.0
Hardness — Brinell	187	311	321	402	430
Rockwell	B90	C32	C34	C42	C44
Fatigue Strength (% of tensile strength)					
10 million cycles	—	—	—	44	—
100 million cycles	—	—	—	41	—

Elastic Limit: Tension — Approximately 75% UTS (Condition CH 900)

                  Torsion — Approximately 55% UTS (Condition TH 1050 AND RH 950)

                                  Approximately 45% UTS (Condition CH 900)

**Table IV**  
**Fatigue Strength by Rotating Wire Arc Fatigue Test**  
**Condition CH 900**

	Endurance Limit, psi (MPa) 10 <sup>8</sup> cycles
Commercial Surface (Cold Drawn)	65,000 (448)
Machined and Polished	80,000 (552)
Electropolished	100,000 (689)
Centerless Ground	125,000 (862)
Centerless Ground and Electropolished	100,000 (689)

## SPRING PROPERTIES

**Table V**  
**Fatigue Properties of Helical Compression Springs**  
**Condition CH 900**

Wire Size in (mm)	Surface Condition	Endurance Limit (10,000,000 cycles — 10,000 psi [69 MPa] min Stress) Fatigue Strength, psi (MPa)
.067 (1.70)	Cold drawn	85,000 (586)
.067 (1.70)	Electropolish	105,000 (724)
.085 (2.16)	Cold drawn	85,000 (586)
.105 (2.67)	Cold drawn	85,000 (586)
.105 (2.67)	Shot peened	120,000 (827)
.105 (2.67)	Electropolished + shot peened	130,000 (896)
.125 (3.18)	Cold drawn	73,000 (503)
.125 (3.18)	Electropolished	85,000 (586)

Armco 17-7 PH hard drawn wire has elastic properties comparable to those of the best music wire and alloy spring steels. It provides a unique combination of ultra-high strength and good corrosion resistance that makes it ideal for a wider variety of spring applications. For service at elevated temperatures, up to 600 F (316 C), Armco 17-7 PH in Condition CH 900 is the most economical spring material available.

Armco 17-7 PH stainless steel has good dimensional stability when formed into springs. The dimensions of 17-7 PH springs are unaffected by the hardening treatment, and the ends and hooks on helical springs do not change position.

Springs made of 17-7 PH stainless steel can be treated at 1000 to 1050 F (538 to 566 C) to eliminate initial tension and still maintain good spring properties for room temperature applications. This treatment results in a constant spring rate.

Armco 17-7 PH springs show considerably lower loss of load at elevated temperatures than music wire springs. The results of relaxation tests conducted at various temperatures and stress levels on helical compression springs are shown in Table VI. Tables VII and VIII show mechanical property data and dimensions of the various springs tested.

Armco 17-7 PH Condition C wire is supplied with a lubricating coating suitable for automatic spring coiling in sizes .0937" to .331" (2.38 to 8.40 mm) diameter with any of the following: Apex, Cowles, Couperdine, lime, oxalate or copper; also, molydisulphide or lime and Apex drawn with any of these coatings. Oxalate, lime, Cowles and Apex can pick up moisture and therefore should be stored in a dry room, preferably with constant temperature. All the subject coatings can be removed before or after heat treatments with a 10% nitric acid solution at 110-140 F (43-60 C). If difficulty is encountered, a 10% nitric acid-2% hydrofluoric acid solution at the same temperature can be used.

**Table VI — Relaxation Properties**

Type	Size in (mm)	% Loss in Load					
		350 F (177 C)	450 F (232 C)	550 F (288 C)	650 F (343 C)	750 F (399 C)	850 F (454 C)
Initial (RT) Stress 40,000 psi (276 MPa), Time 96 Hours							
17-7 PH (1)	.040 (1.02) Rd.	0.0	1.1	1.8	6.1	15.6	—
17-7 PH (1)	.080 (2.03) Rd.	—	—	2.0	3.9	10.7	—
18 Cr-8 Ni (2)	.040 (1.02) Rd.	0.0	1.6	5.6	11.4	—	—
* Inconel "X" (3)	.085 (2.16) Rd.	—	—	—	0.96	4.91	15.8
Music Wire (4)	.040 (1.02) Rd.	3.3	9.1	—	—	—	—
Initial (RT) Stress 80,000 psi (552 MPa), Time 96 Hours							
17-7 PH (1)	.040 (1.02) Rd.	0.0	0.9	1.26	5.55	20.9	—
17-7 PH (2)	.080 (2.03) Rd.	—	—	3.7	4.0	13.2	—
18 Cr-8 Ni (2)	.040 (1.02) Rd.	1.5	2.1	6.9	16.5	—	—
* Inconel "X" (3)	.085 (2.16) Rd.	—	—	—	2.16	7.6	22.9
Music Wire (4)	.040 (1.02) Rd.	5.07	13.7	—	—	—	—

(1) Aged 900 F (482 C) - 1 hour, air cool

(2) Stress relieved 850 F (454 C) - 1/2 hour, air cool

(3) Aged 1350 F (732 C) - 16 hours, air cool

(4) Stress relieved 750 F (399 C) - 1/2 hour, air cool

\* Relaxation tests were conducted on "spring temper" wire aged at 1350 F (732 C) for 16 hours.

**Table VII  
Mechanical Properties**

Grade	Size in (mm)	Hardness	Modulus in Torsion		Max Stress psi (2) (MPa)
			Calculated	Published (1)	
17-7 PH	.040 (1.02) Rd.	—	10,160,000	11,000,000	94,400 (650)
17-7 PH	.080 (2.03) Rd.	R <sub>C</sub> 54	10,720,000	11,000,000	99,800 (687)
18 Cr-8 Ni	.040 (1.02) Rd.	R <sub>C</sub> 47	10,325,000	10,000,000	82,600 (576)
Inconel "X" (3)	.085 (2.16) Rd.	R <sub>C</sub> 47	10,300,000	11,000,000	97,200 (670)
Music Wire	.040 (1.02) Rd.	—	12,060,000	11,500,000 12,000,000	101,250 (697)

(1) Mechanical Springs — Their Engineering and Design,

Wallace Barnes Company, Division of Associated Spring Corporation

(2) Governed by design of spring

(3) Springs supplied in spring temper condition

**Table VIII**  
**Spring Dimensions**

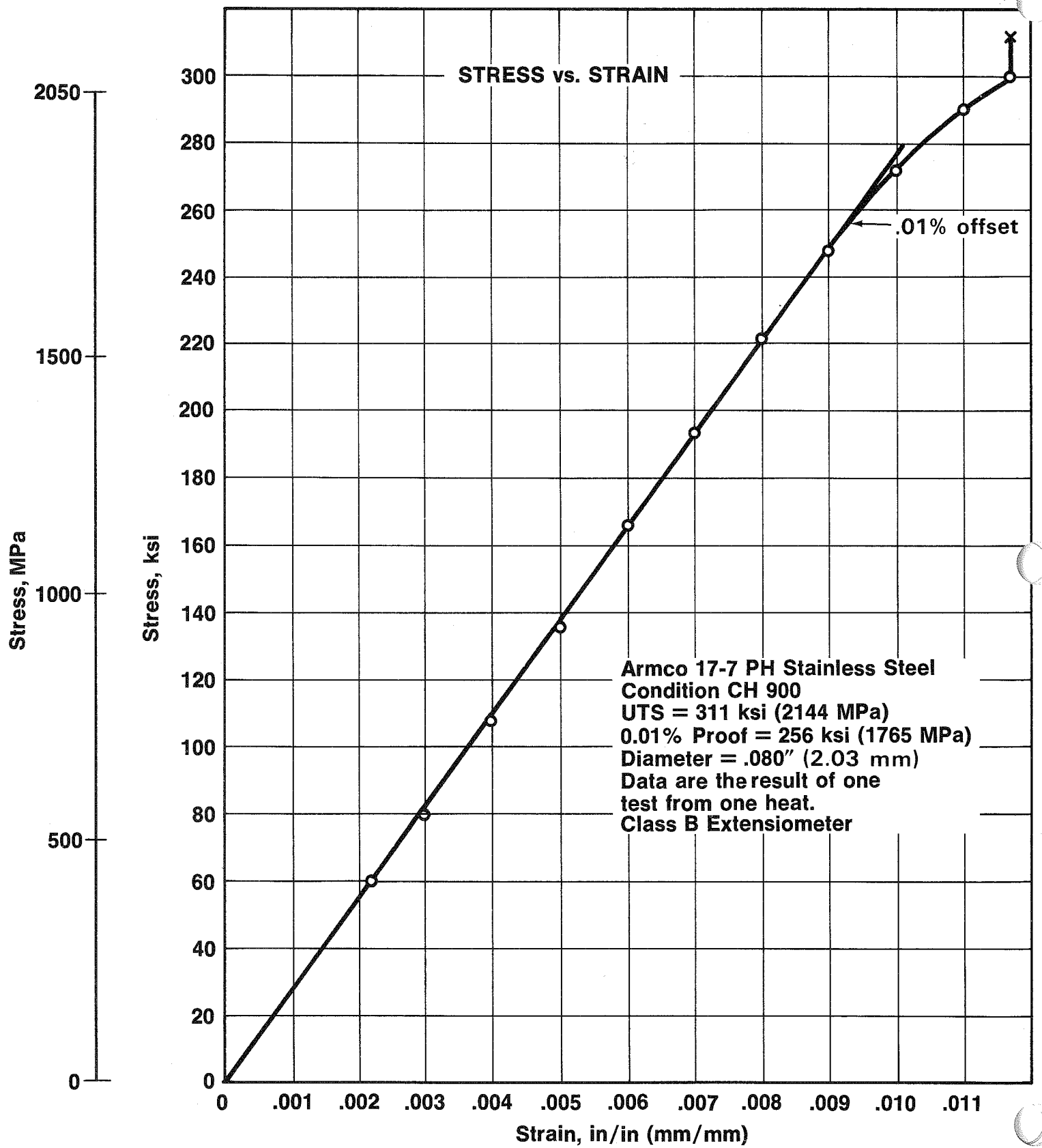
Type	d	OD	D	H	N	K	Type of Ends
17-7 PH	.040" (1.02 mm)	.360" (9.14 mm)	.320" (8.13 mm)	.675" (17.14 mm)	6	1.175	Squared & Ground
17-7 PH	.080" (2.03 mm)	.719" (18.26 mm)	.638" (16.20 mm)	1.325" (33.66 mm)	6	1.180	Squared & Ground
18 Cr-8 Ni	.040" (1.02 mm)	.367" (9.32 mm)	.327" (8.30 mm)	.657" (16.69 mm)	6	1.175	Squared & Ground
Inconel "X"	.085" (2.16 mm)	.772" (19.61 mm)	.687" (17.45 mm)	1.450" (36.83 mm)	6	1.175	Squared & Ground
Music Wire	.040" (1.02 mm)	.360" (9.14 mm)	.320" (8.13 mm)	.660" (16.76 mm)	6	1.775	Squared & Ground

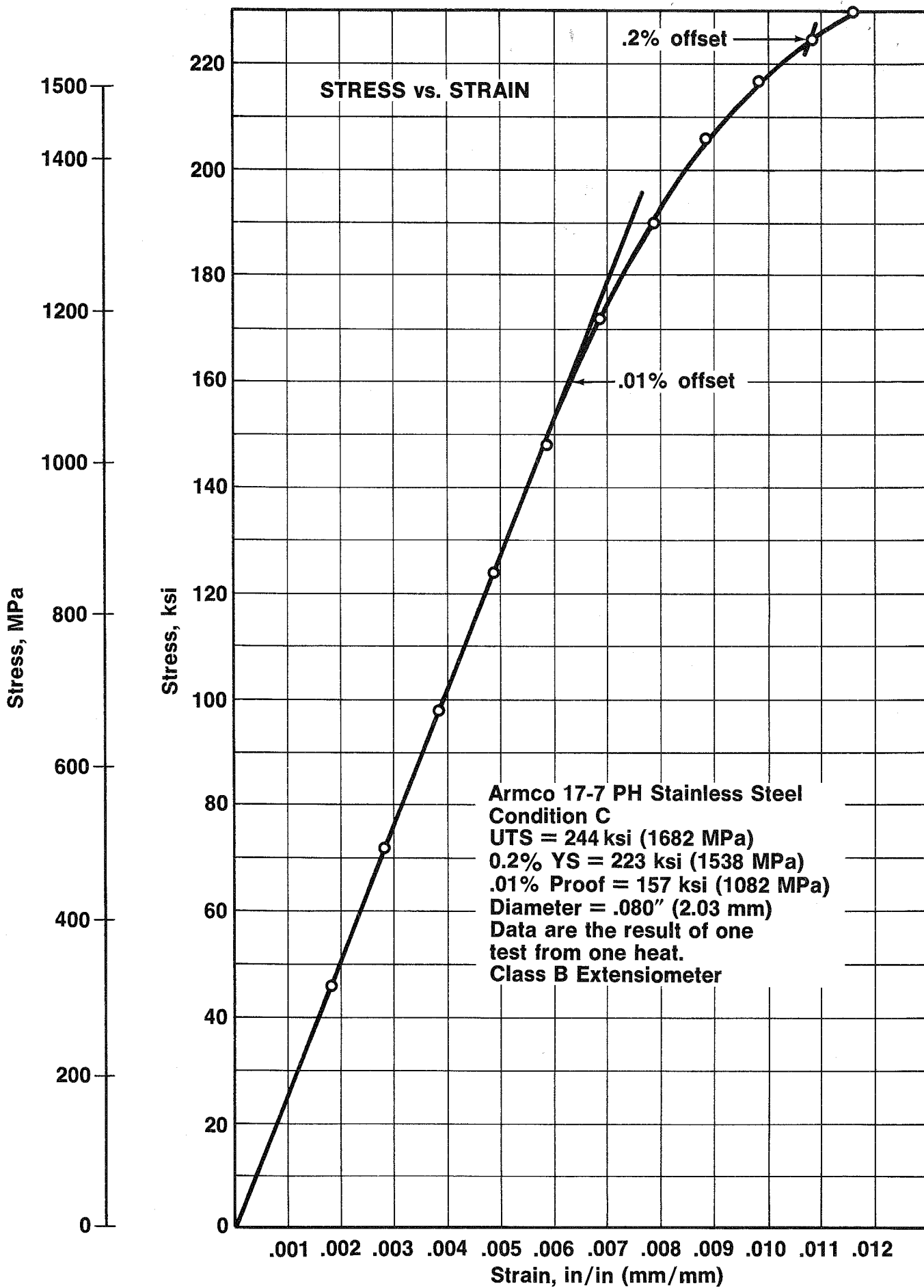
d = Wire Diameter  
 OD = Spring Diameter  
 D = Mean Diameter of Coil  
 H = Free Length  
 N = Number of Active Coils  
 K = Curvature Correction Factor

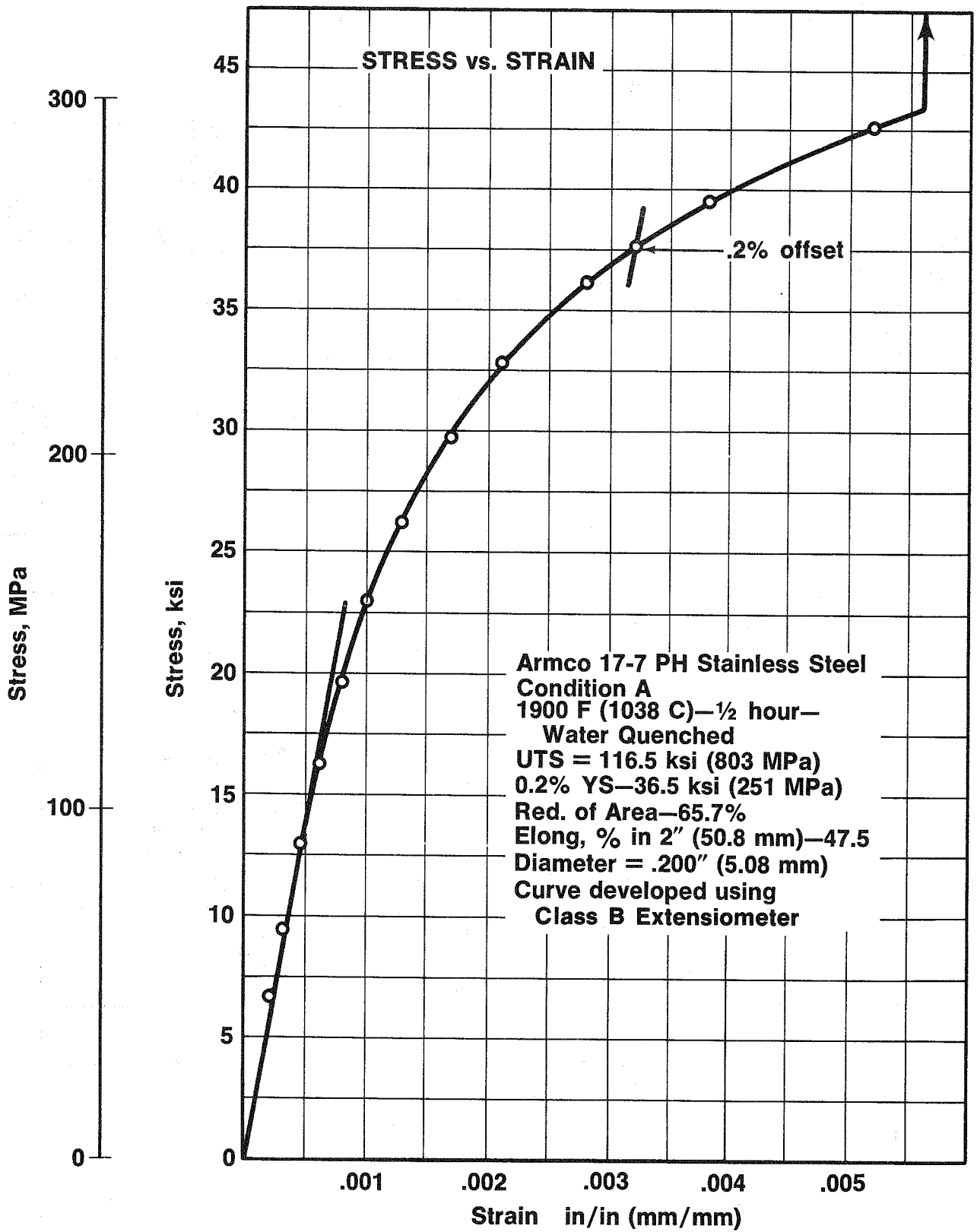
Table IX shows the effect of temperature on the torsional modulus of spring materials. The change in modulus was determined on compression springs in a temperature range of -105 F to 750 F (-76 to 399 C). In calculating the torsional modulus at various temperatures, the room temperature (80 F or 27 C) modulus of the compression springs was considered as 100%.

**Table IX**  
**Effect of Temperature on Torsional Modulus**

Material	% Change of Torsional Modulus									
	-105 F (-76 C)	-65 F (-54 C)	0 F (-18 C)	80 F (27 C)	150 F (121 C)	350 F (177 C)	450 F (232 C)	550 F (288 C)	650 F (343 C)	750 F (399 C)
17-7 PH	+2.4	+1.8	+1.5	0	-2.4	-4.8	-6.9	-9.2	-11.4	-15.4
Type 302	+2.9	+2.7	+1.6	0	-3.8	-6.8	-8.7	-11.6	-14.5	—
Music Wire	—	—	—	0	-3.2	-5.5	-7.5	-12.9	—	—







## Effect of Heat Loading on Relaxation Properties

Heat loading is known to improve the resistance to relaxation. Heat loading is accomplished by preloading the springs to a stress 10% above the predetermined test stress and holding for one hour at a temperature 100 F (38 C) above the test temperature. Test results for 17-7 PH and Type 302 stainless steel compression springs are shown in Table X.

As indicated by the test data, heat loading effectively increased the resistance to relaxation in both 17-7 PH and Type 302 compression springs.

**Table X**  
**Effect of Heat Loading on Relaxation Properties**

Test	Type	Size	% Loss in Load	
			650 F (343 C)	750 F (399 C)
Initial RT Stress 40,000 psi (276 MPa) Time 96 Hours	17-7 PH (1)	.040" (1.02 mm) Rd	1.0	2.4
	Type 302 (2)	.040" (1.02 mm) Rd	3.4	—
Initial RT Stress 75,000 psi (517 MPa) Time 96 Hours	17-7 PH	.040" (1.02 mm) Rd	—	7.64
Initial RT Stress 80,000 psi (552 MPa) Time 96 Hours	17-7 PH (1)	.040" (1.02 mm) Rd	2.44	—

(1) Aged 900 F (482 C), 1 hour, air cool

(2) Stress relieved, 850 F (454 C), 1 hour, air cool

# PHYSICAL PROPERTIES

**Table XI**  
**Physical Properties**

Property	Condition			
	A	TH 1050	RH 950	CH 900
Density: gm/cm <sup>3</sup>	7.81	7.65	7.65	7.67
lbs/in <sup>3</sup>	0.282	0.276	0.276	0.277
Electrical Resistivity: microhm-cm	80	82	83	83.8
Magnetic Permeability:				
25 oersteds (199 A/m)	1.4-3.4	132-194	82-88	—
50 oersteds (398 A/m)	1.4-3.6	120-167	113-130	—
100 oersteds (796 A/m)	1.4-3.5	80-99	75-87	70
200 oersteds (1592 A/m)	1.4-3.2	46-55	44-52	43.5
maximum	1.4-3.6	134-208	119-135	125
Mean Coefficient of Thermal Expansion x 10 <sup>-6</sup> in/in/°F (1/K)				
70-200 F (21-93 C)	8.5 (15.3)	5.6 (10.0)	5.7 (10.3)	6.1 (11.0)
70-400 F (21-204 C)	9.0 (16.2)	6.1 (11.0)	6.6 (11.9)	6.2 (11.2)
70-600 F (21-316 C)	9.5 (17.1)	6.3 (11.3)	6.8 (12.2)	6.4 (11.5)
70-800 F (21-427 C)	9.6 (17.3)	6.6 (11.9)	6.9 (12.4)	6.6 (11.9)
Thermal Conductivity: BTU/hr/ft <sup>2</sup> /in/°F (W/m•K)				
300 F (149 C)	—	117 (16.9)	117 (16.9) (est.)	114 (16.4)
500 F (260 C)	—	128 (18.4)	128 (18.4) (est.)	127 (18.3)
840 F (448 C)	—	146 (21.1)	146 (21.1) (est.)	150 (21.6)
900 F (482 C)	—	146 (21.1)	146 (21.1) (est.)	151 (21.8)

Variations in heat treating temperature have negligible effect on electrical resistivity. Annealing, transforming and hardening treatment variations of  $\pm 100$  F (56 C) will not cause the resistivity to vary more than  $\pm 3\%$  from the listed value. The electrical resistivity value for Condition T is 107 microhm-cm.

## Modulus of Elasticity

The static modulus of elasticity of 17-7 PH (Condition CH 900) is:

Tension — 29,500,000 psi (200,000 MPa)

Torsion — 10,500,000 psi (72,000 MPa)

The dynamic modulus of elasticity of 17-7 PH (Condition H 1050) is 29,500,000 psi (200,000 MPa).

## Dimensional Changes

When Armco 17-7 PH in Condition A is heat treated to Conditions T or R (after austenite conditioning and transforming), a predictable expansion of 0.0045" per inch (mm/mm) will occur. Upon precipitation hardening to develop Condition TH 1050 or RH 950, there is a contraction of about 0.0005" per inch (mm/mm). The combined net effect is an expansion of about .004" per inch (mm/mm).

## **FABRICATION**

### **Heat Treating and Annealing**

When solution treating (annealing) hot worked or forged material, the metal should be heated to  $1900 \pm 10$  F ( $1038 \pm 5.6$  C), held for a minimum of 30 minutes at this temperature, and water quenched.

Condition C material is heat treated to high strength levels by a 900 F (482 C) heat treatment for 1 hour followed by air cooling. The heat treatment may be done either in a reducing atmosphere or in air. If an open furnace is used, the material will develop a light heat tint that is easily removed.

### **Equipment and Atmosphere**

Thorough cleaning of parts and assemblies prior to heat treatment facilitates scale removal. The removal of oils and lubricants with solvents also assures that the steel will not be carburized from this source. Carburized 17-7 PH parts do not develop the minimum mechanical properties shown.

Selection of heat treating equipment depends to some extent upon the nature of the particular parts to be treated. However, heat source, atmosphere and control of temperature are primary considerations.

Furnaces fired with oil or natural gas are difficult to use in the heat treatment of stainless steels, particularly if combustion control is uncertain and if flame impingement on the parts is possible. Electric furnaces or gas and oil fired radiant tube furnaces generally are used for heat treating 17-7 PH stainless steel.

Air has proved to be the most satisfactory furnace atmosphere for heat treating operations. Controlled reducing atmospheres such as bright annealing gas and dissociated ammonia introduce the hazard of carburizing and nitriding. Scale-free heat treatment in dry hydrogen atmosphere is difficult to achieve because of the extremely low dew point required at the heat treating temperatures of 1400 F (760 C) and lower. If complete freedom from scale or heat discoloration is necessary, a vacuum furnace is required. Dry hydrogen may be used for the 1750 F (954 C) heat treatment outlined for Condition RH 950 and will provide a scale-free surface.

When heat treating to the RH condition, it is necessary to cool 17-7 PH to a temperature of -100 F (-73 C) for a period of 8 hours. Commercial equipment is available for refrigeration at this temperature, but a saturated bath of dry ice in alcohol or acetone maintains a temperature of -100 to -109 F (-73 to -78 C) without control equipment.

## Forging

Forging practices for Armco 17-7 PH stainless are similar to those used with Type 302 stainless steel. Forging temperature should not exceed 2250 F (1232 C), but the material may be worked at lower temperatures of 2150 F (1177 C) or less, depending on size and shape. Scale loss will be lessened when lower forging temperatures are used. There is no critical temperature range in which the material may not be worked.

Charging practice is not critical and 17-7 PH may be charged in either a hot or cold furnace. Air cooling, oil or water quenching may be employed.

## Scale Removal

Scale develops during most heat treating operations. The amount and nature of the scale formation varies with the cleanliness of the parts, the furnace atmosphere and the temperature and time of heat treatment. A variety of descaling methods may be employed, and the method chosen often depends upon the facilities available. A tabulation of the recommended methods of scale removal after various heat treatments is shown in the following table.

**Table XII**  
**Scale Removal Methods**

Heat Treated to Condition	Preferred Methods After Heat Treatment	Secondary Methods
A	Wet Grit Blast (1) or Pickle (2)	Scale Condition and Pickle (3)
CH 900	Wet Grit Blast (1) or Pickle (2)	—
A 1750	Wet Grit Blast (1)	Pickle (2) or Scale Condition and Pickle (4)
T and R 100	Wet Grit Blast (1)	Pickle (2) or Scale Condition and Pickle (5)
TH 1050 and RH 950	Wet Grit Blast (1)	Pickle (2) or Scale Condition and Pickle (3)

- (1) Wet grit blasting processes are widely used and have been found to be highly satisfactory. These methods eliminate the hazard of intergranular attack from acid pickling. There also are advantages in better fatigue strength and corrosion resistance.
- (2) 10% HNO<sub>3</sub> + 2% HF at 110-140 F (43-60 C) for three minutes maximum. This pickling time limit is necessary to keep intergranular attack by the acid to a minimum. Removal of loosened scale may be facilitated by the use of high pressure water or steam spray. A scale conditioning treatment is not necessary for parts that have been thoroughly cleaned. Uniform pickling of the entire surface is evidence of a well cleaned part. A spotty scale and

nonuniform removal is evidence of a poorly cleaned part, and a scale conditioning process is a necessity prior to pickling.

- (3) Scale conditioners:
  - a) Hooker Electrochemical — Virgo Salts
  - b) Kolene Process
  - c) duPont Hydride Process
  - d) Caustic permanganate (boiling aqueous solution 10% NaOH + 3%  $\text{KMnO}_4$  for one hour)
- (4) Use caustic permanganate scale conditioning followed by  $\text{HNO}_3$  - HF pickle only. Do not use fused salts. The use of fused salts as scale conditioners on 17-7 PH in Condition A 1750 will prevent the steel from developing maximum transformation upon subsequent refrigeration.
- (5) Scale condition and pickle as in footnote 3. The Virgo and Kolene fused salt baths may be operated at temperatures up to 1100 F (593 C) so that the hardening and scale conditioning treatment may be combined if desired. However, the operation of a salt bath at such temperatures should be checked with the manufacturer before proceeding.

Some degree of intergranular penetration occurs during any pickling operation. However, in Condition CH 900, the penetration resulting from the short-time pickling is generally slight. Other conditions of heat treatment are more susceptible to intergranular penetration during pickling, and pickling methods should be avoided or carefully controlled if they must be used for such removal.

For removal of light discoloration or heat tint produced by final hardening treatment at 900-1200 F (482-649 C), the standard 10%  $\text{HNO}_3$  + 2% HF acid bath may be used.

### **Machining**

Machining characteristics of Armco 17-7 PH stainless are similar to those of Type 302 stainless steel. Transformed and heat-treated Armco 17-7 PH machines like other materials of equal hardness. Normal practice for machining materials in the hardness range of 275-400 BHN should be followed.

### **Welding**

Armco 17-7 PH stainless steel is readily welded by methods normally used for stainless steels. One of the most desirable welding characteristics is the elimination of preheating and post-annealing practices necessary for standard hardenable stainless steels.

## **CORROSION RESISTANCE**

In general, the corrosion resistance of Armco 17-7 PH stainless steel in Conditions TH 1050 and RH 950 is superior to that of the standard hardenable chromium types of stainless steels such as Types 410, 420 and 431, but not quite as good as the chromium-nickel Type 304. The corrosion resistance of Armco 17-7 PH stainless in Condition CH 900 approaches that of Type 304 in most environments.

## Atmospheric Exposure

Samples exposed at Kure Beach, North Carolina, show considerably better corrosion resistance to a marine atmosphere than hardened chromium stainless steels such as Type 410. Although there is little difference between any successive two ratings in the following table, samples indicate the following order of corrosion resistance based on general appearance:

- 1) Type 301 stainless steel
- 2) Armco 17-7 PH stainless steel, Condition CH 900
- 3) Armco 17-7 PH stainless steel, Condition TH 1050
- 4) Armco 17-7 PH stainless steel, Condition RH 950

In all heat-treated conditions, Armco 17-7 PH stainless, like other types of stainless steels, will develop superficial rust in some environments. For example, in a marine atmosphere, stainless steels show evidence of rusting after relatively short periods of exposure. However, after exposure of one or two years, the amount of rust present is little more than that which was present at six months.

## Corrosion Resistance and Compatability in Rocket Fuels

**Oxygen** — While oxygen is highly reactive chemically, liquid oxygen is noncorrosive to most metals. The precipitation-hardening stainless steels have no problem in this media.

**Ammonia** — Armco 17-7 PH stainless is satisfactory for handling ammonia.

**Hydrogen** — Liquid hydrogen and gaseous hydrogen at low temperatures are noncorrosive.

## Hydrogen Sulfide Environments

Like all martensitic stainless steels, Armco 17-7 PH stainless may be subject to cracking when exposed under stress in environments containing hydrogen sulfide.

Springs made from 17-7 PH stainless in Condition CH 900 have cracked readily in laboratory testing in synthetic sour well solution (5% NaCl + 0.5% acetic acid, saturated with  $H_2S$ ). In this type of environment, the use of a cold-drawn austenitic stainless steel such as Type 304 or NITRONIC 50, or A-286 (an age-hardenable alloy), is suggested.

## Chemical Media

Hundreds of accelerated laboratory corrosion tests have been conducted on the precipitation-hardening stainless steels since their development. The following table shows typical corrosion rates for Armco 17-7 PH and Type 304 stainless steels in seven common reagents. Sheet coupons and chemically pure laboratory reagents were used. Consequently, the data can be used only as a guide to comparative performance.

**Corrosion Rates\***  
**Mils per year**

Media	17-7 PH		Type 304 Annealed
	TH 1050	RH 950	
H <sub>2</sub> SO <sub>4</sub> , 35 C			
1%	0.5	0.2	0.4
2%	0.9	0.7	1.3
5%	124	132	7.7
H <sub>2</sub> SO <sub>4</sub> , 80 C			
1%	50	297	22.2
2%	374	884 <sup>(2)</sup>	65
HCl, 35 C			
0.5%	65	4	7.1
1 %	695 <sup>(2)</sup>	447 <sup>(3)</sup>	17.3
HNO <sub>3</sub> , Boil			
25%	19	20.4	1.2
50%	70	81	3.0
65%	128	136	7.2
Formic Acid, 80 C			
5%	2.7	4.3	4.1
10%	5.5	5.7	18.0
Acetic Acid, Boil			
33%	3.1	5.6	2.6
60%	12.3	3.0	10.9
H <sub>3</sub> PO <sub>4</sub> , Boil			
20%	7.0	18	1.6
50%	24	46	8.5
70%	104	315	39
NaOH, 80 C			
30%	13.1	3.7	0.9
NaOH, Boil			
30%	67	58	17.5

\* Rates were determined by total immersion for five 48-hour periods. Specimens were activated last three test periods except in the 65% nitric acid. Rate is average of number of periods indicated in parenthesis.

**Stress Corrosion Cracking in Marine Environments**

The hardenable chromium stainless steels are known to be subject to spontaneous fracture when stressed and exposed to some corrosive environments. Likewise, the precipitation-hardening stainless steels may, under some conditions, also fail by stress cracking. The tendency appears to be associated with the type of stainless steel, its hardness, the level of applied tension stress, and the environment.

Armco has conducted stress-cracking tests on the precipitation-hardening alloys in the marine environment at Kure Beach, North Carolina, using two-point loaded bent-beam specimens.

Data reported here are the results of multiple specimens exposed at stress levels of 50 and 75% of the actual yield strength of the materials tested. Test specimens were 0.050" (1.27 mm) thick sheet coupons, heat treated to Conditions TH 1050 and RH 950. Specimens in Condition CH 900 were 0.041" (1.04 mm) thick. The long dimension of all specimens was cut transverse to the rolling direction.

When comparing the various heat-treated conditions, data show that 17-7 PH stainless has the greatest resistance to stress cracking in Condition CH 900. Condition TH 1050, although somewhat less resistant than Condition CH 900, appears to be more resistant to stress cracking than Condition RH 950.

The following table summarizes the test data. In addition, in the mild industrial atmosphere at Middletown, Ohio, specimens stressed at 90% of their yield strength had not broken after 730 days of exposure.

### Summary of Stress Cracking Failures at Kure Beach 800 foot (244 meters) lot

Material and Heat Treatment	Stressed at 50% of the 0.2% YS			Stressed at 75% of the 0.2% YS		
	Stress psi (MPa)	Days to Failure	Range Days	Stress psi (MPa)	Days to Failure	Range Days
17-7 PH						
TH 1050	100,800 (694)	No Failures in 746 days	16-49	151,300 (1043)	100 <sup>[2]</sup> *	82-118**
TH 1050	89,000 (614)	No Failures in 746 days		133,600 (921)	No Failures in 746 days	
RH 950	111,600 (769)	30.2		167,500 (1154)	7.4	6-10
RH 950	110,200 (759)	116 <sup>[1]</sup> *		165,400 (1141)	51.6	26-71
CH 900	142,800 (986)	No Failures in 746 days		214,200 (1476)	No Failures in 746 days	
m						

\* Number in brackets indicates number of failed specimens. Remainder of 5 specimens unbroken after 746 days.

\*\* Range of unbroken specimens only. Remainder of 5 specimens unbroken after 746 days.

Note: All tests made in transverse direction. Tests discontinued after 746 days' exposure.

## SPECIFICATIONS

The following specifications covering Armco 17-7 PH stainless steel are listed without year of revision indications. Contact ASTM headquarters for latest ASTM revisions. For AMS revisions, consult AMS Division of SAE.

- ASTM 564 Grade 631 Bars and Shapes
- ASTM 313 Grade 631 Spring Wire
- ASTM 705 Grade 631 Forgings
- AMS 5644 Bars and Forgings
- AMS 5763 Wire Spring Temper