

S P E C I A L

S T E E L

S T R I P



# 世界品質 Global Quality

## 1 Features

### 1 Consistent quality control

Our consistent quality control system covering all the processes from upstream operation (with the blast furnace) to finishing work enables us to offer our customers products of uniform quality.

### 2 Production techniques for high special steel quality

Efficient use of our state-of-the-art production facilities and close attention to details enable us to manufacture special steel products with high quality performance.

### 3 The largest market share of special steel strips/sheets in Japan

We enjoy the largest market share of special steel strips/sheets in Japan, supplying some 160 different types of steel comprising the JIS-designated products along with our original steel grades. Our accumulated know-how on special steel enables us to meet a wide variety of customer needs both at home and abroad.

#### Special steel

##### Carbon steel for machine structural use

Steel with a high carbon content (0.2% - 0.6%)

##### Alloy steel for machine structural use

Steel with alloying elements (Cr, Mo, etc.) as well as a high carbon content

##### Carbon tool steel

Steel with a high carbon content (0.6% - 1.5%)

##### Alloy tool steel

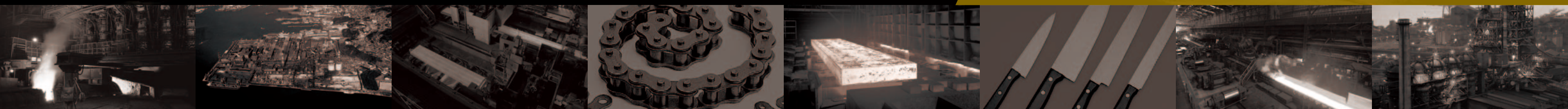
Steel with alloying elements as well as a high carbon content (0.6% - 1.5%)

##### Spring steel

Steel of improved spring characteristics with alloying elements (Si, Mn, Cr, etc.) as well as a high carbon content

##### Bearing steel

High-carbon, high-chromium steel of improved abrasion resistance



With an integrated iron and steel production system and high-mix low-volume production manufacturing techniques, we provide special steel products that meet a wide variety of customer needs. In addition to JIS designated products, we offer a broad line of our original steel grades superior in various characteristics. Furthermore, we design and control product qualities according to customers' intended uses, methods of processing and heat treatment.

Our special steel, featuring precise dimensions and beautiful surface finishes as well as high strength, good abrasion resistance, and high toughness, finds wide use in applications including automotive drive-train components, chains, springs and blades where superior quality is demanded. We have the largest market share of special steel strips/sheets in Japan.

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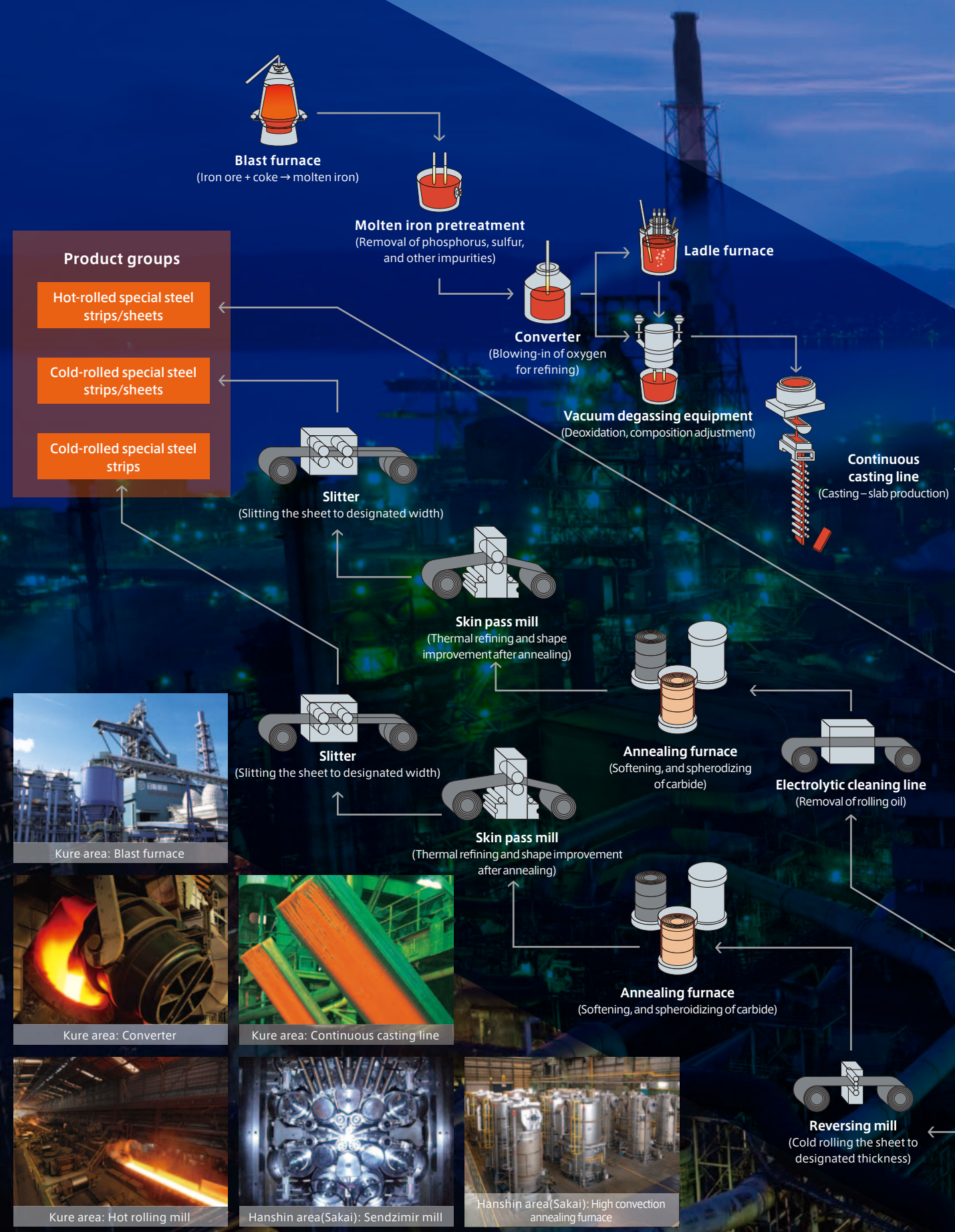
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## 2 Manufacturing Process/Production Bases



### Production bases





### 3 Typical Applications

SPECIAL STEEL STRIP

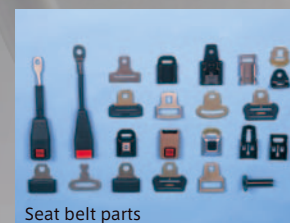
# 01

## Carbon steel and carbon steel for machine structural use

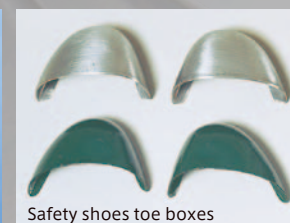
- Clutch plates ●Seat belt parts ●Safety shoes toe boxes
- Seat gears ●Hollow stabilizers



Clutch plates



Seat belt parts



Safety shoes toe boxes



Seat gears



Hollow stabilizers

# 02

## Carbon tool steel

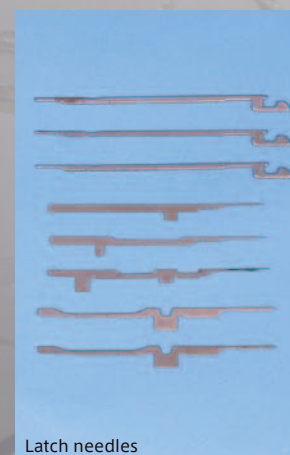
- Diaphragm springs ●Latch needles ●Springs/washers
- Washers



Diaphragm springs



Washers



Latch needles



Springs/washers

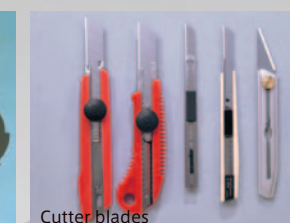
# 03

## Alloy tool steel

- Circular saws ●Cutter blades
- Band saws ●Golf shafts



Circular saws



Cutter blades



Band saws

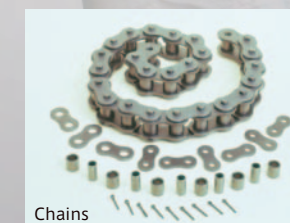


Golf shafts

# 04

## Structural alloy steel

- Chains ●Rocker arms



Chains



Rocker arms

# 05

## Others(spring steel, bearing steel, bainite steel strip, etc.)

- Bearing retainers ●Supporting grips



Bearing retainers



Supporting grips



# 4 Grades of Steel Manufactured and their Chemical Compositions

SPECIAL STEEL STRIP

## (1) Hot- and cold-rolled steel strips

### ① Carbon steel and carbon steel for machine structural use (including boron-added steel)

| JIS   | SAE     | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |             |           |        |        |       |       |           |               |       |
|-------|---------|-----------------------------|--------------------------|-------------|-----------|--------|--------|-------|-------|-----------|---------------|-------|
|       |         |                             | C                        | Si          | Mn        | P      | S      | Cu    | Ni    | Cr        | B             | Ni+Cr |
|       |         | N15CK                       | 0.10-0.15                | 0.15-0.35   | 0.30-0.60 | ≤0.025 | ≤0.025 | —     | —     | —         | —             | —     |
| S15CK |         |                             | 0.13-0.18                | 0.15-0.35   | 0.30-0.60 | ≤0.025 | ≤0.025 | ≤0.25 | ≤0.20 | ≤0.20     | —             | ≤0.30 |
| S15C  |         |                             | 0.13-0.18                | 0.15-0.35   | 0.30-0.60 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       | SAE1020 |                             | 0.17-0.23                | (0.15-0.35) | 0.30-0.60 | ≤0.030 | ≤0.050 | —     | —     | —         | —             | —     |
| S20C  |         |                             | 0.18-0.23                | 0.15-0.35   | 0.30-0.60 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       |         | NM19CB                      | 0.18-0.21                | ≤0.25       | 1.20-1.40 | ≤0.025 | ≤0.025 | —     | —     | ≤0.40     | 0.0010-0.0050 | —     |
| S20CK |         |                             | 0.18-0.23                | 0.15-0.35   | 0.30-0.60 | ≤0.025 | ≤0.025 | ≤0.25 | ≤0.20 | ≤0.20     | —             | ≤0.30 |
|       |         | N22CB                       | 0.20-0.25                | ≤0.25       | 0.30-0.60 | ≤0.025 | ≤0.025 | —     | —     | ≤0.50     | 0.0010-0.0050 | —     |
|       |         | N22CB5                      | 0.20-0.25                | ≤0.25       | 0.70-0.90 | ≤0.025 | ≤0.025 | —     | —     | ≤0.50     | 0.0010-0.0050 | —     |
|       |         | NM22CB                      | 0.20-0.25                | ≤0.25       | 1.40-1.60 | ≤0.025 | ≤0.025 | —     | —     | ≤0.50     | 0.0010-0.0050 | —     |
| S25C  |         |                             | 0.22-0.28                | 0.15-0.35   | 0.30-0.60 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       |         | N28CB                       | 0.26-0.30                | ≤0.15       | 0.35-0.60 | ≤0.025 | ≤0.025 | —     | —     | ≤0.50     | 0.0010-0.0050 | —     |
| S33C  |         |                             | 0.30-0.36                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       |         | N35C                        | 0.29-0.35                | ≤0.35       | 0.90-1.15 | ≤0.020 | ≤0.020 | —     | —     | 0.20-0.30 | —             | —     |
| S35C  |         |                             | 0.32-0.38                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       | SAE1035 |                             | 0.32-0.38                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | N35CB                       | 0.32-0.38                | ≤0.10       | 0.25-0.50 | ≤0.015 | ≤0.010 | —     | —     | ≤0.40     | 0.0010-0.0050 | —     |
|       |         | N36CB                       | 0.34-0.38                | ≤0.10       | 0.50-0.70 | ≤0.015 | ≤0.010 | —     | —     | —         | —             | —     |
| S38C  |         |                             | 0.35-0.41                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
| S40C  |         |                             | 0.37-0.43                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       |         | N40CB                       | 0.38-0.43                | ≤0.35       | 1.20-1.40 | ≤0.025 | ≤0.025 | —     | —     | ≤0.30     | 0.0010-0.0050 | —     |
| S45C  |         |                             | 0.42-0.48                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       | SAE1045 |                             | 0.43-0.50                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
| S48C  |         |                             | 0.45-0.51                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
| S50C  |         |                             | 0.47-0.53                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       | SAE1050 |                             | 0.48-0.55                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
| S53C  |         |                             | 0.50-0.56                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
| S55C  |         |                             | 0.52-0.58                | 0.15-0.35   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       | SAE1055 |                             | 0.50-0.60                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | N55D                        | 0.52-0.58                | ≤0.10       | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
| S58C  |         |                             | 0.55-0.61                | 0.15-0.30   | 0.60-0.90 | ≤0.030 | ≤0.035 | ≤0.30 | ≤0.20 | ≤0.20     | —             | ≤0.35 |
|       | SAE1060 |                             | 0.55-0.65                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | N60C                        | 0.55-0.65                | 0.15-0.30   | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | N63C                        | 0.60-0.65                | 0.15-0.30   | 0.70-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       | SAE1065 |                             | 0.60-0.70                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | N65C                        | 0.60-0.70                | 0.15-0.30   | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       | SAE1070 |                             | 0.65-0.75                | (0.15-0.35) | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | N70C                        | 0.65-0.75                | 0.15-0.30   | 0.60-0.90 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       |         | NK11                        | 0.65-0.75                | ≤0.35       | 0.50-0.80 | ≤0.030 | ≤0.030 | —     | —     | —         | —             | —     |
|       | SAE1074 |                             | 0.70-0.80                | (0.15-0.35) | 0.50-0.80 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |
|       | SAE1075 |                             | 0.70-0.80                | (0.15-0.35) | 0.40-0.70 | ≤0.030 | ≤0.035 | —     | —     | —         | —             | —     |

### ② Carbon tool steel

| JIS   | SAE     | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |             |           |        |        |       |       |           |
|-------|---------|-----------------------------|--------------------------|-------------|-----------|--------|--------|-------|-------|-----------|
|       |         |                             | C                        | Si          | Mn        | P      | S      | Cu    | Ni    | Cr        |
|       |         | NK7CR                       | 0.57-0.63                | 0.15-0.30   | 0.35-0.45 | ≤0.020 | ≤0.020 | —     | —     | 0.45-0.55 |
| SK65  |         |                             | 0.60-0.70                | 0.10-0.35   | 0.10-0.50 | ≤0.030 | ≤0.030 | ≤0.25 | ≤0.25 | ≤0.30     |
|       | SAE1078 |                             | 0.72-0.85                | (0.15-0.35) | 0.30-0.60 | ≤0.050 | —      | —     | —     | —         |
|       |         | NK6DCR                      | 0.72-0.86                | ≤0.15       | 0.30-0.60 | ≤0.025 | ≤0.025 | —     | —     | 0.40-0.60 |
| SK75  |         |                             | 0.70-0.80                | 0.10-0.35   | 0.10-0.50 | ≤0.030 | ≤0.030 | ≤0.25 | ≤0.25 | ≤0.30     |
|       |         | NK5D                        | 0.80-0.90                | ≤0.15       | 0.30-0.50 | ≤0.030 | ≤0.030 | —     | —     | —         |
| SK85  |         |                             | 0.80-0.90                | 0.10-0.35   | 0.10-0.50 | ≤0.030 | ≤0.030 | ≤0.25 | ≤0.25 | ≤0.30     |
|       | SAE1085 |                             | 0.80-0.93                | (0.15-0.35) | 0.70-1.00 | ≤0.030 | ≤0.050 | —     | —     | —         |
|       | SAE1086 |                             | 0.80-0.94                | (0.15-0.35) | 0.30-0.50 | ≤0.040 | ≤0.050 | —     | —     | —         |
| SK95  |         |                             | 0.90-1.00                | 0.10-0.35   | 0.10-0.50 | ≤0.030 | ≤0.030 | ≤0.25 | ≤0.25 | ≤0.30     |
|       | SAE1095 |                             | 0.90-1.03                | (0.15-0.35) | 0.30-0.50 | ≤0.030 | ≤0.050 | —     | —     | —         |
| SK120 |         |                             | 1.15-1.25                | 0.10-0.35   | 0.10-0.50 | ≤0.030 | ≤0.030 | ≤0.25 | ≤0.25 | ≤0.30     |

### ③ Alloy tool steel

| JIS   | SAE | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |           |           |        |        |       |           |           |           |           |           |
|-------|-----|-----------------------------|--------------------------|-----------|-----------|--------|--------|-------|-----------|-----------|-----------|-----------|-----------|
|       |     |                             | C                        | Si        | Mn        | P      | S      | Cu    | Ni        | Cr        | Mo        | V         | Nb        |
|       |     | NKS100                      | 0.30-0.35                | 0.20-0.40 | 0.40-0.60 | ≤0.020 | ≤0.010 | —     | —         | 1.35-1.65 | 1.40-1.70 | 0.25-0.35 | 0.01-0.03 |
|       |     | NKS62                       | 0.58-0.65                | 0.15-0.35 | 0.60-0.90 | ≤0.030 | ≤0.030 | —     | —         | 0.80-1.10 | —         | 0.15-0.25 | —         |
|       |     | NKS41                       | 0.75-0.85                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | 1.30-2.00 | ≤0.50     | —         | 0.20-0.30 | —         |
|       |     | NKS32                       | 0.77-0.83                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | 2.00-2.50 | ≤0.25     | —         | —         | —         |
|       |     | NKS85                       | 0.75-0.85                | 0.15-0.35 | 0.40-0.50 | ≤0.030 | ≤0.030 | —     | 0.70-1.30 | 0.30-0.50 | 0.10-0.20 | 0.10-0.20 | —         |
| SKS51 |     |                             | 0.75-0.85                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | ≤0.25 | 1.30-2.00 | 0.20-0.50 | —         | —         | —         |
| SKS5  |     |                             | 0.75-0.85                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | ≤0.25 | 0.70-1.30 | 0.20-0.50 | —         | —         | —         |
|       |     | NKS60                       | 0.80-0.87                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | —         | 0.40-0.60 | —         | 0.25-0.35 | —         |
|       |     | NKS59                       | 0.80-0.90                | ≤0.35     | 0.80-1.00 | ≤0.030 | ≤0.030 | —     | —         | 0.40-0.60 | —         | —         | —         |
|       |     | NKS80                       | 0.81-0.90                | ≤0.30     | 0.40-0.50 | ≤0.020 | ≤0.010 | —     | —         | 0.10-0.20 | 0.10-0.30 | —         | —         |
|       |     | NKS36                       | 0.85-0.95                | ≤0.35     | 0.40-0.60 | ≤0.030 | ≤0.030 | —     | 0.40-0.70 | 0.25-0.45 | —         | —         | —         |
|       |     | NKS37                       | 0.85-0.95                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | 0.70-1.30 | ≤0.50     | —         | —         | —         |
|       |     | NKS49                       | 0.90-1.00                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | —         | 0.20-0.40 | —         | —         | —         |
|       |     | NKS52                       | 0.90-1.04                | ≤0.35     | 0.60-0.90 | ≤0.030 | ≤0.030 | —     | —         | 0.20-0.40 | —         | —         | —         |
|       |     | NKS1                        | 0.97-1.03                | ≤0.30     | 0.40-0.50 | ≤0.020 | ≤0.010 | —     | 0.90-1.10 | 0.30-0.50 | 0.10-0.18 | 0.12-0.18 | —         |
|       |     | NKS39                       | 1.10-1.20                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | 0.70-1.30 | ≤0.50     | —         | —         | —         |
|       |     | NKS56                       | 1.10-1.30                | ≤0.35     | ≤0.50     | ≤0.030 | ≤0.030 | —     | —         | 0.20-0.50 | —         | —         | —         |

### ④ Structural alloy steel

#### Chromium steel

| JIS    | SAE | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |           |           |        |        |       |       |           |
|--------|-----|-----------------------------|--------------------------|-----------|-----------|--------|--------|-------|-------|-----------|
|        |     |                             | C                        | Si        | Mn        | P      | S      | Cu    | Ni    | Cr        |
| SCr415 |     |                             | 0.13-0.18                | 0.15-0.35 | 0.60-0.90 | ≤0.030 | ≤0.030 | ≤0.30 | ≤0.25 | 0.90-1.20 |
| SCr420 |     |                             | 0.18-0.23                | 0.15-0.35 | 0.60-0.90 | ≤0.030 | ≤0.030 | ≤0.30 | ≤0.25 | 0.90-1.20 |
| SCr435 |     |                             | 0.33-0.38                | 0.15-0.35 | 0.60-0.90 | ≤0.030 | ≤0.030 | ≤0.30 | ≤0.25 | 0.90-1.20 |
| SCr440 |     |                             | 0.38-0.43                | 0.15-0.35 | 0.60-0.90 | ≤0.030 | ≤0.030 | ≤0.30 | ≤0.25 | 0.90-1.20 |
|        |     | N50CRN                      | 0.50-0.55                | 0.15-0.30 | 0.65-0.85 | ≤0.020 | ≤0.010 | —     | —     | 0.40-0.60 |



Chromium molybdenum steel

| JIS    | SAE     | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |             |           |        |        |       |       |           |           |
|--------|---------|-----------------------------|--------------------------|-------------|-----------|--------|--------|-------|-------|-----------|-----------|
|        |         |                             | C                        | Si          | Mn        | P      | S      | Cu    | Ni    | Cr        | Mo        |
| SCM415 |         |                             | 0.13-0.18                | 0.15-0.35   | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | 0.90-1.20 | 0.15-0.25 |
| SCM420 |         |                             | 0.18-0.23                | 0.15-0.35   | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | 0.90-1.20 | 0.15-0.25 |
| SCM430 |         |                             | 0.28-0.33                | 0.15-0.35   | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | 0.90-1.20 | 0.15-0.30 |
| SCM435 |         |                             | 0.33-0.38                | 0.15-0.35   | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | 0.90-1.20 | 0.15-0.30 |
| SCM440 |         |                             | 0.38-0.43                | 0.15-0.35   | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | 0.90-1.20 | 0.15-0.30 |
|        | SAE4130 |                             | 0.28-0.33                | (0.15-0.35) | 0.40-0.60 | ≦0.030 | ≦0.040 | —     | —     | 0.80-1.10 | 0.15-0.25 |

Nickel-chromium-molybdenum steel

| JIS     | SAE     | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |             |           |        |        |       |           |           |           |       |
|---------|---------|-----------------------------|--------------------------|-------------|-----------|--------|--------|-------|-----------|-----------|-----------|-------|
|         |         |                             | C                        | Si          | Mn        | P      | S      | Cu    | Ni        | Cr        | Mo        | V     |
| SNCM220 |         |                             | 0.17-0.23                | 0.15-0.35   | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | —     |
| SNCM420 |         |                             | 0.17-0.23                | 0.15-0.35   | 0.40-0.70 | ≦0.030 | ≦0.030 | ≦0.30 | 1.60-2.00 | 0.40-0.60 | 0.15-0.30 | —     |
|         |         | NCSF60                      | 0.55-0.65                | 0.15-0.35   | 0.30-0.50 | ≦0.020 | ≦0.010 | —     | 0.85-1.15 | 0.10-0.20 | 0.08-0.15 | ≦0.10 |
|         | SAE8660 |                             | 0.55-0.65                | (0.15-0.35) | 0.75-1.00 | ≦0.040 | ≦0.040 | —     | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | —     |

Manganese steel

| JIS    | SAE     | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |             |           |        |        |       |       |       |
|--------|---------|-----------------------------|--------------------------|-------------|-----------|--------|--------|-------|-------|-------|
|        |         |                             | C                        | Si          | Mn        | P      | S      | Cu    | Ni    | Cr    |
| SMn420 |         |                             | 0.17-0.23                | 0.15-0.35   | 1.20-1.50 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | ≦0.35 |
|        | SAE1524 |                             | 0.19-0.25                | (0.15-0.35) | 1.35-1.65 | ≦0.030 | ≦0.050 | —     | —     | —     |
|        | SAE1536 |                             | 0.30-0.37                | (0.15-0.35) | 1.20-1.50 | ≦0.030 | ≦0.050 | —     | —     | —     |
|        | SAE1541 |                             | 0.36-0.44                | (0.15-0.35) | 1.35-1.65 | ≦0.030 | ≦0.050 | —     | —     | —     |
| SMn443 |         |                             | 0.40-0.46                | 0.15-0.35   | 1.35-1.65 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25 | ≦0.35 |
|        | SAE1552 |                             | 0.47-0.55                | (0.15-0.35) | 1.20-1.50 | ≦0.030 | ≦0.050 | —     | —     | —     |
|        | SAE1566 |                             | 0.60-0.71                | (0.15-0.35) | 0.85-1.15 | ≦0.030 | ≦0.050 | —     | —     | —     |
|        |         | IRS2                        | 0.80-1.00                | ≦0.55       | 11.0-14.0 | ≦0.070 | ≦0.035 | —     | —     | —     |

⑤Alloy steel for boiler heat exchangers

| JIS | SAE | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |           |           |        |        |           |           |  |
|-----|-----|-----------------------------|--------------------------|-----------|-----------|--------|--------|-----------|-----------|--|
|     |     |                             | C                        | Si        | Mn        | P      | S      | Cr        | Mo        |  |
|     |     | NTBA12                      | 0.10-0.20                | 0.10-0.50 | 0.30-0.80 | ≦0.035 | ≦0.035 | —         | 0.15-0.65 |  |
|     |     | NTBA25                      | ≦0.15                    | ≦0.50     | 0.30-0.60 | ≦0.030 | ≦0.030 | 4.00-6.00 | 0.45-0.65 |  |

⑥Spring steel

| JIS   | SAE | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |           |           |        |        |       |           |           |           |
|-------|-----|-----------------------------|--------------------------|-----------|-----------|--------|--------|-------|-----------|-----------|-----------|
|       |     |                             | C                        | Si        | Mn        | P      | S      | Cu    | Cr        | Mo        | V         |
| SUP10 |     |                             | 0.47-0.55                | 0.15-0.35 | 0.65-0.95 | ≦0.030 | ≦0.030 | ≦0.30 | 0.80-1.10 | —         | 0.15-0.25 |
| SUP6  |     |                             | 0.56-0.64                | 1.50-1.80 | 0.70-1.00 | ≦0.030 | ≦0.030 | ≦0.30 | —         | —         | —         |
|       |     | NUP7                        | 0.65-0.75                | 1.80-2.10 | 0.45-0.55 | ≦0.020 | ≦0.020 | —     | 0.45-0.55 | 0.15-0.25 | —         |

⑦Bearing steel

| JIS  | SAE | NIPPON<br>STEEL<br>Standard | Chemical composition (%) |           |       |        |        |       |       |           |       |
|------|-----|-----------------------------|--------------------------|-----------|-------|--------|--------|-------|-------|-----------|-------|
|      |     |                             | C                        | Si        | Mn    | P      | S      | Cu    | Ni    | Cr        | Mo    |
| SUJ2 |     |                             | 0.95-1.10                | 0.15-0.35 | ≦0.50 | ≦0.025 | ≦0.025 | ≦0.25 | ≦0.25 | 1.30-1.60 | ≦0.08 |

(2)Cold-rolled special steel strips

|   |  | JIS      | Chemical composition (%) |           |           |        |        |       |           |           |           |           |       |
|---|--|----------|--------------------------|-----------|-----------|--------|--------|-------|-----------|-----------|-----------|-----------|-------|
|   |  |          | C                        | Si        | Mn        | P      | S      | Cu    | Ni        | Cr        | Mo        | V         | Ni+Cr |
| ① | Carbon steel and carbon steel for machine structural use | S35CM    | 0.32-0.38                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S45CM    | 0.42-0.48                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S50CM    | 0.47-0.53                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S55CM    | 0.52-0.58                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S60CM    | 0.55-0.65                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S65CM    | 0.60-0.70                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S70CM    | 0.65-0.75                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
|   |  | S75CM    | 0.70-0.80                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.035 | ≦0.30 | ≦0.20     | ≦0.20     | —         | —         | ≦0.35 |
| ② | Carbon tool steel  | SK65M    | 0.60-0.70                | 0.10-0.35 | 0.10-0.50 | ≦0.030 | ≦0.030 | ≦0.25 | ≦0.25     | ≦0.30     | —         | —         |       |
|   |  | SK75M    | 0.70-0.80                | 0.10-0.35 | 0.10-0.50 | ≦0.030 | ≦0.030 | ≦0.25 | ≦0.25     | ≦0.30     | —         | —         |       |
|   |  | SK85M    | 0.80-0.90                | 0.10-0.35 | 0.10-0.50 | ≦0.030 | ≦0.030 | ≦0.25 | ≦0.25     | ≦0.30     | —         | —         |       |
|   |  | SK95M    | 0.90-1.00                | 0.10-0.35 | 0.10-0.50 | ≦0.030 | ≦0.030 | ≦0.25 | ≦0.25     | ≦0.30     | —         | —         |       |
|   |  | SK120M   | 1.10-1.30                | 0.10-0.35 | 0.10-0.50 | ≦0.030 | ≦0.030 | ≦0.25 | ≦0.25     | ≦0.30     | —         | —         |       |
| ③ | Alloy tool steel   | SKS5M    | 0.75-0.85                | ≦0.35     | ≦0.50     | ≦0.030 | ≦0.030 | ≦0.25 | 0.70-1.30 | 0.20-0.50 | —         | —         |       |
|   |  | SKS51M   | 0.75-0.85                | ≦0.35     | ≦0.50     | ≦0.030 | ≦0.030 | ≦0.25 | 1.30-2.00 | 0.20-0.50 | —         | —         |       |
| ④ | Chromium steel   | SCr415   | 0.13-0.18                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | —         | —         |       |
|   |  | SCr420M  | 0.18-0.23                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | —         | —         |       |
|   |  | SCr435M  | 0.33-0.38                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | —         | —         |       |
|   |  | SCr440M  | 0.38-0.43                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | —         | —         |       |
|   | Chromium molybdenum steel                                | SCM415M  | 0.13-0.18                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | 0.15-0.25 | —         |       |
|   |  | SCM420   | 0.18-0.23                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | 0.15-0.25 | —         |       |
|   |  | SCM435M  | 0.33-0.38                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | 0.15-0.30 | —         |       |
|   |  | SCM440M  | 0.38-0.43                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | ≦0.25     | 0.90-1.20 | 0.15-0.30 | —         |       |
|   | Nickel-chromium-molybdenum steel                         | SNCM220M | 0.17-0.23                | 0.15-0.35 | 0.60-0.90 | ≦0.030 | ≦0.030 | ≦0.30 | 0.40-0.70 | 0.40-0.60 | 0.15-0.25 | —         |       |
|   |  |          |                          |           |           |        |        |       |           |           |           |           |       |
| ⑤ | Spring steel   | SUP10M   | 0.47-0.55                | 0.15-0.35 | 0.65-0.95 | ≦0.035 | ≦0.035 | ≦0.30 | —         | 0.80-1.10 | —         | 0.15-0.25 |       |
|   |  | SUP6M    | 0.56-0.64                | 1.50-1.80 | 0.70-1.00 | ≦0.030 | ≦0.030 | ≦0.30 | —         | —         | —         | —         |       |
| ⑥ | Bearing steel  | SUJ2     | 0.95-1.10                | 0.15-0.35 | ≦0.50     | ≦0.025 | ≦0.025 | ≦0.25 | ≦0.25     | 1.30-1.60 | ≦0.08     | —         |       |



## 5 Surface Finishes

SPECIAL STEEL STRIP

| Products   | Classification                       |                | Finish symbol | Description   |
|--|--------------------------------------|----------------|---------------|---|
|  | Processes involved                   | Surface finish |               |   |
| Hot-rolled steel strips                                      | As hot rolled                        | Mill scale     | BY            | As hot rolled   |
|  | Hot rolling → Pickling               | Pickled        | PY            | Surface scales were removed by pickling after hot rolling                           |
|  | Hot rolling → Pickling → Annealing   | Pickled        | AY            | Annealed after hot rolling and pickling   |
| Cold-rolled steel strips<br>Cold-rolled special steel strips | As cold rolled                       | Bright finish  | CB            | As cold rolled (bright finish)  |
|  |                                      | Dull finish    | CD            | As cold rolled (dull finish)  |
|  | Cold rolling → Annealing             | Bright finish  | AB            | Annealed after cold rolling (bright finish)   |
|  |                                      | Dull finish    | AD            | Annealed after cold rolling (dull finish)   |
|  | Cold rolling → Annealing → Skin pass | Bright finish  | SB            | Temper rolled under light pressure after cold rolling and annealing (bright finish) |
|  |                                      | Dull finish    | SD            | Temper rolled under light pressure after cold rolling and annealing (dull finish)   |

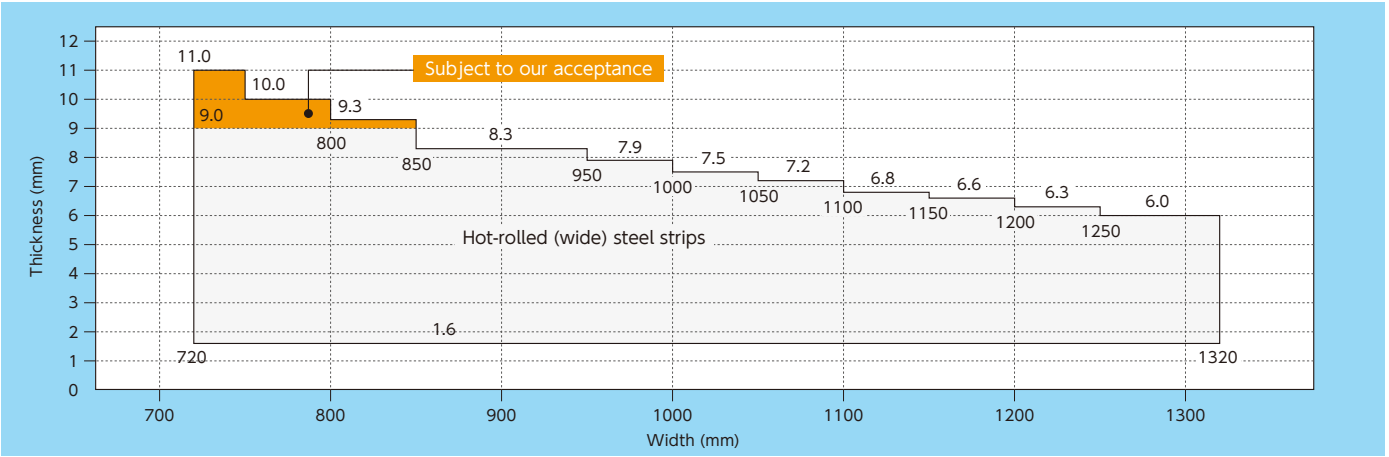
## 6 Available sizes

SPECIAL STEEL STRIP

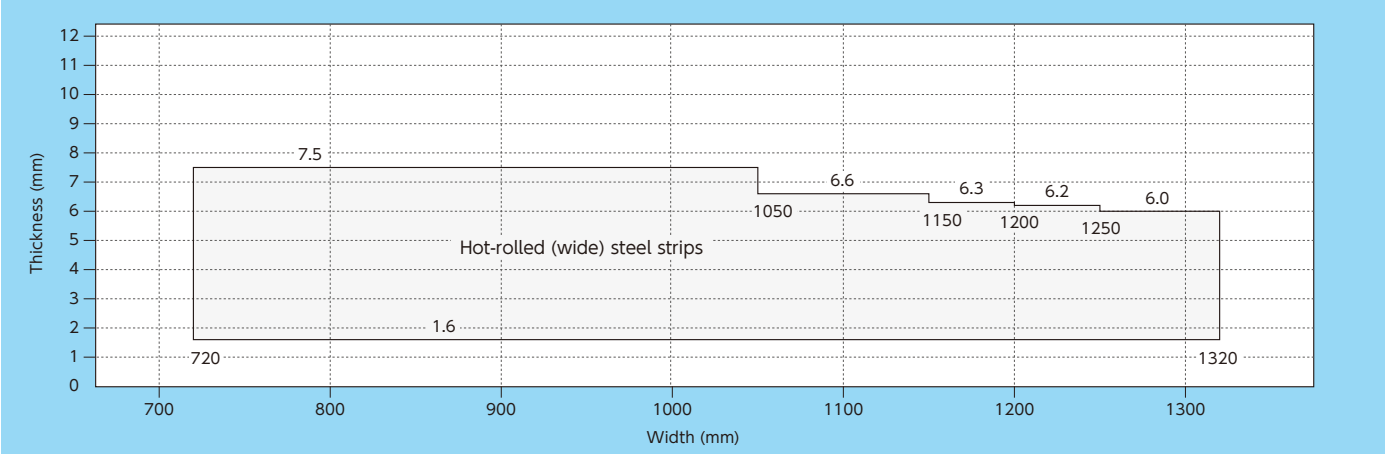
Available sizes for our special steel strips are shown below.

### (1) Hot-rolled steel

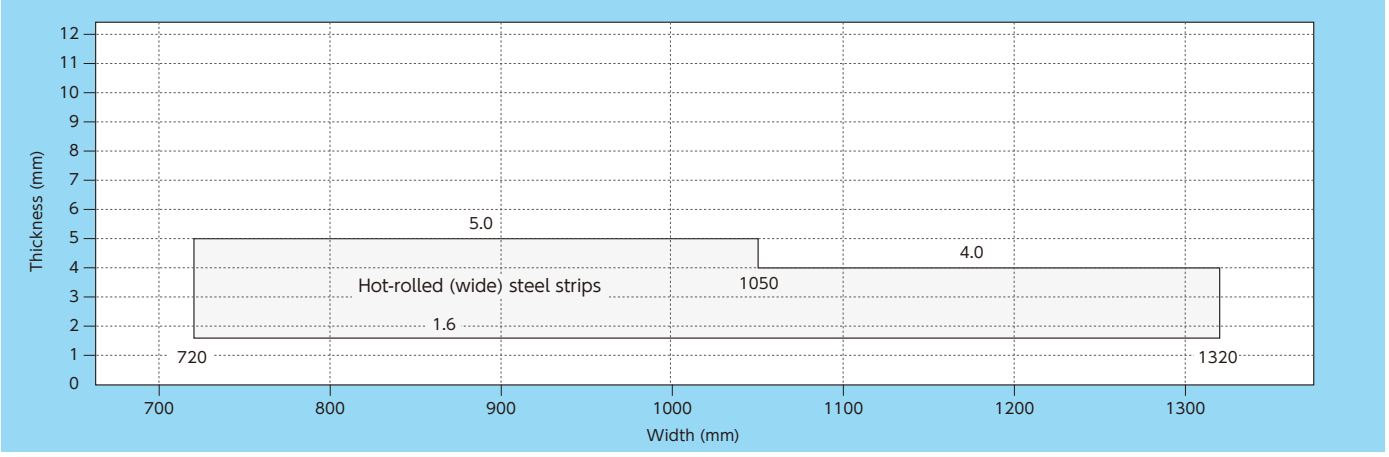
① As pickled (PY), as pickled and annealed (AY) [S45C, SCr420, SCM415, etc.]



② As pickled (PY), as pickled and annealed (AY) [SK85, SKS51, SUP10 etc.]



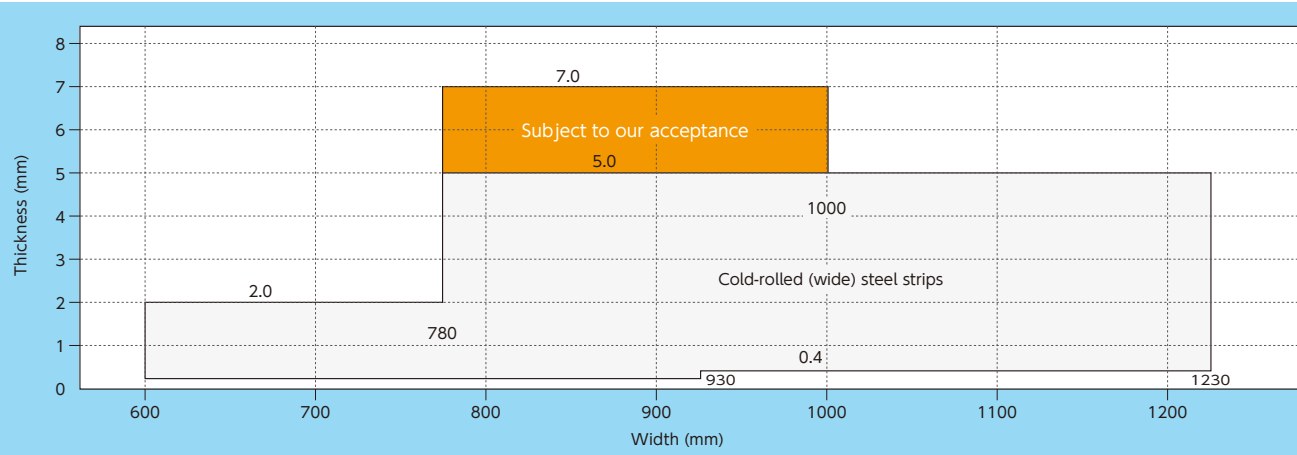
③ As pickled (PY), as pickled and annealed (AY) [SUJ2, NKS37, etc.]



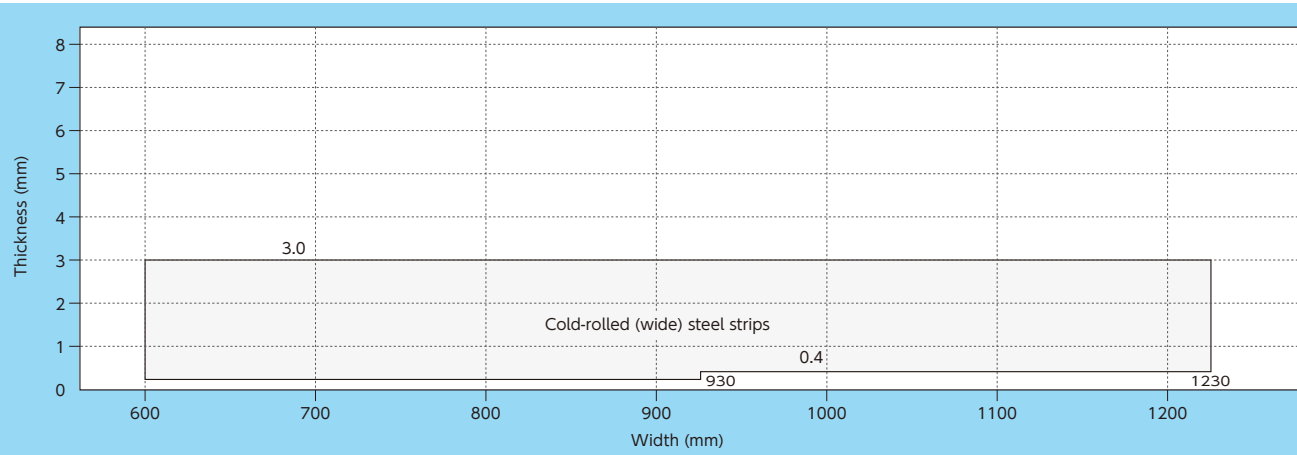


(2)Cold-rolled (wide) steel strips

①As annealed (SB, SD, AB, AD) [S45C, SCr420, SCM415, SK85, etc.]

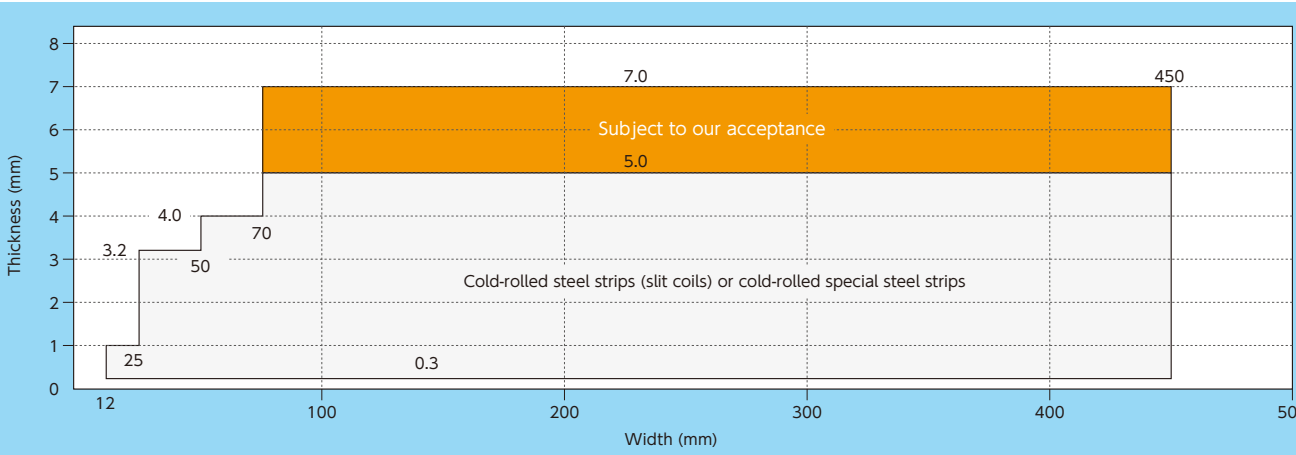


②As rolled (CB, CD) [S45C, SCr420, SCM415, SK85, etc.]

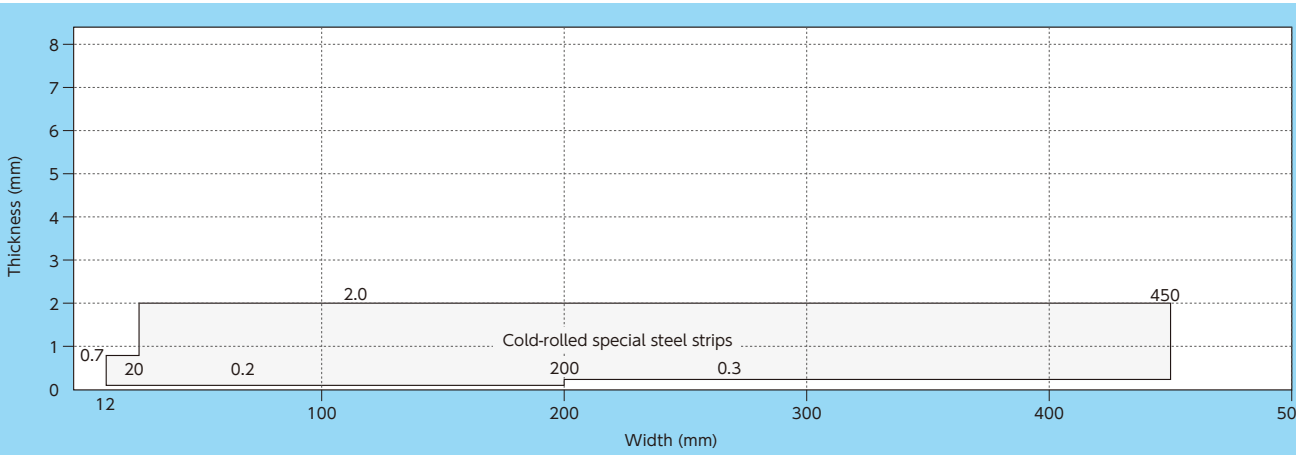


(3)Cold-rolled steel strips (slit coils), cold-rolled special steel strips

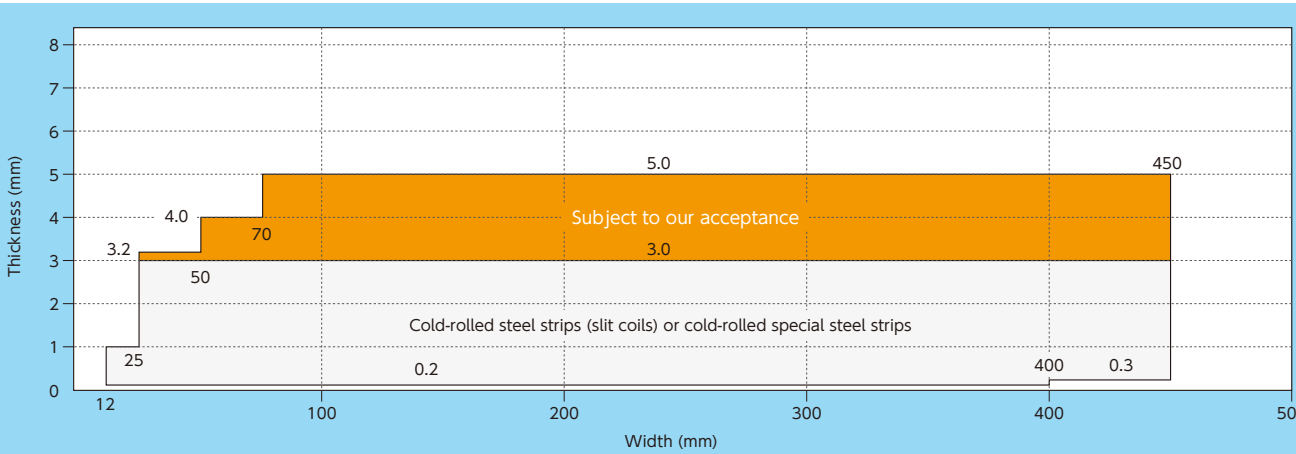
①As annealed (SB, SD, AB, AD) [S45C, SCr420, SCM415, SK85, etc.]



②As annealed (SB, SD, AB, AD) [SUJ2]



③As rolled (CB, CD) [S45C, SCr420, SCM415, SK85, etc.]





7 Dimensional Tolerances

SPECIAL STEEL STRIP

(1)Thickness tolerance

①Hot-rolled steel strips

| Sheet thickness (mm) | JIS G 3193 | NIPPON STEEL Standard |       |
|----------------------|------------|-----------------------|-------|
|                      |            | Regular               | Tight |
| 1.60 ≦ t < 2.00      | ±0.19      | ±0.15                 | ±0.10 |
| 2.00 ≦ t < 2.50      | ±0.20      | ±0.15                 | ±0.10 |
| 2.50 ≦ t < 3.15      | ±0.22      | ±0.16                 | ±0.10 |
| 3.15 ≦ t < 4.00      | ±0.24      | ±0.18                 | ±0.10 |
| 4.00 ≦ t < 5.00      | ±0.45      | ±0.20                 | ±0.10 |
| 5.00 ≦ t < 6.30      | ±0.50      | ±0.25                 | ±0.12 |
| 6.30 ≦ t < 8.00      | ±0.55      | ±0.35                 | ±0.25 |
| 8.00 ≦ t < 11.00     | ±0.55      | ±0.40                 | ±0.30 |

②Cold-rolled steel strips, cold-rolled special steel strips

| Sheet thickness (mm) | JIS G 3141 A<br>800 ≦ w ≦ 999 (mm) | NIPPON STEEL Standard    |                    |                |              |                                  |              |
|----------------------|------------------------------------|--------------------------|--------------------|----------------|--------------|----------------------------------|--------------|
|                      |                                    | Cold-rolled steel strips |                    |                |              | Cold-rolled special steel strips |              |
|                      |                                    | Regular (wide)           | Tight (wide)       | Regular (slit) | Tight (slit) | Regular                          | Tight        |
|                      |                                    | w ≦ 1230 (mm)            | 800 ≦ w ≦ 999 (mm) | w ≦ 400 (mm)   | w ≦ 400 (mm) | w ≦ 400 (mm)                     | w ≦ 200 (mm) |
| 0.25 ≦ t < 0.40      | ±0.040                             | ±0.040                   | ±0.020             | ±0.030         | ±0.015       | ±0.010                           | ±0.008       |
| 0.40 ≦ t < 0.60      | ±0.050                             | ±0.045                   | ±0.025             | ±0.035         | ±0.020       | ±0.015                           | ±0.010       |
| 0.60 ≦ t < 0.80      | ±0.060                             | ±0.050                   | ±0.030             | ±0.050         | ±0.025       | ±0.020                           | ±0.015       |
| 0.80 ≦ t < 1.00      | ±0.060                             | ±0.060                   | ±0.035             | ±0.055         | ±0.030       | ±0.025                           | ±0.020       |
| 1.00 ≦ t < 1.25      | ±0.070                             | ±0.070                   | ±0.040             | ±0.060         | ±0.035       | ±0.030                           | ±0.025       |
| 1.25 ≦ t < 1.60      | ±0.090                             | ±0.080                   | ±0.050             | ±0.065         | ±0.040       | ±0.030                           | ±0.025       |
| 1.60 ≦ t < 2.00      | ±0.110                             | ±0.090                   | ±0.055             | ±0.070         | ±0.045       | ±0.040                           | ±0.030       |
| 2.00 ≦ t < 2.50      | ±0.130                             | ±0.100                   | ±0.065             | ±0.080         | ±0.050       | ±0.045                           | ±0.040       |
| 2.50 ≦ t < 3.15      | ±0.150                             | ±0.110                   | ±0.075             | ±0.085         | ±0.055       | ±0.050                           | ±0.045       |
| 3.15 ≦ t < 3.20      | ±0.170                             | ±0.120                   | ±0.085             | ±0.090         | ±0.055       | ±0.050                           | ±0.045       |
| 3.20 ≦ t < 4.00      | —                                  | ±0.130                   | ±0.090             | ±0.095         | ±0.060       | ±0.060                           | ±0.050       |
| 4.00 ≦ t < 5.00      | —                                  | ±0.140                   | ±0.095             | ±0.100         | ±0.065       | ±0.070                           | ±0.060       |

(2)Width tolerance

①Hot-rolled steel strips ②Cold-rolled steel strips (wide)

| Sheet thickness (mm) | Sheet width (mm) | Mill edge | Cut edge |
|----------------------|------------------|-----------|----------|
| 0.25 ≦ t < 11.00     | 630 ≦ w ≦ 1320   | +25、-0    | +3.0、-0  |

②Cold-rolled steel strips (slit), cold-rolled special steel strips

| Sheet thickness (mm) | 200 ≦ w ≦ 500 (mm) | w < 200 (mm) |
|----------------------|--------------------|--------------|
| t < 0.60             | ±0.20              | ±0.15        |
| 0.60 ≦ t < 1.20      | ±0.30              | ±0.20        |
| 1.20 ≦ t < 2.00      | ±0.30              | ±0.25        |
| 2.00 ≦ t < 3.20      | ±0.40              | ±0.30        |
| 3.20 ≦ t < 4.00      | ±0.45              | ±0.35        |
| 4.00 ≦ t < 5.00      | ±0.55              | ±0.40        |

8 Mechanical Properties (Surface Hardness) SPECIAL STEEL STRIP

[Hot-rolled steel strips]

①Carbon steel and carbon steel for machine structural use (including boron added steel)

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| N15CK                    | ≦ 83HRB                          | —                |
| S15CK                    | ≦ 83HRB                          | —                |
| S15C                     | ≦ 83HRB                          | —                |
| SAE1020                  | ≦ 86HRB                          | ≦ 80HRB          |
| S20C                     | ≦ 86HRB                          | ≦ 80HRB          |
| NM19CB                   | ≦ 86HRB                          | ≦ 80HRB          |
| S20CK                    | ≦ 86HRB                          | ≦ 80HRB          |
| N22CB                    | ≦ 87HRB                          | ≦ 80HRB          |
| N22CB5                   | ≦ 87HRB                          | ≦ 80HRB          |
| NM22CB                   | ≦ 90HRB                          | ≦ 85HRB          |
| S25C                     | ≦ 90HRB                          | ≦ 85HRB          |
| N28CB                    | ≦ 90HRB                          | ≦ 85HRB          |
| S33C                     | ≦ 97HRB                          | ≦ 85HRB          |
| N35C                     | ≦ 98HRB                          | ≦ 88HRB          |
| S35C                     | ≦ 98HRB                          | ≦ 88HRB          |
| SAE1035                  | ≦ 99HRB                          | ≦ 88HRB          |
| N35CB                    | ≦ 99HRB                          | ≦ 88HRB          |
| N36CB                    | ≦ 99HRB                          | ≦ 88HRB          |
| S38C                     | ≦ 99HRB                          | ≦ 88HRB          |
| S40C                     | ≦ 99HRB                          | ≦ 90HRB          |
| N40CB                    | ≦ 99HRB                          | ≦ 90HRB          |
| S45C                     | ≦ 101HRB                         | ≦ 91HRB          |
| SAE1045                  | ≦ 101HRB                         | ≦ 91HRB          |
| S48C                     | ≦ 102HRB                         | ≦ 91HRB          |
| S50C                     | ≦ 104HRB                         | ≦ 92HRB          |
| SAE1050                  | ≦ 107HRB                         | ≦ 92HRB          |
| S53C                     | ≦ 107HRB                         | ≦ 92HRB          |
| S55C                     | ≦ 107HRB                         | ≦ 93HRB          |
| SAE1055                  | ≦ 107HRB                         | ≦ 93HRB          |
| N55D                     | ≦ 107HRB                         | ≦ 93HRB          |
| S58C                     | ≦ 108HRB                         | ≦ 93HRB          |
| SAE1060                  | ≦ 34HRC                          | ≦ 94HRB          |
| N60C                     | ≦ 34HRC                          | ≦ 94HRB          |
| N63C                     | ≦ 34HRC                          | ≦ 94HRB          |
| SAE1065                  | ≦ 35HRC                          | ≦ 94HRB          |
| N65C                     | ≦ 35HRC                          | ≦ 94HRB          |
| SAE1070                  | ≦ 37HRC                          | ≦ 96HRB          |
| N70C                     | ≦ 37HRC                          | ≦ 96HRB          |
| NK11                     | ≦ 37HRC                          | ≦ 96HRB          |
| SAE1074                  | ≦ 38HRC                          | ≦ 96HRB          |
| SAE1075                  | ≦ 38HRC                          | ≦ 96HRB          |

\*For hardness outside the specified range, contact us.



②Carbon tool steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| NK7CR                    | ≧ 32HRC                          | ≧ 96HRB          |
| SK65                     | ≧ 32HRC                          | ≧ 96HRB          |
| SAE1078                  | ≧ 40HRC                          | ≧ 96HRB          |
| NK6DCR                   | ≧ 40HRC                          | ≧ 96HRB          |
| SK75                     | ≧ 40HRC                          | ≧ 96HRB          |
| NK5D                     | ≧ 43HRC                          | ≧ 97HRB          |
| SK85                     | ≧ 43HRC                          | ≧ 97HRB          |
| SAE1085                  | ≧ 44HRC                          | ≧ 97HRB          |
| SAE1086                  | ≧ 44HRC                          | ≧ 97HRB          |
| SK95                     | ≧ 44HRC                          | ≧ 97HRB          |
| SAE1095                  | ≧ 44HRC                          | ≧ 97HRB          |
| SK120                    | ≧ 46HRC                          | ≧ 98HRB          |

\*For hardness outside the specified range, contact us.

③Alloy tool steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| NKS100                   | —                                | ≧ 103HRB         |
| NKS62                    | —                                | ≧ 100HRB         |
| NKS41                    | —                                | ≧ 96HRB          |
| NKS32                    | —                                | ≧ 95HRB          |
| NKS85                    | —                                | ≧ 98HRB          |
| SKS51                    | —                                | ≧ 98HRB          |
| SKS5                     | —                                | ≧ 98HRB          |
| NKS60                    | —                                | ≧ 100HRB         |
| NKS59                    | —                                | ≧ 100HRB         |
| NKS80                    | —                                | ≧ 100HRB         |
| NKS36                    | —                                | ≧ 97HRB          |
| NKS37                    | —                                | ≧ 97HRB          |
| NKS49                    | —                                | ≧ 100HRB         |
| NKS52                    | —                                | ≧ 100HRB         |
| NKS39                    | —                                | ≧ 97HRB          |
| NKS56                    | —                                | ≧ 98HRB          |

\*For hardness outside the specified range, contact us.

④Structural alloy steel

Chromium steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| SCr415                   | ≧ 105HRB                         | ≧ 90HRB          |
| SCr420                   | ≧ 106HRB                         | ≧ 93HRB          |
| SCr435                   | ≧ 35HRC                          | ≧ 94HRB          |
| SCr440                   | ≧ 36HRC                          | ≧ 95HRB          |
| N50CRN                   | —                                | ≧ 100HRB         |

\*For hardness outside the specified range, contact us.

Chromium molybdenum steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| SCM415                   | ≧ 105HRB                         | ≧ 90HRB          |
| SCM420                   | ≧ 105HRB                         | ≧ 90HRB          |
| SCM430                   | ≧ 36HRC                          | ≧ 93HRB          |
| SCM435                   | ≧ 38HRC                          | ≧ 93HRB          |
| SCM440                   | ≧ 39HRC                          | ≧ 95HRB          |
| SAE4130                  | ≧ 36HRC                          | ≧ 93HRB          |

\*For hardness outside the specified range, contact us.

Nickel-chromium-molybdenum steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| SNCM220                  | ≧ 105HRB                         | ≧ 88HRB          |
| SNCM420                  | ≧ 33HRC                          | ≧ 90HRB          |
| NCSF60                   | ≧ 39HRC                          | ≧ 95HRB          |
| SAE8660                  | ≧ 39HRC                          | ≧ 95HRB          |

\*For hardness outside the specified range, contact us.

Manganese steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| SMn420                   | ≧ 93HRB                          | ≧ 88HRB          |
| SAE1524                  | ≧ 93HRB                          | ≧ 88HRB          |
| SAE1536                  | ≧ 100HRB                         | ≧ 91HRB          |
| SAE1541                  | ≧ 103HRB                         | ≧ 93HRB          |
| SMn443                   | ≧ 103HRB                         | ≧ 93HRB          |
| SAE1552                  | ≧ 106HRB                         | ≧ 95HRB          |
| SAE1566                  | ≧ 106HRB                         | ≧ 95HRB          |
| IRS2                     | —                                | ≧ 105HRB         |

\*For hardness outside the specified range, contact us.

⑤Alloy steel for boiler heat exchangers

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| NTBA12                   | ≧ 105HRB                         | ≧ 90HRB          |
| NTBA15                   | —                                | ≧ 100HRB         |

\*For hardness outside the specified range, contact us.

⑥Spring steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| SUP10                    | ≧ 36HRC                          | ≧ 90HRB          |
| SUP6                     | ≧ 45HRC                          | ≧ 97HRB          |
| NUP7                     | ≧ 45HRC                          | ≧ 97HRB          |

\*For hardness outside the specified range, contact us.

⑦Bearing steel

| Steel designation / name | Mill scale (BY), as pickled (PY) | As annealed (AY) |
|--------------------------|----------------------------------|------------------|
| SUJ2                     | —                                | 85~98HRB         |

\*For hardness outside the specified range, contact us.

[Cold-rolled steel strips]

①Carbon steel and carbon steel for machine structural use (including boron added steel)

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| N15CK                    | ≧ 140HV                      | 150~180HV               |
| S15CK                    | ≧ 140HV                      | 150~180HV               |
| S15C                     | ≧ 140HV                      | 150~180HV               |
| SAE1020                  | ≧ 150HV                      | 160~220HV               |
| S20C                     | ≧ 150HV                      | 160~220HV               |
| NM19CB                   | ≧ 150HV                      | 160~220HV               |
| S20CK                    | ≧ 150HV                      | 160~220HV               |
| N22CB                    | ≧ 150HV                      | 160~220HV               |
| N22CBS                   | ≧ 150HV                      | 160~220HV               |
| NM22CB                   | ≧ 150HV                      | 160~220HV               |



| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| S25C                     | ≧ 150HV                      | 160~220HV               |
| N28CB                    | ≧ 150HV                      | 160~220HV               |
| S33C                     | ≧ 150HV                      | 160~220HV               |
| N35C                     | ≧ 150HV                      | 160~220HV               |
| S35C                     | ≧ 150HV                      | 160~240HV               |
| SAE1035                  | ≧ 150HV                      | 160~240HV               |
| N35CB                    | ≧ 150HV                      | 160~240HV               |
| N36CB                    | ≧ 150HV                      | 160~240HV               |
| S38C                     | ≧ 160HV                      | 170~240HV               |
| S40C                     | ≧ 160HV                      | 170~240HV               |
| N40CB                    | ≧ 160HV                      | 170~240HV               |
| S45C                     | ≧ 160HV                      | 170~240HV               |
| SAE1045                  | ≧ 160HV                      | 170~240HV               |
| S48C                     | ≧ 160HV                      | 180~260HV               |
| S50C                     | ≧ 160HV                      | 180~260HV               |
| SAE1050                  | ≧ 160HV                      | 180~260HV               |
| S53C                     | ≧ 170HV                      | 180~260HV               |
| S55C                     | ≧ 170HV                      | 180~260HV               |
| SAE1055                  | ≧ 170HV                      | 180~260HV               |
| N55D                     | ≧ 160HV                      | 180~260HV               |
| S58C                     | ≧ 170HV                      | 180~260HV               |
| SAE1060                  | ≧ 170HV                      | 180~280HV               |
| N60C                     | ≧ 170HV                      | 180~280HV               |
| N63C                     | ≧ 170HV                      | 180~280HV               |
| SAE1065                  | ≧ 170HV                      | 180~280HV               |
| N65C                     | ≧ 170HV                      | 180~280HV               |
| SAE1070                  | ≧ 180HV                      | 180~280HV               |
| N70C                     | ≧ 180HV                      | 180~280HV               |
| NK11                     | ≧ 180HV                      | 180~280HV               |
| SAE1074                  | ≧ 180HV                      | 180~280HV               |
| SAE1075                  | ≧ 180HV                      | 180~280HV               |

\*For hardness outside the specified range, contact us.

②Carbon tool steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| NK7CR                    | ≧ 180HV                      | 180~260HV               |
| SK65                     | ≧ 180HV                      | 180~260HV               |
| SAE1078                  | ≧ 180HV                      | 180~260HV               |
| NK6DCR                   | ≧ 180HV                      | 180~280HV               |
| SK75                     | ≧ 180HV                      | 180~280HV               |
| NK5D                     | ≧ 180HV                      | 200~280HV               |
| SK85                     | ≧ 180HV                      | 200~280HV               |
| SAE1085                  | ≧ 190HV                      | 200~280HV               |
| SAE1086                  | ≧ 190HV                      | 200~280HV               |
| SK95                     | ≧ 200HV                      | 200~280HV               |
| SAE1095                  | ≧ 200HV                      | 200~280HV               |
| SK120                    | ≧ 220HV                      | —                       |

\*For hardness outside the specified range, contact us.

③Alloy tool steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| NKS100                   | ≧ 240HV                      | 260~350HV               |
| NKS62                    | ≧ 200HV                      | 220~280HV               |
| NKS41                    | ≧ 200HV                      | 200~260HV               |
| NKS32                    | ≧ 200HV                      | 200~280HV               |
| NKS85                    | ≧ 200HV                      | 200~280HV               |
| SKS51                    | ≧ 190HV                      | 200~280HV               |
| SKS5                     | ≧ 190HV                      | 200~280HV               |
| NKS60                    | ≧ 200HV                      | 220~280HV               |
| NKS59                    | ≧ 220HV                      | 220~280HV               |
| NKS80                    | ≧ 220HV                      | 220~280HV               |
| NKS36                    | ≧ 200HV                      | 200~280HV               |
| NKS37                    | ≧ 200HV                      | 200~300HV               |
| NKS49                    | ≧ 220HV                      | 220~280HV               |
| NKS52                    | ≧ 220HV                      | 220~280HV               |
| NKS39                    | ≧ 220HV                      | 220~280HV               |
| NKS56                    | ≧ 220HV                      | 220~320HV               |

\*For hardness outside the specified range, contact us.

④Structural alloy steel

Chromium steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SCr415                   | ≧ 170HV                      | —                       |
| SCr420                   | ≧ 170HV                      | —                       |
| SCr435                   | ≧ 180HV                      | —                       |
| SCr440                   | ≧ 180HV                      | —                       |
| N50CRN                   | ≧ 220HV                      | 220~300HV               |

\*For hardness outside the specified range, contact us.

Chromium molybdenum steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SCM415                   | ≧ 160HV                      | —                       |
| SCM420                   | ≧ 160HV                      | —                       |
| SCM430                   | ≧ 180HV                      | 200~260HV               |
| SCM435                   | ≧ 180HV                      | 200~260HV               |
| SCM440                   | ≧ 180HV                      | 200~260HV               |
| SAE4130                  | ≧ 180HV                      | 200~260HV               |

\*For hardness outside the specified range, contact us.

Nickel-chromium-molybdenum steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SNCM220                  | ≧ 170HV                      | —                       |
| SNCM420                  | ≧ 180HV                      | —                       |
| NCSF60                   | ≧ 190HV                      | 200~280HV               |
| SAE8660                  | ≧ 190HV                      | 200~280HV               |

\*For hardness outside the specified range, contact us.

Manganese steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SMn420                   | ≧ 170HV                      | —                       |
| SAE1524                  | ≧ 170HV                      | —                       |



| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SAE1536                  | ≧ 170HV                      | 220~280HV               |
| SAE1541                  | ≧ 170HV                      | 240~280HV               |
| SMn443                   | ≧ 180HV                      | 240~280HV               |
| SAE1552                  | ≧ 180HV                      | 240~280HV               |
| SAE1566                  | ≧ 180HV                      | 240~280HV               |

\*For hardness outside the specified range, contact us.

⑤Spring steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SUP10                    | ≧ 190HV                      | 200~260HV               |
| SUP6                     | ≧ 210HV                      | —                       |
| NUP7                     | ≧ 210HV                      | —                       |

\*For hardness outside the specified range, contact us.

⑥Bearing steel

| Steel designation / name | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |
|--------------------------|------------------------------|-------------------------|
| SUJ2                     | ≧ 220HV                      | —                       |

\*For hardness outside the specified range, contact us.

[Cold-rolled special steel strips]

|   |  | JIS                       | As annealed (AB, AD, SB, SD) | As cold rolled (CB, CD) |           |
|---|--|---------------------------|------------------------------|-------------------------|-----------|
| ① | Carbon steel and carbon steel for machine structural use | S35CM                     | ≧ 150HV                      | 160~240HV               |           |
|   |  | S45CM                     | ≧ 160HV                      | 170~240HV               |           |
|   |  | S50CM                     | ≧ 160HV                      | 180~260HV               |           |
|   |  | S55CM                     | ≧ 170HV                      | 180~260HV               |           |
|   |  | S60CM                     | ≧ 170HV                      | 180~280HV               |           |
|   |  | S65CM                     | ≧ 170HV                      | 180~280HV               |           |
|   |  | S70CM                     | ≧ 180HV                      | 180~280HV               |           |
|   |  | S75CM                     | ≧ 180HV                      | 180~280HV               |           |
| ② | Carbon tool steel  | SK65M                     | ≧ 180HV                      | 180~260HV               |           |
|   |  | SK75M                     | ≧ 180HV                      | 180~280HV               |           |
|   |  | SK85M                     | ≧ 180HV                      | 200~280HV               |           |
|   |  | SK95M                     | ≧ 200HV                      | 200~280HV               |           |
|   |  | SK120M                    | ≧ 220HV                      | —                       |           |
| ③ | Alloy tool steel   | SKS5M                     | ≧ 190HV                      | 200~280HV               |           |
|   |  | SKS51M                    | ≧ 190HV                      | 200~280HV               |           |
| ④ | Structural alloy steel                                   | Chromium steel            | SCr415                       | ≧ 170HV                 | —         |
|   |  |                           | SCr420M                      | ≧ 170HV                 | —         |
|   |  |                           | SCr435M                      | ≧ 180HV                 | —         |
|   |  |                           | SCr440M                      | ≧ 180HV                 | —         |
|   |  | Chromium molybdenum steel | SCM415M                      | ≧ 160HV                 | —         |
|   |  |                           | SCM420                       | ≧ 160HV                 | —         |
|   |  |                           | SCM435M                      | ≧ 180HV                 | 200~260HV |
|   |  |                           | SCM440M                      | ≧ 180HV                 | 200~260HV |
|   | Nickel-chromium-molybdenum steel                         | SNCM220M                  | ≧ 170HV                      | —                       |           |
| ⑤ | Spring steel   | SUP10M                    | ≧ 190HV                      | 200~260HV               |           |
|   |  | SUP6M                     | ≧ 210HV                      | —                       |           |
| ⑥ | Bearing steel  | SUJ2                      | ≧ 220HV                      | —                       |           |

\*For hardness outside the specified range, consult with.

9 Packing and Labeling

Coil products

(1)Labeling

Items indicated on the label

Trademark, dimension, steel grade, finish, process symbol (or serial number), coil number, cast number

Identification method

A label is attached to each coil.

(2)Standard packing

①Wide coils

Metal pad

Bering hoop

Seal

Package paper

Inspection sheet

ID protective ring

Hessian cloth

②Slit coils

| PP laminated packing |               |
|----------------------|---------------|
| Packing unit         | Product width |
| 1 coil               | W≧50mm        |
| 2 coils              | 30mm≦W<50mm   |
| 3 coils              | 20mm≦W<30mm   |
| 4 coils              | W<20mm        |

Packed coils are banded together or banded together with a pallet or with a pallet and skids, depending on the transportation conditions or the customer' s request.

Unit packing weights come in the following five types (maximum weight for each case): 500 kg, 1,000 kg, 1,500 kg, 2,000 kg, 2,500 kg

Banded together

Banded together with a pallet

Banded together with a pallet and skids



Cut-to-length products

(1) Labeling

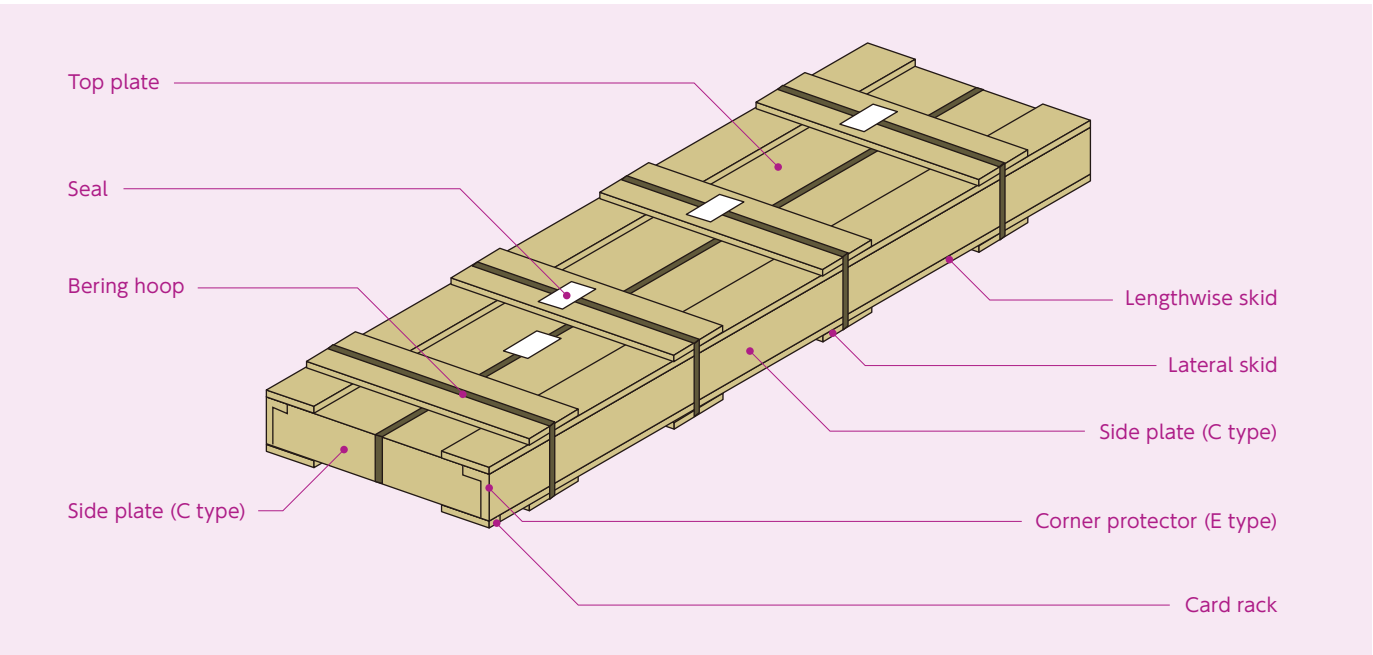
Items indicated on the label

Trademark, dimension, steel grade, finish, process symbol (or serial number), coil number, cast number

Identification method

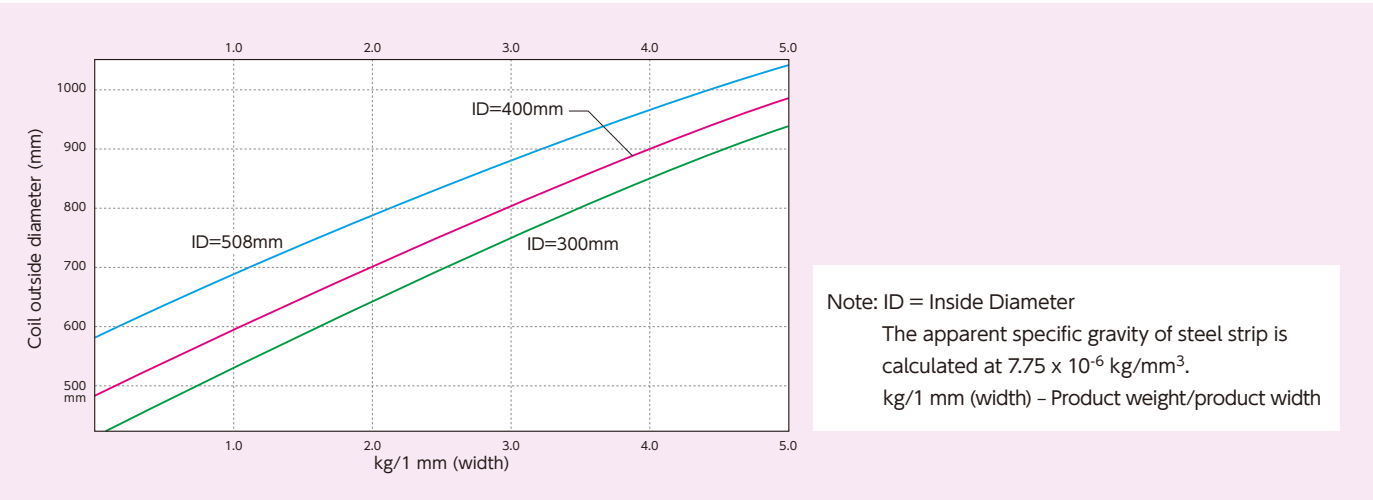
A label is attached to each package.

(2) Standard packing



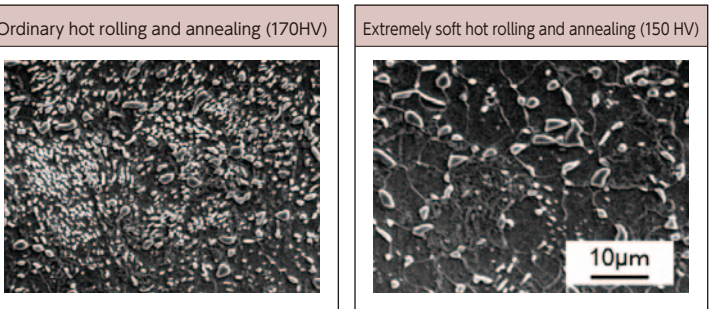
Appendix table

Relationship between inside and outside diameters



(1) High workability (extra soft) hot-rolled special steel

Special steel is commonly associated with high carbon content and poor workability. Utilizing its original annealing techniques, Nippon Steel has developed special steel with high workability. The dispersing behavior of spheroidal carbide is controlled to create soft special steel.



Photos: Typical metallographic structure of hot-rolled and annealed steel sheet (S55C)

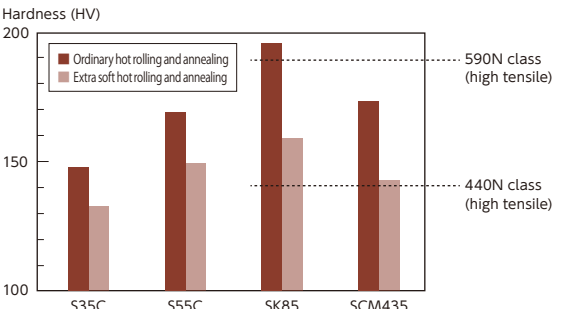
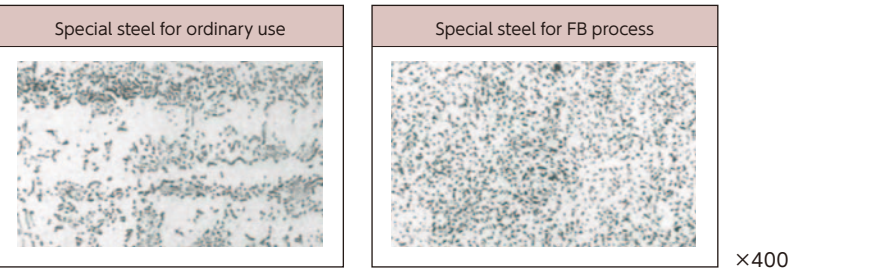


Figure: Hardness of hot-rolled and annealed steel sheets

(2) Hot-rolled special steel for fine blanking process

Nippon Steel produces hot-rolled and annealed special steel for fine blanking (FB) process. Generation of cracks can be suppressed during FB process by finely and uniformly dispersing spheroidal carbide.

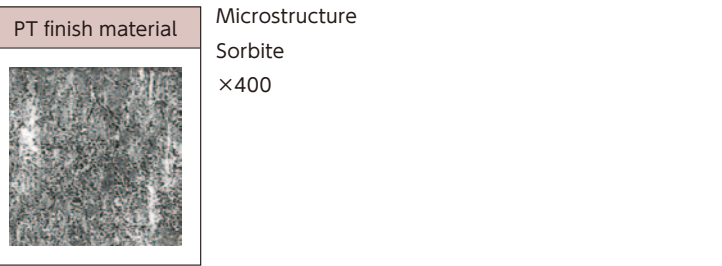


(3) Special - finish steel (PT finish, PPC finish)

①PT finish

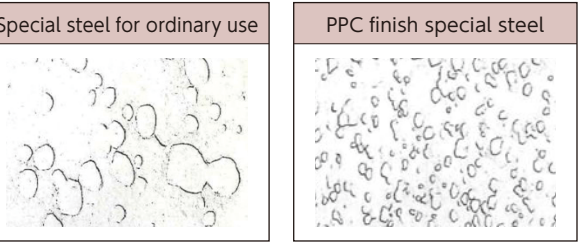
Cold rolled after patenting treatment Hardness of 500 HV or higher can be obtained with the processes from cold rolling to ageing treatment. Suitable for coil springs or for saving heat treatment.

| Steel grade | Hardness  | Typical application     |
|-------------|-----------|-------------------------|
| NK11        | 300~400HV | Chains for ordinary use |
|             |           | Coil springs            |



②PPC finish

Spheroidal carbide is very finely dispersed in hot-rolled steel strip manufactured under special hot rolling conditions. In the customer's heat treatment sequences, quenching time can be shortened with reduced austenizing time.



| Steel grades | Hardness    | Available thicknesses |
|--------------|-------------|-----------------------|
| NK11         | 230 — 290HV | 0.3 — 2.0mm           |
| SK85,SK95    | 250 — 310HV |                       |



(4)Bainite steel strips

The Bainite steel strips, heat-treated products developed with the primary purpose of enabling customers to eliminate the processes of heat treatment and stress relief, have the following features.

①Freely selectable strength (hardness)

Products with hardness of up to 460 HV can be provided through varying combinations of steel grades and heat treatment conditions.

②Excellent workability

Thanks to the bainitic structure formed by isothermal transformation treatment to provide high strength and excellent workability, these products achieve high bending and drawing workability which has been difficult to obtain with traditional annealed steel strips (with martensite structure).

③Highly abrasion-resistant blanked face

Because of their considerable work quenching by blanking, Super Bainite products, for which SUP6 is used as base material, allow the processes of carburizing and nitriding to be omitted.

①Types

Bainite steel strips are classified into the types shown in Table 1. If other types of the steel strips are required, consult with us.

Table 1 Types of Bainite steel strips

|               | Type symbol | Steel grade used |
|---------------|-------------|------------------|
| Bainite       | NBS45       | S45CM            |
|               | NBS50       | S50CM            |
|               | NBS55       | S55CM            |
|               | NBS60       | S60CM            |
|               | NBS70       | S70CM            |
|               | NBS85       | SK85M            |
| Super Bainite | NBS99       | Alloy steels     |
|               | NBS150      | SUP6             |

②Surface finishes

Surface finishes available for Bainite steel strips are shown in Table 2.

Table 2 Surface finishes for Bainite steel strips

| Finish   | Symbol | Description   |
|----------|--------|---|
| Standard | N      | As special heat treated   |
| White    | V      | As non-oxidation treated after special heat treatment             |
| Blue     | B      | As bluing treated after special heat and non-oxidation treatments |

③Hardness

The hardness range for Bainite steel strips is shown in Table 3. For mechanical properties other than hardness, contact us.

Table 3 Hardness range for Bainite steel strips

| Symbol | Hardness   |
|--------|--|
| 1      | HV-320 ± 20  |
| 2      | HV-360 ± 20  |
| 3      | HV-400 ± 20  |
| 4      | HV-440 ± 20  |
| S      | "A value other than the above ones taken as the central value within the range of 270 - 460 HV" and ± 20 allowed |

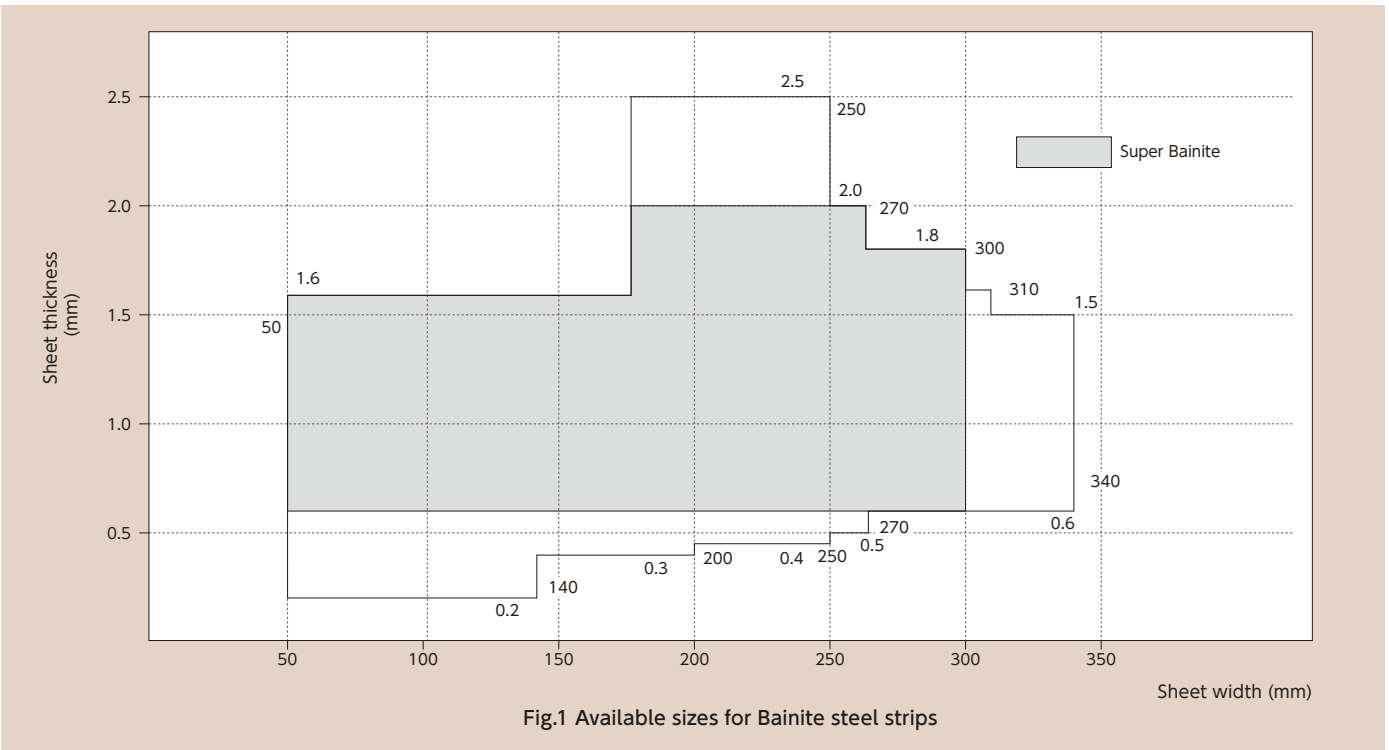
(Identification example) Type symbol

NBS45 N 2  
① ② ③

(1): Type (2): Finish (3): Hardness

④Available sizes

Available sizes for Bainite steel strips are shown in Fig. 1. For sizes outside this range, contact us.



⑤Dimensional tolerances

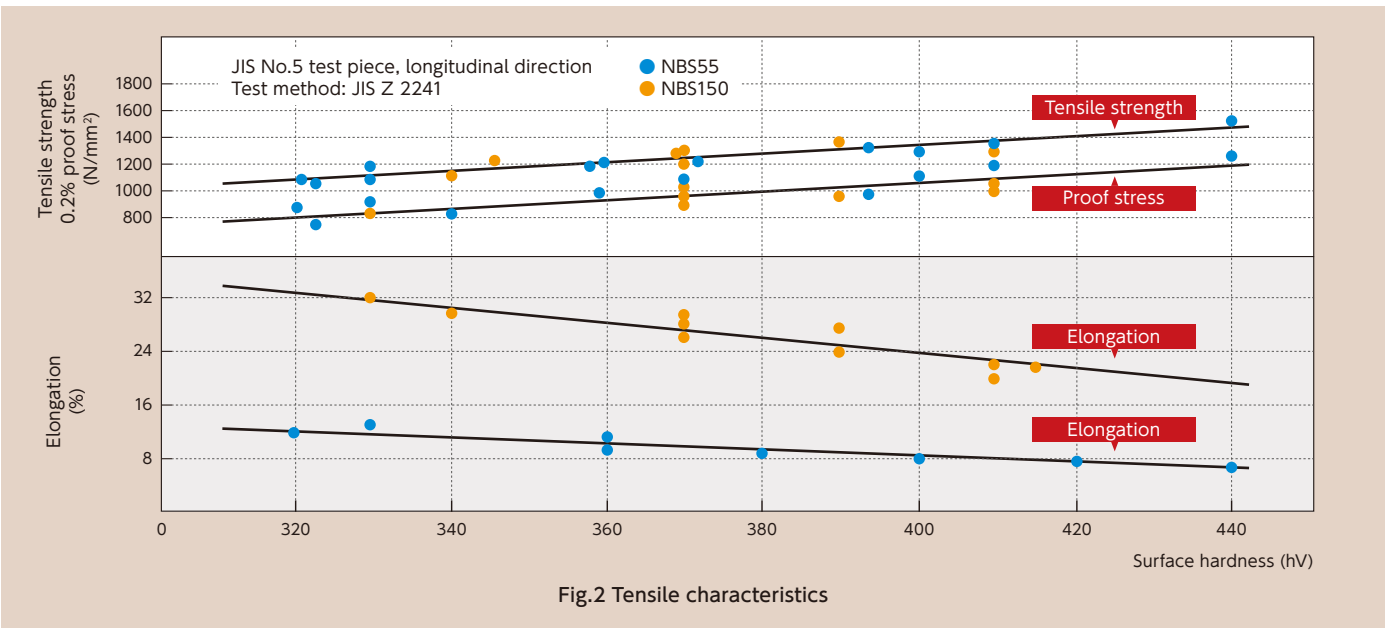
The specifications for cold-rolled special steel strips apply here. (If tighter tolerances are required, consult with us)

⑥Mechanical properties

□Tensile characteristics

The relationship among surface hardness, tensile strength, 0.2% proof stress, and elongation is shown in Fig. 2. NBS150 (Super Bainite) is superior to NBS55 in terms of elongation although the former is equivalent in tensile strength and proof stress to the latter.

Their average values are shown in Table 4.





# 11 Precautions for Use

SPECIAL STEEL STRIP

## (1) Rust prevention

- Although our products are evenly coated with oil which is excellent in rust prevention, they may rust if exposed to water or moisture, for instance, due to condensation or when left unprotected for a long period of time.  
Due care should therefore be exercised when handling them.  
Rust may also occur when packaging paper is damaged. In such cases, repair the paper.

## (2) Safety

- To prevent coils from falling down and cut-to-length products from shifting, store the materials in a secure place.
- Since special steel sheets have higher strength than ordinary steel materials, their springback is wider. When cutting coil bands, use utmost care as the coil end may spring.
- Thin cold-rolled steel sheets have very sharp edges. When handling them, be extremely careful and wear heavy gloves.

## (3) Processing

- Special steel sheets greatly vary in hardness, depending on their compositions and finishes. This significantly affects the service lives of metal molds.  
Before placing an order, be sure to thoroughly check the desired material characteristics.  
(Refer to Section 12 under “Guide for Ordering.”)

## (4) Heat treated surfaces

- The conditions for heat treatment vary, depending on the product characteristics (e.g., hardness and toughness) and the chemical compositions required by the user.  
Select the optimum heat treatment conditions after checking the desired product characteristics in advance.
- Although excellent in hardenability, boron-added steel is not suited for heat treatment  
If subjected to such heat treatment, boron nitride (BN) may be formed near the surface, resulting in lowered hardenability and formation of soft layer on the surface.

# 12 Guide for Ordering

SPECIAL STEEL STRIP

Before ordering, check the following items so that you may select the most suitable grades for your intended applications.

## (1) Standards

We have a broad line of products compatible with the JIS and in addition, made to our original standard. If you require products conforming to overseas standards, feel free to contact us.  
Select the standard best suited for your processing method.

## (2) Dimensions

Check the desired sheet thickness and width (check the length for steel sheets).  
Sheet thicknesses are available in increments of 0.1 mm. As we can also accept thicknesses in increments of 0.01 mm depending on customers' requirements, feel free to contact us when necessary.

## (3) Hardness (mechanical property)

Check the desired hardness.  
Special steel, rich in carbon, is susceptible to cracking while processing. For normal use, this material is annealed and softened.  
The annealing process may be omitted, depending on your intended applications.

## (4) Dimensional tolerance

Check the desired sheet thickness and width tolerances.  
(For steel sheets, also check the length tolerance.)

## (5) Surface finish

Check the desired surface finish.  
Either “as unpickled (as rolled)” or “as pickled” is offered for hot-rolled steel strips, and either “bright finish” or “dull finish” offered for cold-rolled steel strips and cold-rolled special steel strips.

## (6) Inner coil diameter

Check the desired inner coil diameter.  
An inner diameter of 610 mm is generally offered for hot-rolled coils and an inner diameter of 508 mm offered for cold-rolled coils. When an inner diameter other than these is required, contact us.

## (7) Applications

Let us know your intended use.  
We offer special steel best suited for your intended applications so that you may use our products with a sense of security.

## (8) Others

More stringent specifications than normal may be required, depending on your usage environment and conditions. Check with us, when necessary.  
If you are not certain about what steel grades/specifications best suit your requirements, feel free to contact us.

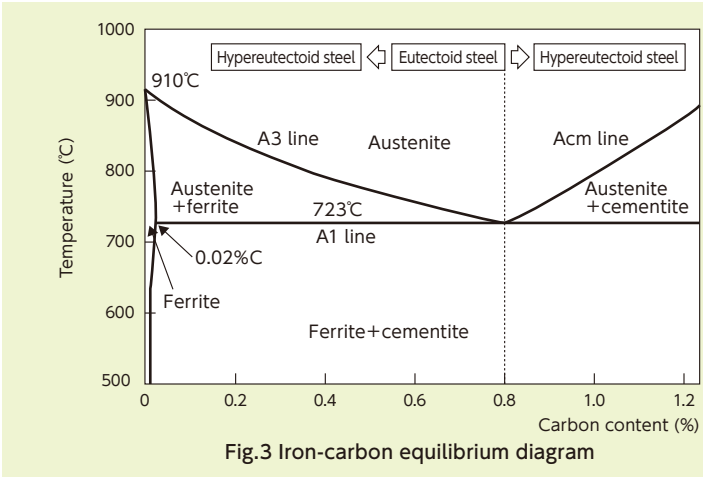


(1)Effects of added elements on steel

| Element | Effect of added element   |
|---------|---|
| C       | <ul style="list-style-type: none"><li>Carbon is the most important of all added elements and depending on its content, the metallic structure and characteristics of steel greatly vary,</li><li>The higher the carbon content, the harder will steel materials (hot-rolled, annealed, or hardened materials) tend to become.</li><li>The iron - carbon equilibrium diagram (Fig.1) shows the status that prevails when steel containing carbon is kept at a specified temperature.</li><li>The hardening penetration increases with more carbon addition. When the percentage of addition exceeds 0.6%, however, the hardness of steel will stagnate.</li><li>Rigid carbide is formed with the addition of such elements as Cr, Mo, and V.</li></ul> |
| Si      | <ul style="list-style-type: none"><li>Silicon is added as a deoxidizing agent in the steelmaking process.</li><li>Adding this element causes hardening of steel (solid solution strengthening). It also increases the resistance to temper softening at temperatures below 300°C .</li></ul>  |
| Mn      | <ul style="list-style-type: none"><li>When manganese is added, the hardenability and strength of steel increase but its resistance to temper softening remains the same.</li><li>Effective as a deoxidizing agent. This element suppresses embrittlement of steel by sulfur.</li><li>Adding a large quantity of manganese generates residual austenite after quenching.</li></ul>   |
| P       | <ul style="list-style-type: none"><li>Generally, phosphorus is contained in steel as an impurity.</li><li>This element segregates in the grain boundary region, decreasing the toughness of steel.</li></ul>  |
| S       | <ul style="list-style-type: none"><li>Generally, sulfur is contained in steel as an impurity.</li><li>When compounded with iron, this element decreases the hot workability of steel, which is improved by the addition of manganese.</li><li>The sulfide with manganese decreases the workability of the material (especially in case of bulging and FB involving local deformation) and its post-heat treatment toughness.</li></ul>  |
| Cr      | <ul style="list-style-type: none"><li>Adding chromium improves the hardenability of steel and its resistance to temper softening. When the percentage of chromium added is several percent, it dissolves in the cementite (replaces iron) to stabilize it.</li></ul>  |
| Mo      | <ul style="list-style-type: none"><li>Adding molybdenum improves the hardenability of steel.</li><li>When this element is added, a carbide is formed, resulting in improvement of the resistance of steel to temper softening.</li></ul>  |
| Ni      | <ul style="list-style-type: none"><li>Adding nickel causes the austenite to stabilize, lowering the A1 point and improving the hardenability of steel.</li><li>This element improves the toughness of steel at low temperature.</li></ul>   |
| V       | <ul style="list-style-type: none"><li>Adding a small quantity of vanadium improves the hardenability of steel.</li><li>Excessive addition, however, decreases its hardenability.</li><li>This element causes formation of a stable carbide so that it is effective in improving the abrasion resistance of steel and crystal (austenite) grains (improving its toughness).</li></ul>  |
| W       | <ul style="list-style-type: none"><li>Adding tungsten improves the resistance of steel to temper softening.</li><li>Addition of this element causes formation of a carbide, resulting in an increase in hardness.</li></ul>   |
| B       | <ul style="list-style-type: none"><li>Adding a very small quantity (several to several tens of ppm) of boron improves the hardenability and toughness of steel.</li></ul>   |
| Ti      | <ul style="list-style-type: none"><li>Addition of titanium causes formation of a stable carbide/nitride. This element is also effective in refining crystal (prior austenite) grains (improving the toughness of steel).</li></ul>  |
| Nb      | <ul style="list-style-type: none"><li>Effective in refining crystal (prior austenite) grains (improving the toughness of steel).</li><li>Addition of this element causes formation of a hard carbide. It is also instrumental in improving the abrasion resistance of steel.</li></ul>  |
| Al      | <ul style="list-style-type: none"><li>Effective as a deoxidizing agent. Adding a large quantity of aluminum leads to characteristic deterioration because of formation of a nonmetallic inclusion.</li></ul>  |
| N       | <ul style="list-style-type: none"><li>This element combines with Al, V, Ti, Zr, Nb or the like to form a nitride or carbonitride.</li></ul>   |

(2)Heat treatment of steel

●Iron-carbon equilibrium diagram



|                              |   |
|------------------------------|---|
| Austenite                    | Iron in stable state (phase) at high temperature<br>Symbol: $\gamma$  |
| Ferrite                      | Iron in stable state (phase) in low temperature<br>Symbol: $\alpha$   |
| Cementite                    | Iron carbide ( $\text{Fe}_3\text{C}$ )<br>Symbol: $\theta$  |
| A <sub>1</sub> point         | Temperature (723°C) at which $\alpha$ and $\theta$ are generated from $\gamma$ (eutectoid transformation) during cooling<br>A reverse transformation takes place during heating |
| A <sub>3</sub> line (point)  | Temperature at which $\alpha$ is generated from $\gamma$ during cooling and $\alpha$ disappears during heating  |
| A <sub>cm</sub> line (point) | Temperature at which $\theta$ is generated from $\gamma$ during cooling and $\theta$ disappears during heating  |
| Transformation               | Change in state (turning of water into ice is a kind of transformation.)  |
| Transformation point         | Temperature at which transformation takes place   |

●Outline of heat treatment of special steel

| Type of heat treatment    |                         | Heat treatment method   | Purpose   |
|---------------------------|-------------------------|---|---|
| Normalizing               |                         | Heating to $\gamma$ region $\rightarrow$ Air cooling  | Improvement in structure conditioning, stress relief, segregation, machinability, and plastic workability |
| Annealing                 | Full annealing          | Heating to $\gamma$ (+ $\theta$ ) region $\rightarrow$ Furnace cooling                        |   |
|                           | Spheroidizing           | Heating to near A <sub>1</sub> point $\rightarrow$ Furnace cooling                            | Improvement in plastic workability and machinability  |
|                           | Stress relief annealing | Heating to 500 - 650 °C $\rightarrow$ Air cooling   | Improvement in stress relief and plastic workability  |
| Quenching                 |                         | Heating to $\gamma$ (+ $\theta$ ) region $\rightarrow$ Rapid cooling                          | Stiffening  |
| Tempering                 |                         | Heating to below (up to) A <sub>1</sub> point $\rightarrow$ Cooling                           | • Stiffening<br>• Improvement in abrasion resistance<br>• Improvement in toughness                        |
| Isothermal heat treatment | Austempering            | Heating to $\gamma$ (+ $\theta$ ) region $\rightarrow$ Isothermal holding just above Ms point |   |
|                           | Martempering            | Heating to $\gamma$ (+ $\theta$ ) region $\rightarrow$ Isothermal holding below Ms point      |   |

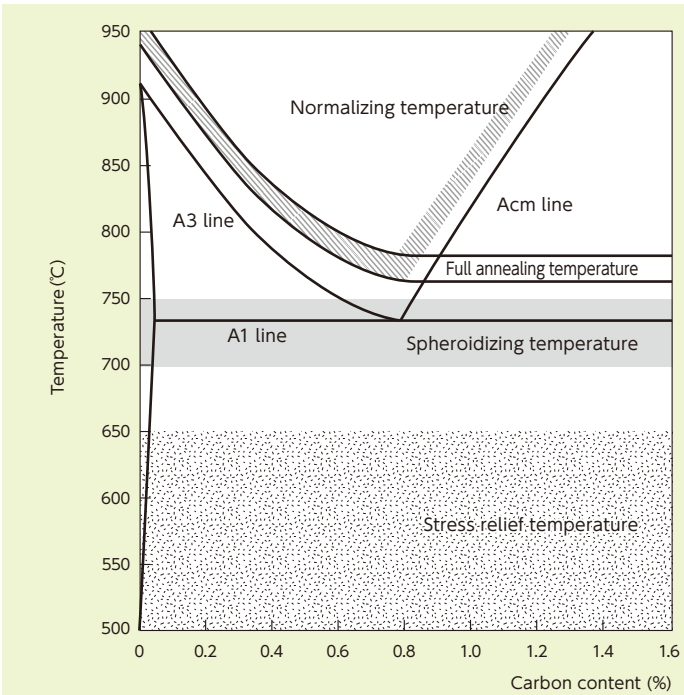
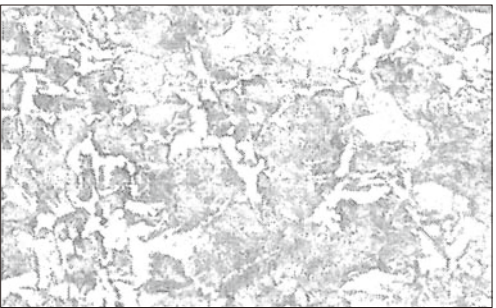


Fig.4 Heating temperature for normalizing and annealing of carbon steel



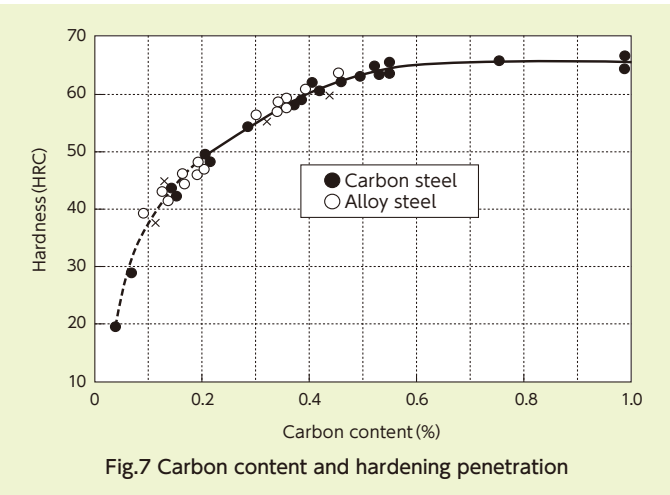
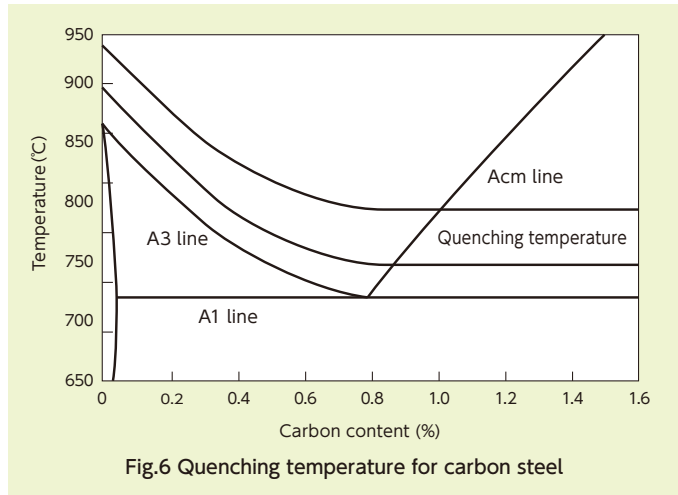
(a) Hot rolling structure (Ferrite + praline)



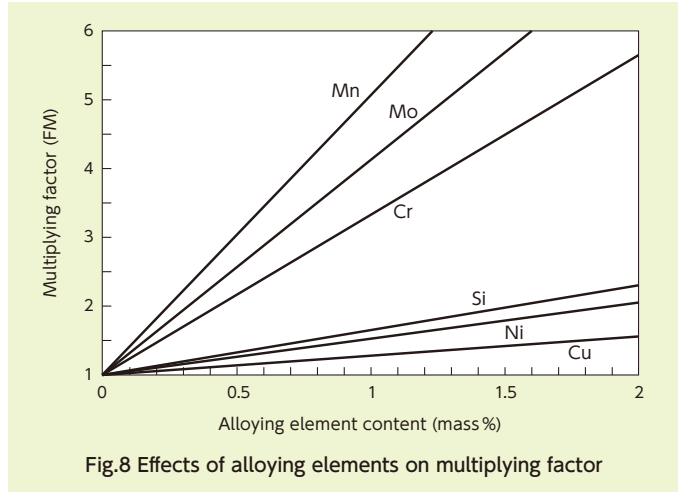
(b) Annealing structure (Ferrite + spheroidal cementite)

Fig. 5 Examples of metallographic structure of S35C

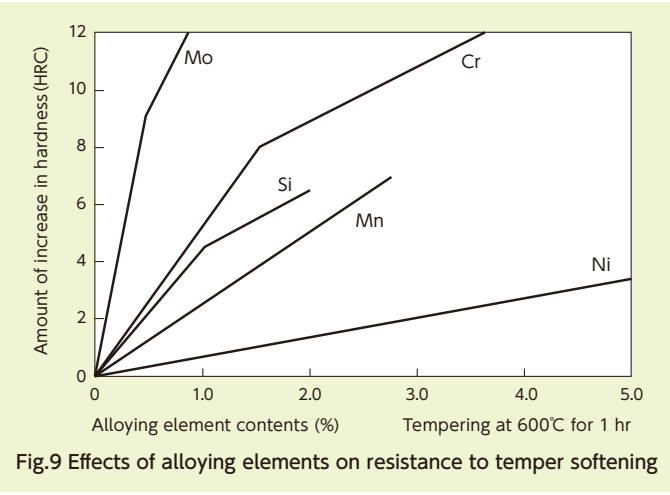




The maximum hardness obtained by quenching is determined by the carbon content (the quantity of carbon dissolved in austenite), regardless of the alloying elements.



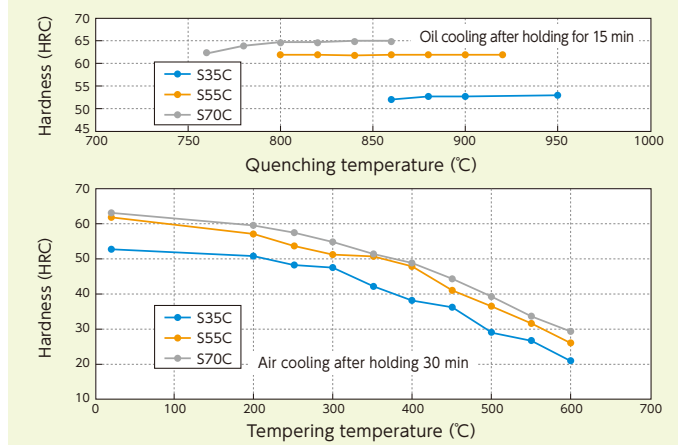
Multiplying factor: Coefficient indicating the increase in ideal critical diameter with the alloying elements contained. (The ideal critical diameter is an indicator of hardenability. The greater this indicator, the higher the hardenability.)



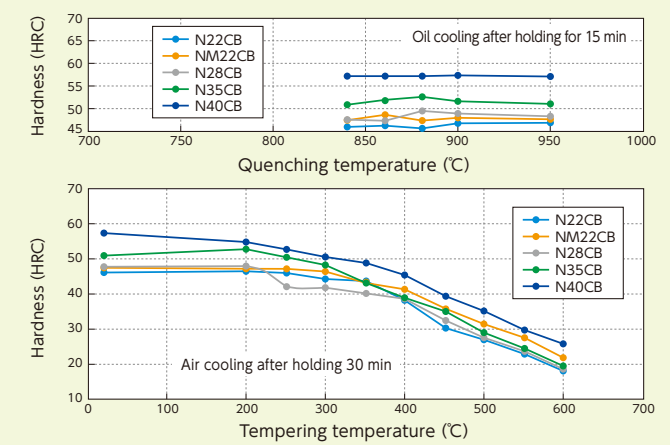
Amount of increase in hardness: Difference in tempering hardness between steels containing and not containing alloying elements

(3)Heat treatment characteristics (hardening and tempering curves)

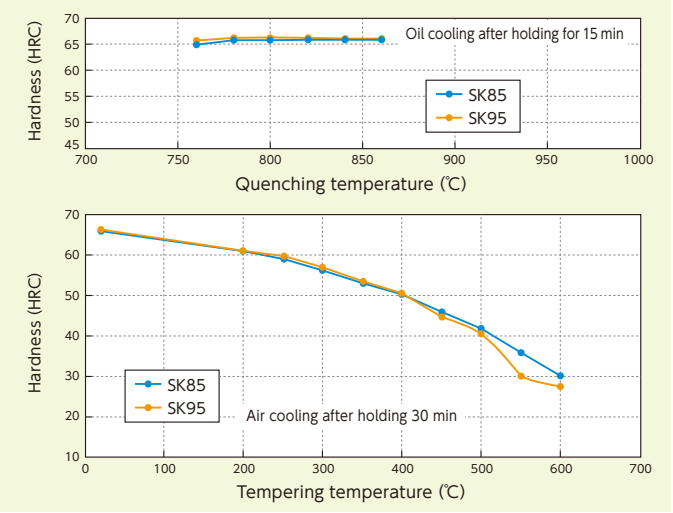
(1)Carbon steel for machine structural use (common)



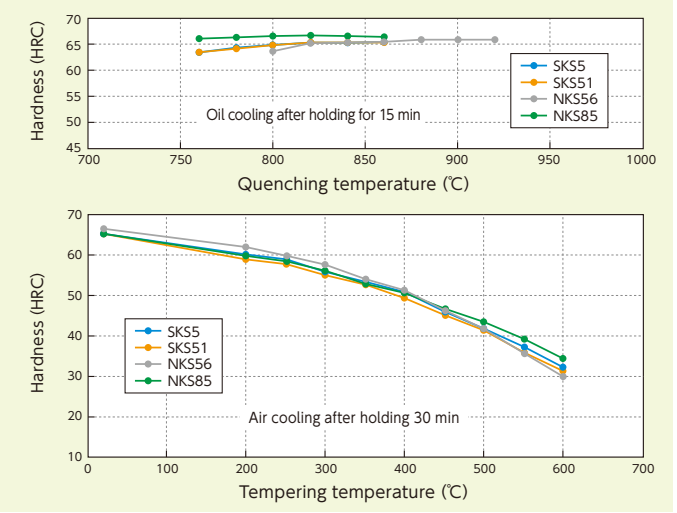
(2)Carbon steel for machine structural use (boron added steel)



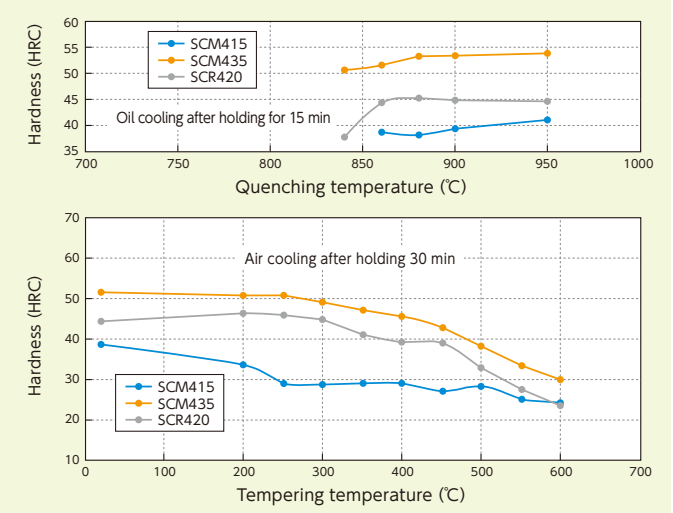
(3)Carbon tool steel



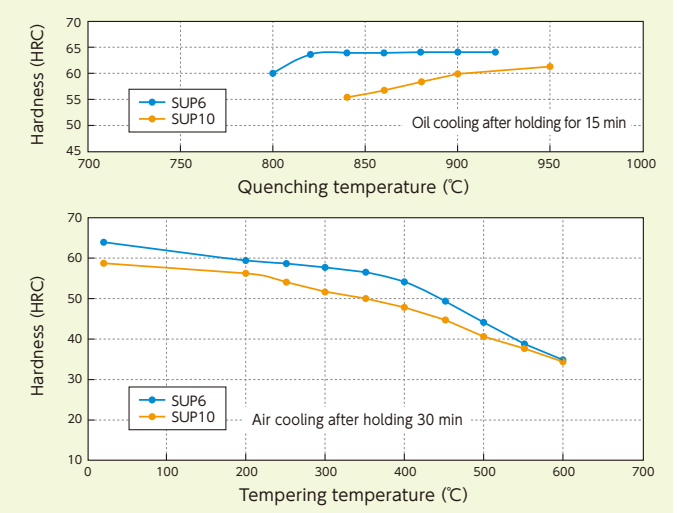
(4)Alloy tool steel



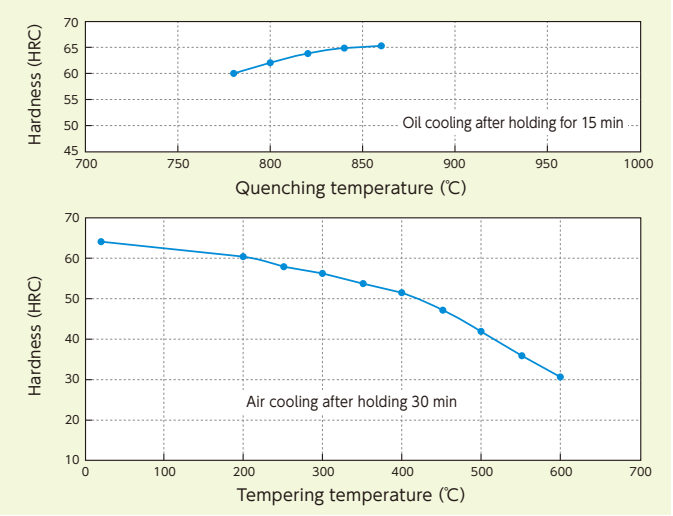
(5)Structural alloy steel



(6)Spring steel



(7)Bearing steel





(4)Hardness conversion table (Approximate hardness of steel corresponding to Vickers hardness)

| Vickers hardness<br>(DPH) | Brinell hardness<br>0 mm ball load: 29.42 kN |               |                          | Rockwell hardness                          |   |   |  | Rockwell special hardness<br>Special brale indenter |                                |                               | Shore hardness | Tensile strength | Vickers hardness<br>Load: 490.3 N |
|---------------------------|--|---------------|--------------------------|--|---|---|--|---|--------------------------------|-------------------------------|----------------|------------------|-----------------------------------|
|                           | Standard ball                                | Hultgren ball | Tungsten carbide<br>ball | A scale<br>Load: 588.4 N<br>Brale indenter | B scale<br>Load: 980.7 N<br>1/16 in. ball | C scale<br>Load: 1471 N<br>Brale indenter |  | 15-N<br>Scale<br>Load: 147.1 N                      | 30-N<br>Scale<br>Load: 294.2 N | 45-N<br>Scale<br>Load: 441.3N |                |                  |                                   |
| 700                       | —  | 615           | 666                      | 81.3                                       | —   | 60.1                                      |  | 90.3  | 77.6                           | 66.7                          | 81             | —                | 700                               |
| 690                       | —  | 610           | 647                      | 81.1                                       | —   | 59.7                                      |  | 90.1  | 77.2                           | 66.2                          | —              | —                | 690                               |
| 680                       | —  | 603           | 638                      | 80.8                                       | —   | 59.2                                      |  | 89.3  | 76.8                           | 65.7                          | 80             | —                | 680                               |
| 670                       | —  | 597           | 630                      | 80.6                                       | —   | 58.8                                      |  | 89.7  | 76.4                           | 65.3                          | —              | —                | 670                               |
| 660                       | —  | 590           | 620                      | 80.3                                       | —   | 58.3                                      |  | 89.5  | 75.9                           | 64.7                          | 79             | —                | 660                               |
| 650                       | —  | 585           | 611                      | 80.0                                       | —   | 57.8                                      |  | 89.2  | 75.5                           | 64.1                          | —              | —                | 650                               |
| 640                       | —  | 578           | 601                      | 79.8                                       | —   | 57.3                                      |  | 89.0  | 75.1                           | 63.5                          | 77             | —                | 640                               |
| 630                       | —  | 571           | 591                      | 79.5                                       | —   | 56.8                                      |  | 88.8  | 74.6                           | 63.0                          | —              | —                | 630                               |
| 620                       | —  | 564           | 582                      | 79.2                                       | —   | 56.3                                      |  | 88.5  | 74.2                           | 62.4                          | 75             | —                | 620                               |
| 610                       | —  | 557           | 573                      | 78.9                                       | —   | 55.7                                      |  | 88.2  | 73.6                           | 61.7                          | —              | —                | 610                               |
| 600                       | —  | 550           | 564                      | 78.6                                       | —   | 55.2                                      |  | 88.0  | 73.2                           | 61.2                          | 74             | —                | 600                               |
| 590                       | —  | 542           | 554                      | 78.4                                       | —   | 54.7                                      |  | 87.8  | 72.7                           | 60.5                          | —              | 2055 (210)       | 590                               |
| 580                       | —  | 535           | 545                      | 78.0                                       | —   | 54.1                                      |  | 87.5  | 72.1                           | 59.9                          | 72             | 2020 (206)       | 580                               |
| 570                       | —  | 527           | 555                      | 77.8                                       | —   | 53.6                                      |  | 87.2  | 71.7                           | 59.3                          | —              | 1985 (202)       | 570                               |
| 560                       | —  | 519           | 525                      | 77.4                                       | —   | 53.0                                      |  | 86.9  | 71.2                           | 58.6                          | 71             | 1950 (199)       | 560                               |
| 550                       | 505  | 512           | 517                      | 77.0                                       | —   | 52.3                                      |  | 86.6  | 70.5                           | 57.8                          | —              | 1905 (194)       | 550                               |
| 540                       | 496  | 503           | 507                      | 76.7                                       | —   | 51.7                                      |  | 86.3  | 70.0                           | 57.0                          | 69             | 1860 (190)       | 540                               |
| 530                       | 488  | 495           | 497                      | 76.4                                       | —   | 51.1                                      |  | 86.0  | 69.5                           | 56.2                          | —              | 1825 (186)       | 530                               |
| 520                       | 480  | 487           | 488                      | 76.1                                       | —   | 50.5                                      |  | 85.7  | 69.0                           | 55.6                          | 67             | 1795 (183)       | 520                               |
| 510                       | 473  | 479           | 479                      | 75.7                                       | —   | 49.8                                      |  | 85.4  | 68.3                           | 54.7                          | —              | 1750 (179)       | 510                               |
| 500                       | 465  | 471           | 471                      | 75.3                                       | —   | 49.1                                      |  | 85.0  | 67.7                           | 53.9                          | 66             | 1705 (174)       | 500                               |
| 490                       | 456  | 460           | 460                      | 74.9                                       | —   | 48.4                                      |  | 84.7  | 67.1                           | 53.1                          | —              | 1660 (169)       | 490                               |
| 480                       | 448  | 452           | 452                      | 74.5                                       | —   | 47.7                                      |  | 84.3  | 66.4                           | 52.2                          | 64             | 1620 (165)       | 480                               |
| 470                       | 441  | 442           | 442                      | 74.1                                       | —   | 46.9                                      |  | 83.9  | 65.7                           | 51.3                          | —              | 1570 (160)       | 470                               |
| 460                       | 433  | 433           | 433                      | 73.6                                       | —   | 46.1                                      |  | 83.6  | 64.9                           | 50.4                          | 62             | 1530 (156)       | 460                               |
| 450                       | 425  | 425           | 425                      | 73.3                                       | —   | 45.3                                      |  | 83.2  | 64.3                           | 49.4                          | —              | 1495 (153)       | 450                               |
| 440                       | 415  | 415           | 415                      | 72.8                                       | —   | 44.5                                      |  | 82.8  | 63.5                           | 48.4                          | 59             | 1460 (149)       | 440                               |
| 430                       | 405  | 405           | 405                      | 72.3                                       | —   | 43.6                                      |  | 82.3  | 62.8                           | 47.4                          | —              | 1410 (144)       | 430                               |
| 420                       | 397  | 397           | 397                      | 71.8                                       | —   | 42.7                                      |  | 81.8  | 61.9                           | 46.4                          | 57             | 1370 (140)       | 420                               |
| 410                       | 388  | 388           | 388                      | 71.4                                       | —   | 41.8                                      |  | 81.4  | 61.1                           | 45.3                          | —              | 1330 (136)       | 410                               |
| 400                       | 379  | 379           | 379                      | 70.8                                       | —   | 40.8                                      |  | 81.0  | 60.2                           | 44.1                          | 55             | 1290 (131)       | 400                               |
| 390                       | 369  | 369           | 369                      | 70.3                                       | —   | 39.8                                      |  | 80.3  | 59.3                           | 42.9                          | —              | 1240 (127)       | 390                               |
| 380                       | 360  | 360           | 360                      | 69.8                                       | (110.0)                                   | 38.8                                      |  | 79.8  | 58.4                           | 41.7                          | 52             | 1205 (123)       | 380                               |
| 370                       | 350  | 350           | 350                      | 69.2                                       | —   | 37.7                                      |  | 79.2  | 57.4                           | 40.4                          | —              | 1170 (120)       | 370                               |
| 360                       | 341  | 341           | 341                      | 68.7                                       | (109.0)                                   | 36.6                                      |  | 78.6  | 56.4                           | 39.1                          | 50             | 1130 (115)       | 360                               |
| 350                       | 331  | 331           | 331                      | 68.1                                       | —   | 35.5                                      |  | 78.0  | 55.4                           | 37.8                          | —              | 1095 (112)       | 350                               |
| 340                       | 322  | 322           | 322                      | 67.6                                       | (108.0)                                   | 34.4                                      |  | 77.4  | 54.4                           | 36.5                          | 47             | 1070 (109)       | 340                               |
| 330                       | 313  | 313           | 313                      | 67.0                                       | —   | 33.3                                      |  | 76.8  | 53.6                           | 35.2                          | —              | 1035 (105)       | 330                               |
| 320                       | 303  | 303           | 303                      | 66.4                                       | (107.0)                                   | 32.2                                      |  | 76.2  | 52.3                           | 33.9                          | 45             | 1005 (103)       | 320                               |
| 310                       | 294  | 294           | 294                      | 65.8                                       | —   | 31.0                                      |  | 75.6  | 51.3                           | 32.5                          | —              | 980 (100)        | 310                               |
| 300                       | 284  | 284           | 284                      | 65.2                                       | (105.5)                                   | 29.8                                      |  | 74.9  | 50.2                           | 31.1                          | 42             | 950 ( 97)        | 300                               |
| 295                       | 280  | 280           | 280                      | 64.8                                       | —   | 29.2                                      |  | 74.6  | 49.7                           | 30.4                          | —              | 935 ( 96)        | 295                               |
| 290                       | 275  | 275           | 275                      | 64.5                                       | (104.5)                                   | 28.5                                      |  | 74.2  | 49.0                           | 29.5                          | 41             | 915 ( 94)        | 290                               |
| 285                       | 270  | 270           | 270                      | 64.2                                       | —   | 27.8                                      |  | 73.8  | 48.4                           | 28.7                          | —              | 905 ( 92)        | 285                               |
| 280                       | 265  | 265           | 265                      | 63.8                                       | (103.5)                                   | 27.1                                      |  | 73.4  | 47.8                           | 27.9                          | 40             | 890 ( 91)        | 280                               |
| 275                       | 261  | 261           | 261                      | 63.5                                       | —   | 26.4                                      |  | 73.0  | 47.2                           | 27.1                          | —              | 875 ( 89)        | 275                               |
| 270                       | 256  | 256           | 256                      | 63.1                                       | (102.0)                                   | 25.6                                      |  | 72.6  | 46.4                           | 26.2                          | 38             | 855 ( 87)        | 270                               |
| 265                       | 252  | 252           | 252                      | 62.7                                       | —   | 24.8                                      |  | 72.1  | 45.7                           | 25.2                          | —              | 840 ( 86)        | 265                               |
| 260                       | 247  | 247           | 247                      | 62.4                                       | (101.0)                                   | 24.0                                      |  | 71.6  | 45.0                           | 24.3                          | 37             | 825 ( 84)        | 260                               |
| 255                       | 243  | 243           | 243                      | 62.0                                       | —   | 23.1                                      |  | 71.1  | 44.2                           | 23.2                          | —              | 805 ( 82)        | 255                               |
| 250                       | 238  | 238           | 238                      | 61.6                                       | 99.5                                      | 22.2                                      |  | 70.6  | 43.4                           | 22.2                          | 36             | 795 ( 81)        | 250                               |
| 245                       | 233  | 233           | 233                      | 61.2                                       | —   | 21.3                                      |  | 70.1  | 42.5                           | 21.1                          | —              | 780 ( 79)        | 245                               |
| 240                       | 228  | 228           | 228                      | 60.7                                       | 98.1                                      | 20.3                                      |  | 69.6  | 41.7                           | 19.9                          | 34             | 765 ( 78)        | 240                               |
| 230                       | 219  | 219           | 219                      | —  | 96.7                                      | (18.0)                                    |  | —   | —                              | —                             | 33             | 730 ( 75)        | 230                               |
| 220                       | 209  | 209           | 209                      | —  | 95.0                                      | (15.7)                                    |  | —   | —                              | —                             | 32             | 695 ( 71)        | 220                               |
| 210                       | 200  | 200           | 200                      | —  | 93.4                                      | (13.4)                                    |  | —   | —                              | —                             | 30             | 670 ( 68)        | 210                               |
| 200                       | 190  | 190           | 190                      | —  | 91.5                                      | (11.0)                                    |  | —   | —                              | —                             | 29             | 635 ( 65)        | 200                               |
| 190                       | 181  | 181           | 181                      | —  | 89.5                                      | ( 8.5)                                    |  | —   | —                              | —                             | 28             | 605 ( 62)        | 190                               |
| 180                       | 171  | 171           | 171                      | —  | 87.1                                      | ( 6.0)                                    |  | —   | —                              | —                             | 26             | 580 ( 59)        | 180                               |
| 170                       | 162  | 162           | 162                      | —  | 85.0                                      | ( 3.0)                                    |  | —   | —                              | —                             | 25             | 545 ( 56)        | 170                               |
| 160                       | 152  | 152           | 152                      | —  | 81.7                                      | ( 0.0)                                    |  | —   | —                              | —                             | 24             | 515 ( 53)        | 160                               |
| 150                       | 143  | 143           | 143                      | —  | 78.7                                      | —   |  | —   | —                              | —                             | 22             | 490 ( 50)        | 150                               |
| 140                       | 133  | 133           | 133                      | —  | 75.0                                      | —   |  | —   | —                              | —                             | 21             | 455 ( 46)        | 140                               |
| 130                       | 124  | 124           | 124                      | —  | 71.2                                      | —   |  | —   | —                              | —                             | 20             | 425 ( 44)        | 130                               |
| 120                       | 114  | 114           | 114                      | —  | 66.7                                      | —   |  | —   | —                              | —                             | —              | 390 ( 40)        | 120                               |
| 110                       | 105  | 105           | 105                      | —  | 62.3                                      | —   |  | —   | —                              | —                             | —              | —                | 110                               |
| 100                       | 95   | 95            | 95                       | —  | 56.2                                      | —   |  | —   | —                              | —                             | —              | —                | 100                               |