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شرکت آریا سپهر کیهان با نام اختصاری ASK، طراح و تولیدکننده پمپ های گریز از مرکز و روتاری و ارائه دهنده راهکارهای بهینه سازی سیستم های فرایندی و پمپاژ می باشد.

توجه !

مقالات تخصصی با عنوان White Papers جهت افزایش دانش عمومی پمپ ها در بخش تحقیق و توسعه این شرکت نگارش شده است. استفاده از این مقالات رایگان می باشد و لازم است جهت استفاده از محتویات آن به موارد ذیل توجه فرمایید:

1- انتشار مجدد مطالب مقالات (به شکل اولیه و بدون تغییر در ساختار محتوایی و ظاهری) با ذکر منبع، بلامانع است.

2- استفاده تجاری از محتویات مقالات در نشریات مجاز نمی باشد.

فهرست

مقدمه

کاربرد بالای مواد آهنی در ساخت قطعات مختلف پمپ های سانتریفیوژ باعث شده است که انتخاب ماده ی مناسب برای ساخت هر قطعه و شناخت خواص آن به یکی از دغدغه های اصلی کارخانه های پمپ سازی بدل شود. از این رو بر آن شدیم تا با مطالعه و به کارگیری استاندارد جهانی مواد آهنی (ASTM)، این قطعات با کیفیتی مطابق با این استاندارد تولید شود.

در ادامه با توجه به تنوع مواد آهنی، چکیده ای از کاربرد ، ترکیب شیمیایی، خصوصیات مکانیکی، نحوه ی تست و تعمیر و ترمیم هر کدام از آنها ارائه شده است. در پیوست ارائه شده، چکیده ی برخی از استانداردهای مرتبط با مواد آهنی که در متن به آنها اشاره شده بود آورده شده است. همچنین در پایان، متن اصلی هرکدام از استانداردهای معرفی شده ضمیمه شده است تا در صورت نیاز به اطلاعات بیشتر به آن مراجعه شود.

استاندارد ASTM – A29

SPECIFICATION FOR STEEL BARS, CARBON AND ALLOY, HOT WROUGHT AND COLD-FINISHED ,GENERAL REQUIREMENTS FOR

این متریال مربوط به شمش های فولاد کربنی یا آلیاژی ای می شود که تحت کار گرم[1] و اتمام سرد[2] قرار گرفته شده اند. این متریال در گرید های بسیار زیادی موجود می باشد که در زیر به بررسی خواص گرید ۴۱۴۰ پرداخته شده است.

❖ کاربرد در اجزای پمپ

از گرید ۴۱۴۰ متریال A29 در ساختن شفت پمپ استفاده می شود.

❖ ترکیب شیمیایی

گرید های مختلف این متریال دارای ترکیبات مختلفی از عناصر مانند کربن، منگنز، فسفر، گوگرد و... هستند که ترکیبات گرید ۴۱۴۰ در جدول ۱-۱ آورده شده است.

جدول ۱-۱

مولیبدن (٪)	کروم (٪)	سیلیکون (٪)	گوگرد (٪)	فسفر (٪)	منگنز (٪)	کربن (٪)	گرید
0.15-0.25	0.8-1.1	0.15-0.35	0.04 max	0.035 max	0.75-1	0.38-0.43	4140

❖ خواص مکانیکی

خواص مکانیکی متریال A29 گرید ۴۱۴۰ در جدول ۲-۱ آورده شده است.

جدول ۲-۱

ازدیاد طول (٪)	سختی (HB)	استحکام کششی (MPa)	استحکام تسلیم (MPa)	گرید
۲۵/۷	۱۹۷	۶۵۵	۴۱۷	۴۱۴۰

❖ تست نمونه

برای آزمایش و آنالیز ترکیبات محصول باید به وسیله ی یکی از ۴ روش زیر نمونه هایی از آن گرفته شود:

[1] hot-wrought
[2] cold finished

i. در این روش که قابل استفاده برای محصولاتی با مساحت سطح مقطع کمتر از ۰/۷۵ اینچ مربع (معادل با ۵۰۰ میلیمتر مربع)است، تراشه ها به وسیله ی ماشین کاری یا فرزکاری تمام سطح مقطع قطعه، گرفته می شود. مته کاری برای گرفتن تراشه برای این دسته اصلا مناسب نیست.

ii. در این روش که قابل استفاده برای محصولاتی که در آنها عرض سطح مقطع بسیار بیشتر از ضخامت آن است (مثل شمش های تخت سبک) است، تراشه ها به وسیله ی مته زنی از نقطه ی میانی بین وسط سطح مقطع و لبه و یا به وسیله ی ماشین کاری یا فرزکاری از تمام سطح مقطع گرفته می شود.

iii. در این روش که قابل استفاده برای هندسه ی دایروی بزرگ و مربع های ناقص است، تراشه ها به وسیله ی مته زنی از نقطه ی میانی بین وسط سطح مقطع و لبه و یا به وسیله ی ماشین کاری یا فرزکاری از تمام سطح مقطع گرفته می شود. البته راه عملی تر به این گونه است که قطعه از سطح جانبی مته زده می شود تا دقیقا به نقطه ی وسط بین نقطه ی میانی سطح مقطع و لبه ی خارجی برسد و سپس تراشه برداشته می شود.

iv. در این روش که قابل استفاده برای محصولاتی که می خواهند تحت کشش قرار بگیرند است، از نمونه ی تست کشش به جای نمونه استفاده می شود. در این حالت تراشه از نمونه ی تست کشش به وسیله ی مته زنی از سرتاسر نمونه صورت می گیرد.

در نمونه برداری باید به نکات زیر توجه کرد:

۱- هرگاه نمونه ها توسط مته زنی برداشته شوند باید شرایط زیر ارضا شود:

قطر مته (in)	مساحت سطح مقطع (in^2)
0.5	≤ 16
1	> 16

۲- حداقل تعداد نمونه هایی که از یک قطعه برداشته می شود به شرح زیر است:

حداقل تعداد نمونه	وزن قطعه
۴	≤ 15 tons
۶	> 15 *tons*

استاندارد ASTM – A48

Standard Specification for Gray Iron Castings

این متریال مربوط به چدن خاکستری است. این متریال در گرید های مختلفی موجود است که نامگذاری این گرید ها بر اساس یک حرف و یک عدد می باشد. عدد نشان دهنده ی مقاومت کششی متریال بر حسب ksi می باشد و حرف نیز نشان دهنده ی اندازه ی شمش تست است که در قسمت تست نمونه به تفصیل شرح داده خواهد شد.

❖ کلاس بندی

گرید های مختلف متریال A48 را می توان در دو کلاس خلاصه کرد:

۱- کلاس اول (شامل گریدهای ۲۰، ۲۵ ،۳۰، ۳۵) : دارای خصوصیات : قابلیت ماشین کاری بالا، ظرفیت دمپینگ بالا، مدول الاستیسیته ی پایین، سهولت نسبی تولید.

۲- کلاس دوم (شامل گرید های ۴۰، ۴۵، ۵۰، ۵۵، ۶۰) : دارای خصوصیات: قابلیت ماشین کاری پایین، ظرفیت دمپینگ پایین، مدول الاستیسیته ی بالا، سخت بودن نسبی تولید.

❖ کاربرد در اجزای پمپ

در قطعات عمومی پمپ که تحت فشار نیستند و متریال مناسب برای آن چدن باشد از A48 استفاده می شود. کلاس های مورد استفاده ی این متریال کلاس های ۲۵، ۳۰ و ۳۵ می باشد.

❖ ترکیب شیمیایی

در متن استاندارد اشاره ای به آن نشده است.

❖ خواص مکانیکی

همانطور که پیشتر بیان شد، استحکام کششی هر کلاس با عدد آن بیان شده است. مثلا متریال B30 دارای استحکام کششی ۳۰ksi است. در مورد سایر خصوصیات مکانیکی این متریال در متن استاندارد اشاره ای نشده است.

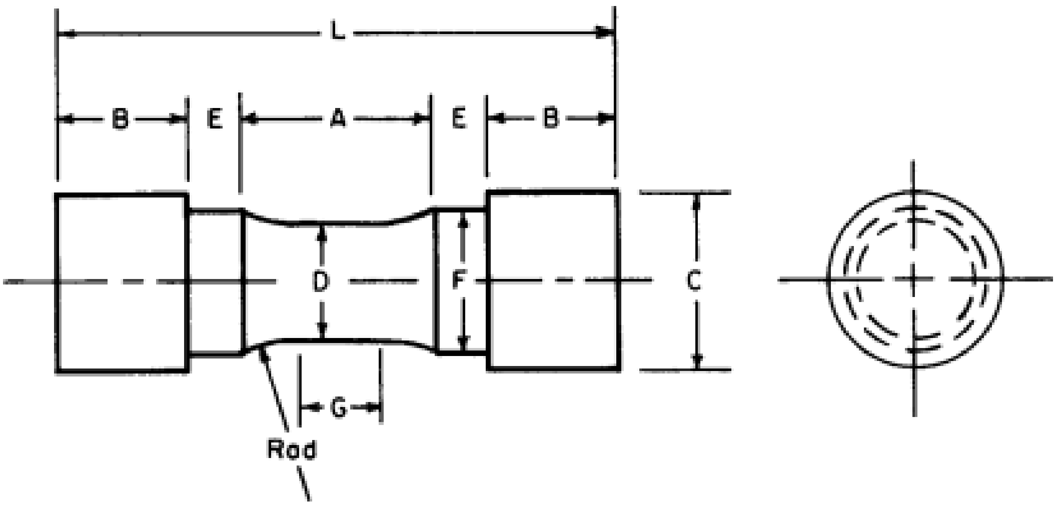
❖ تست نمونه

برای سنجش خصوصیات مکانیکی متریال یک تست کشش روی آن انجام می شود که با توجه به نوع نمونه و زمان شکست آن متفاوت است. اگر نمونه از نوع A باشد نباید زودتر از ۱۵ ثانیه و اگر نمونه از نوع B یا C باشد نباید زودتر از ۲۰ ثانیه گسیخته شود. انواع نمونه ها و ابعاد آنها در جدول ۱- ۲ و جدول ۲-۲ آورده شده است.

جدول ۱-۲

طول (اینچ)		قطر (اینچ)			
ماکزیمم	مینیمم	ماکزیمم	مینیمم	نامی	شمش نمونه
6	5	0.96	0.85	0.88	A
9	6	1.32	1.14	1.2	B
10	7	2.1	1.9	2	C
*	*	*	*	*	S

* توافقی بین خریدار و فروشنده



شکل ۱-۲- نمونه تست

جدول ۲-۲

دیمانسیون (inch)	A	B	C
G (min)	0.5	0.75	1.25
D	0.5±0.01	0.75±0.015	1.25±0.025
R (min)	1	1	2
A (min)	$\frac{5}{4}$	$\frac{3}{2}$	$\frac{9}{4}$
L (min)	$\frac{15}{4}$	4	$\frac{51}{8}$
C	$\frac{7}{8}$	$\frac{5}{4}$	$\frac{15}{8}$
E (min)	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$
F	$\frac{5}{8}\pm\frac{1}{64}$	$\frac{15}{16}\pm\frac{1}{64}$	$\frac{23}{16}\pm\frac{1}{64}$
B	اختیاری	اختیاری	اختیاری

استاندارد ASTM – A105

SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING APPLICATIONS

این استاندارد مربوط به فولادهای کربنی فوذج شده ای است که در پایپینگ کاربرد دارند. این متریال توانایی عملکرد مناسب در دمای محیط و یا دماهای بالاتر و همچنین در سیستم های فشار بالا را دارد. اگر جرم قطعه ی فورج شده بیشتر از ۱۰۰۰۰ پوند (معادل ۴۵۴۰ کیلوگرم) باشد، این استاندارد متریال مناسبی برای این منظور معرفی نمی کند و به جای آن از استاندارد A266 استفاده می شود. همچنین این استاندارد شامل ورق های لوله ای و سیلندر های تو خالی آهنگری شده نمی شود. به عبارت دیگر این استاندارد معرف متریالی برای لوله های یکپارچه و شمش های نورد شده می باشد.

❖ کاربرد در اجزای پمپ

از این متریال برای ساخت فلنج های مورد نیاز در اجزای پایپینگ پمپ ها استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی متریال A105 شامل عناصر مختلفی است که در جدول ۱-۳ نشان داده شده است. همچنین در جدول ۲-۳ میزان انحراف مجاز از مقادیر تعیین شده در جدول ۱-۳ با توجه به مساحت قطعه نشان داده شده است.

جدول ۱-۳

عنصر	درصد
کربن	0.35 (max)
منگنز	0.6 – 1.06
فسفر	0.035 (max)
گوگرد	0.040 (max)
سیلیکون	0.10 – 0.35
مس	0.40 (max) [1]
نیکل	0.40 (max) [1]
کروم	0.30 (max) [1,2]
مولیبدن	0.12 (max) [1,2]
وانادیوم	0.05 (max)
کلمبیوم	0.02 (max)

توضیح کلی : به ازای کاهش هر ۰/۰۱ درصد کربن از ماکزیمم میزان آن، ۰/۰۶ درصد ازدیاد منگنز از مقدار ماکزیمم آن مجاز است.

۱ مجموع درصد های کروم و نیکل و مس و مولیبدن نباید از ۱ بیشتر شود.

۲ مجموع درصد های کروم و مولیبدن نباید از ۰/۳۲ بیشتر شود.

جدول ۲-۳

	$\leq 200\ in^2$	$200 < A \leq 400\ in^2$	$400 < A \leq 800\ in^2$	$800 < A \leq 1600\ in^2$	$A > 1600\ in^2$
کربن	0.02	0.03	0.04	0.05	0.05
منگنز					
کمتر ۰/۹	0.04	0.05	0.06	0.07	0.08
بیشتر از ۰/۹	0.06	0.07	0.08	0.08	0.09
فسفر	0.008	0.010	0.010	0.015	0.015
گوگرد	0.010	0.010	0.010	0.015	0.015
سیلیکون	0.03	0.04	0.04	0.05	0.06
مس	0.03	0.03	0.03	0.03	0.03
نیکل	0.03	0.03	0.03	0.03	0.03
کروم	0.04	0.04	0.04	0.04	0.04
مولیبدن	0.01	0.01	0.01	0.01	0.01
وانادیوم	0.01	0.01	0.01	0.01	0.01
کلمبیوم	0.01	0.01	0.01	0.01	0.01

- **خواص مکانیکی**

خواص مکانیکی این متریال در جدول ۳-۳ آورده شده است.

جدول ۳-۳

استحکام کششی (MPa)	۴۸۵
استحکام تسلیم (MPa)	۲۵۰
ازدیاد طول در هر ۲ اینچ (٪) ازدیاد طول برای دیواره با ضخامت $\frac{5}{16}$اینچ ازدیاد طول برای قطعه ی استوانه ای با طول ۲ اینچ	 ۳۰ ۲۲
سختی (HB)	۱۸۷

❖ تست نمونه

برای تست و آنالیز قطعه، باید نمونه بعد از عملیات حرارتی یا آهنگری احتمالی از قطعه جدا شود و طبق استاندارد A751 تست شود. اگر قطعه نرمالیزه (با حرارت بالا) یا کوئنچ شده یا فورج شده (با حرارت بالا) باشد، نمونه باید از عمق $\frac{1}{4}T$ قطعه برداشته شود. T برابر است بیشترین ضخامت قطعه ی حرارت داده شده و فورج شده.

یک تست کشش و یک تست سختی نیز بر اساس استاندارد A370 باید از قطعه گرفته شود.

❖ تعمیر و ترمیم

تعمیر و ترمیم این متریال به وسیله ی جوشکاری طبق Section IX of the ASME : Boiler and Pressure Vessel Code صورت می گیرد. این فرآیند باید به گونه ای انجام شود که میزان هیدروژن در نواحی جوشکاری شده زیاد نباشد. تاثیرات جانبی جوشکاری نیز به وسیله ی سمباده زدن (یا تراشکاری) برطرف می شود. شایان ذکر است که سطح جوشکاری شده نباید بیشتر از ٪۱۰ کل سطح را در بر بگیرد.

استاندارد ASTM – A106

Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service

این استاندارد معرف متریالی است که با آن می توان لوله هایی یکپارچه از فولاد کربنی ساخت که در دمای بالا کاربرد دارند. لوله های مورد نظر دارای NPS $\frac{1}{8}$ تا 8 می باشند و مناسب برای کاربردهای فلنجینگ، خمش و سایر شکل دهی های مشابه می باشند. این متریال در سه گرید A، B و C ارائه می شود.

❖ کاربرد در اجزای پمپ

از گرید B متریال A106 در ساخت لوله های فولاد کربنی مورد نیاز در اجزای پمپ یا قسمت های پایپینگ استفاده می شود.

❖ ترکیب شیمیایی

عناصر سازنده و میزان سهم آن ها در گرید *B* در جدول ۱-۴ آورده شده است.

جدول ۱-۴

عنصر	Grade B
کربن	0.3 (max)
منگنز	0.29 – 1.06
فسفر	0.035 (max)
گوگرد	0.035 (max)
سیلیکون	0.1 (min)
مس	0.4 (max)
نیکل	0.4 (max)
کروم	0.4 (max)
مولیبدن	0.15 (max)
وانادیوم	0.08 (max)

* مجموع کروم و نیکل و مس و مولیبدن و وانادیم نباید بیشتر از ۱٪ باشد.

❖ خواص مکانیکی

خواص مکانیکی گرید *B* در جدول ۲-۴ آورده شده است. شایان ذکر است که در متن استاندارد اشاره ای به میزان سختی متریال نشده است.

جدول ۲-۴

استحکام کششی (Mpa)	۴۱۵	
استحکام تسلیم (MPa)	۲۴۰	
ازدیاد طول (٪)	طولی	عرضی
	❈	۱

❈ از رابطه ی زیر به دست می آید:

$$e = 1940 \frac{A^{0.2}}{U^{0.9}}$$

که در آن:

e ازدیاد طول (*mm*)

A مساحت سطح مقطع نمونه (mm^2)

U استحکام کششی (*MPa*)

❖ تست نمونه

طبق استاندارد A106 برای سنجش متریال باید یک تست خمش روی آن انجام شود که با توجه به شرایط به صورت زیر است:

I. برای لوله هایی با NPS ۲ و زیر آن اندازه ی مطلوب لوله باید به گونه ای باشد که هنگام سرد بودن به اندازه ی۹۰ درجه حول یک مندرل[۳] (فشنگی) استوانه ای که قطر خارجی آن ۱۲ برابر قطر لوله است، بدون اینکه ترک بخورد پیچانده شود. به جز برای مصارف پیچشی که باید ۱۸۰ درجه حول مندرلی با قطر خارجی ۸ برابر لوله پیچانده شود.

II. برای لوله هایی با قطری بیشتر از ۲۵ اینچ (معادل ۶۳۵ میلیمتر) و نسبت قطر خارجی به ضخامت ۷ یا کمتر، لوله باید در دمای اتاق ۱۸۰ درجه حول استوانه ای به قطر ۱ میلیمتر پیچانده شود بدون اینکه ترک بخورد.

یک تست کشش نیز روی قطعه انجام می شود که شرایط زیر بر آن حکمفرما است:

---

[3] mandrel

I. برای NPS ۸ یا بزرگتر از آن، نمونه می تواند چه به صورت عرضی و چه به صورت طولی بردشته شود.

II. برای NPS کوچکتر از ۸ نمونه برداری تنها به صورت طولی قابل قبول است.

III. برای لوله هایی با ضخامت کمتر از ۱ اینچ، نمونه باید از ناحیه ی میانی قطر داخلی و خارجی برداشته شود.

❖ **برخی ملاحظات**

۱- جرم : جرم هیچ لوله ای نباید از ٪۱۰ بیشتر و ٪۳/۵ کمتر از مقادیر تعریف شده برای NPS مورد نظر تجاوز کند.

۲- قطر : به جز لوله هایی با ضخامت خیلی کم بقیه از تلورانس های زیر تبعیت می کنند:

I. برای تعیین قطر به جدول ۲-۴ مراجعه شود.

II. برای لوله هایی با NPS بالای ۱۰ اینچ (۲۵۰ میلیمتر) قطر خارجی و قطر داخلی نباید بیش از ٪۱ از مقادیر تعیین شده تلورانس داشته باشد.

۳- ضخامت : نباید بیش از ٪۱۲/۵ کمتر از ضخامت های تعیین شده باشد.

❖ **تعمیر و ترمیم**

تعمیر و ترمیم این متریال توسط جوشکاری انجام می شود که باید طبق استاندارد A530 انجام شود.

جدول ۲-۴

	میزان تغییرات مجاز قطر خارجی			
NPS	بیشتر		کمتر	
	in	mm	in	mm
$\frac{1}{8}$ to $1\frac{1}{2}$	0.015	0.4	0.015	0.4
$1\frac{1}{2}$ to 4	0.031	0.8	0.031	0.8
4 to 8	0.062	1.6	0.031	0.8
8 to 18	0.093	2.4	0.031	0.8
18 to 28	0.125	3.2	0.031	0.8
26 to 34	0.156	4	0.031	0.8
34 to 48	0.187	4.8	0.031	0.8

ASTM – A182 استاندارد

Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service

این استاندارد معرف فولاد ضد زنگ نورد شده و فورج شده ای است که برای ساختن فلنج ها، شیرها و سایر قطعاتی که در دمای بالا کار می کنند، مناسب است. این قطعات مستقیما از شمش تولید می شوند. اگر جرم قطعه بیشتر از ۱۰۰۰۰ پوند (معادل ۴۵۴۰ کیلوگرم) باشد دیگر نمی توان از این استاندارد استفاده کرد و باید به استانداردهای A965 و A336 مراجعه کرد. این متریال در گرید های متعدد و مختلفی موجود است.

❖ کاربرد در اجزای پمپ

دو گرید از این متریال در پمپ و در ساختن فیتینگ به کار می رود. گرید F316L در ساختن فیتینگ های فولادی ضد زنگ سخت شده و گرید F51 در ساختن فیتینگ فولاد ضد زنگ دوبلکس به کار می رود.

❖ ترکیب شیمیایی

در جدول ۱-۵ ترکیب شیمیایی دو گرید کاربردی از این متریال نشان داده شده است.

❖ خواص مکانیکی

خواص مکانیکی دو گرید کاربردی این متریال درپمپ، در جدول ۲-۵ آورده شده است. شایان ذکر است که در متن استاندارد هیچ اشاره ای به میزان سختی این متریال نشده است.

جدول ۱-۵

F51	F316L	
0.03 (max)	0.03 (max)	**کربن** (٪)
2 (max)	2 (max)	**منگنز** (٪)
0.03 (max)	0.045 (max)	**فسفر** (٪)
0.02 (max)	0.03 (max)	**گوگرد** (٪)
1 (max)	1 (max)	**سیلیکون** (٪)
4.5 – 6.5	10 – 15	**نیکل** (٪)
21 – 23	16 – 18	**کروم** (٪)
2.5 – 3.5	2 – 3	**مولیبدن** (٪)
0.08 – 0.2	0.1 (max)	**نیتروژن** (٪)

جدول ۲ -۵

	F316L	F51
استحکام کششی (MPa)	۴۸۵	۶۲۰
استحکام تسلیم (MPa)	۱۷۰[۱]	۴۵۰
ازدیاد طول (٪)	۳۰	۲۵
کاهش مساحت (٪)	۵۰	۴۵

۱ برای سطح مقاطعی با ضخامت بیشتر از ۱۳۰ میلیمتر، تنش تسلیم ۴۵۰ مگاپاسکال است.

❖ تست نمونه

برای هر گرید بسته به نوع فولاد آن تست کششی تعبیه شده است که برای دو گرید کاربردی مذکور به شرح زیر است. برای این گریدها باید یک تست کشش و دو تست سختی سنجی انجام شود. نمونه باید به صورت آهنگری برداشته شود. اگر قطعه نیاز به جوش داشته باشد، نمونه بعد از جوشکاری برداشته می شود.

❖ تعمیر و ترمیم

ترمیم و تعمیر این متریال توسط جوشکاری طبق ASME Section IX (Boiler and pressure vessel) صورت می گیرد. اطلاعات تکمیلی در جدول ۳-۵ آورده شده است.

جدول ۳-۵

محدوده دمای مجاز بعد از جوشکاری (°C)	محدوده دمای توصیه شده برای پیش گرمایش	الکترود	گرید
کوئنچ با آب + 1040	نیاز نیست	• E316L-15 • E316L-16	**F316L**
نیاز نیست	نیاز نیست	22%Cr, 5.5%Ni, 3%Mo	**F51**

استاندارد ASTM- A193

Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications

این استاندارد معرف فولاد ضد زنگی است که در ساختن پیچ و مهره کاربرد دارد. پیچ و مهره های ساخته شده از این متریال توانایی کارکرد در دما و فشار بالا را دارند. این متریال شامل گریدهای مختلفی از فولاد فریتی و آستنیتی می شود که با حرف انگلیسیB آغاز می شود و بعد از آن یک عدد (گاهی همراه با یک حرف انگلیسی دیگر) آورده می شود.

❖ کاربرد در اجزای پمپ

دو گرید از این متریال در پمپ برای ساختن پیچ و استاد های آن کاربرد دارد. از گرید B7 در ساختن پیچ و استادهای فولاد کربنی و آلیاژی و از گرید B8M در ساخت انواع پیچ ها و استادهای فولاد ضد زنگ آستنیتی استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی دو گرید نامبرده در جدول ۱-۶ آورده شده است.

جدول ۱-۶

عنصر	B7	B8M
کربن (٪)	0.37 – 0.49	0.08 (max)
منگنز(٪)	0.65 – 1.1	2 (max)
فسفر(٪)	0.035 (max)	0.045 (max)
گوگرد(٪)	0.04 (max)	0.03 (max)
سیلیکون(٪)	0.15 – 0.35	1 (max)
کروم (٪)	0.75 – 1.1	16 - 18
نیکل(٪)	-	10 - 14
مولیبدن(٪)	0.15 – 0.25	2-3

❖ خواص مکانیکی

در جدول ۲- ۶ خواص مکانیکی دو گرید مذکور نشان داده شده است.

❖ تست نمونه

برای سنجش کیفیت محصول باید به استاندارد A962 رجوع کرد. همچنین باید روی نمونه هایی که از محصول برداشته می شود تست کشش صورت گیرد. اگر جرم محصول کمتر از ۲۰۰۰۰ پوند باشد، حداکثر دو تست کشش روی آن صورت می گیرد. هر ۱۰۰۰۰ پوند که بر جرم آن اضافه شود، یک تست کشش به تست های لازم اضافه می شود.

جدول ۲-۶

گرید	استحکام کششی (ksi)	استحکام تسلیم (ksi)	ازدیاد طول(%)	کاهش سطح مقطع (%)	سختی (HB) max
B7					
قطر کمتر از $2\frac{1}{2}$ اینچ	125	105	16	50	321
قطر بین $2\frac{1}{2}$ و 4 اینچ	115	95	16	50	321
قطر بین 4 و 7 اینچ	100	75	18	50	321
B8M					
قطر کمتر از $\frac{3}{4}$ اینچ	110	95	15	45	321
قطر بین $\frac{3}{4}$ و 1 اینچ	100	80	20	45	321
قطر بین 1 و $1\frac{1}{4}$ اینچ	95	65	25	45	321
قطر بین $1\frac{1}{4}$ و $1\frac{1}{2}$ اینچ	90	50	30	45	321

❖ تعمیر و ترمیم

برای ترمیم و تعمیر این متریال از جوشکاری استفاده می شود. برای تعیین ملزومات جوشکاری به وسیله ی رابطه ی زیر استحکام کششی گرده ی جوش به دست می آید:

$$Ts = UTS \times As$$

که در آن:

Ts : استحکام کششی گرده ی جوش

UTS : استحکام کششی مخصوص

As : مساحت تنش که از رابطه ی زیر تعیین می شود:

$$As = 0.785\left(D - \left(\frac{0.974}{n}\right)\right)^2$$

که در آن:

D : اندازه نامی رزوه

n : تعداد رزوه در هر اینچ

استاندارد ASTM – A194

Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

این استاندارد به معرفی نوعی از فولاد کربنی و آلیاژی می پردازد که برای مهره سازی کاربرد دارد. متریال معرفی شده توانایی کارکرد در دما و فشار بالایی را داراست. از این متریال برای ساخت مهره های مارتنزیتی $\frac{1}{4}$ تا 4 اینچی(یعنی M6 تا M100) و مهره های آستنیتی $\frac{1}{4}$اینچی (یعنی M6) استفاده می شود.

❖ کاربرد در اجزای پمپ

دو گرید از این متریال در پمپ برای ساختن مهره های به کار رفته در اجزای آن کاربرد دارد. از گرید 2H در ساختن مهره های فولاد کربنی و آلیاژی و از گرید 8M در ساخت انواع مهره های فولاد ضد زنگ آستنیتی استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی دو گرید از این متریال که در پمپ کاربرد دارند در جدول ۱-۷ نشان داده شده است.

جدول ۱-۷

گرید	کربن	منگنز	فسفر	گوگرد	سیلیکون	کروم	نیکل	مولیبدن
2H	0.4 (min)	1(max)	0.04(max)	0.05(max)	0.4(max)	-	-	-
8M	0.08(max)	2(max)	0.045(max)	0.03(max)	1(max)	16-18	10-14	2-3

❖ خواص مکانیکی

در جدول ۲-۷ سختی دو گرید از این متریال نشان داده شده است. شایان ذکر است که در متن استاندارد اشاره ای به استحکام کششی و تسلیم متریال نشده است.

جدول ۲-۷

گرید		**سختی برینل**
2H	**تا M36**	248 – 327
	بزرگتر از M36	212 – 327
8M		126 – 300

❖ تست نمونه

برای آنالیز سختی محصولات بسته به گرید متریال روی آنها تست های سختی انجام می شود. برای متریال با گرید 2H، با توجه به جدول ۳-۷ تعداد نمونه های برداشته شده از محصول مشخص می شود.

جدول ۳- ۷

تعداد نمونه	تعداد محصول
۱	تا ۸۰۰
۲	۸۰۱ تا ۸۰۰۰
۳	۸۰۰۱ تا ۲۲۰۰۰
۵	بیشتر از ۲۲۰۰۰

بار آزمایشی مربوط به تست های سختی سنجی دو گرید در جدول ۴-۷ نشان داده شده است.

جدول ۴-۷

	2H		8M	
سایز نامی	Hex (KN)	Heavy Hex (KN)	Hex (KN)	Heavy Hex (KN)
M6	20.8	29.2	10.4	11.1
M8	37.9	44.1	18.8	20.1
M10	60.0	69.9	29.9	31.9
M12	87.3	101.6	43.4	46.4
M14	119.0	138.6	59.2	63.3
M16	162.5	189.2	80.9	86.4
M20	253.6	295.2	126.2	134.8
M22	313.6	365.1	156.0	166.7
M24	365.4	425.4	181.8	194.2
M27	475.1	553.4	236.4	252.5
M30	580.6	676.0	288.9	308.6
M36	845.6	984.5	420.8	449.4
M42	-	1349.6	-	-
M48	-	1771.4	-	-
M56	-	2446.2	-	-
M64	-	3229.2	-	-
M72	-	4169.3	-	-

❖ **تعمیر و ترمیم**

در متن استاندارد اشاره ای به نحوه ترمیم یا تعمیر متریال نشده است.

استاندارد ASTM – A216

SPECIFICATION FOR STEEL CASTINGS, CARBON SUITABLE FOR FUSION WELDING FOR HIGH-TEMPERATURE SERVICE

این استاندارد معرف فولاد کربنی ریخته گری شده ای است که مناسب برای کاربردهای دما بالا و جوشکاری ذوبی می باشد. به عبارت دیگر در ساخت فیتینگ ها، فلنج ها، شیرها و دیگر ادوات ضامن فشار که در دمای بالایی کار می کنند از A216 استفاده می شود. این متریال دارای سه گرید WCA، WCB و WCC می باشد.

❖ کاربرد در پمپ

گرید WCB از متریال مذکور در ساخت قطعات ریخته گری شده ی تحت فشار پمپ کاربرد دارد.

❖ ترکیب شیمیایی

ترکیب شیمیایی گرید WCB که پرکاربردترین گرید این متریال در صنعت پمپ است، در جدول ۱۲-۸ نشان داده شده است.

جدول ۱ - ۸

ماکزیمم درصد	عنصر
0.3	کربن
1	منگنز*
0.04	فسفر
0.045	گوگرد
0.6	سیلیکون
0.3	مس
0.5	نیکل
0.5	کروم
0.2	مولیبدن
0.03	وانادیوم

* به ازای کاهش هر ۰/۰۱ درصد از کربن ماکزیمم، مقدار منگنز می تواند ۰/۰۴ تا ۱/۱ درصد از ماکزیمم مقدار تعیین شده بیشتر باشد.

❖ خواص مکانیکی

خواص مکانیکی گرید WCB در جدول ۲-۸ آورده شده است. شایان ذکر است که در متن استاندارد اشاره ای به سختی قطعه نشده است.

جدول ۲-۸

خصوصیت مکانیکی	WCB
استحکام کششی (ksi)	70-95
استحکام تسلیم (ksi)	36
ازدیاد طول (٪)	22
کاهش سطح مقطع (٪)	35

❖ تست نمونه

در متن استاندارد اشاره ای به الزامات تست نمونه نشده است.

❖ تعمیر و ترمیم

تعمیر و ترمیم این متریال طبق ASME Section IX انجام می شود. برای بازرسی جوش دو حالت در نظر گرفته می شود. حالت اول بازرسی مغناطیسی است که بازرسی معمول جوش هر فولاد ریختگری است. حالت دوم بازرسی با امواج رادیوگرافی است. از این حالت در مواقعی استفاده می شود که قطعه در تست ریختگی داشته باشد یا حفره ای در سطح قطعه وجود داشته باشد که ضحامت آن بیشتر از ٪۲۰ ضخامت قطعه یا ۱ اینچ یا با مساحت بیشتر از ۱۰ اینچ مربع باشد. در حالت دوم بعد از بازرسی و ترمیم باید روی قطعه عملیات حرارتی متناسب با آن صورت گیرد یا تحت تنش زدایی قرار گیرد.

❖ برخی ملاحظات

برای این متریال کربن معادل طبق رابطه ی زیر تعریف می شود:

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

ماکزیمم مقدار کربن معادل برای گرید WCB برابر است با ۰/۰۵.

استاندارد ASTM- A240

Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

این استاندارد به معرفی نوعی از فولاد ضد زنگ کرومی و نیکل- کرومی می پردازد که برای ساخت صفحه و ورق و نوار های تحت فشار مناسب است. این متریال در گریدهای زیادی ارائه شده است.

❖ کاربرد در پمپ

از میان گرید های متنوع این متریال تنها گرید 316L آن در صنعت پمپ سازی و در ساخت صفحه های آستنیتی ضد زنگ کاربرد دارد.

❖ ترکیب شیمیایی

ترکیب شیمیایی گرید 316L از این متریال در جدول ۱-۹ آورده شده است.

جدول ۱-۹

نیتروژن	مولیبدن	نیکل	کروم	سیلیکون	گوگرد	فسفر	منگنز	کربن	گرید
0.1 (max)	2 – 3	10 – 14	16 – 18	0.75 (max)	0.03 (max)	0.045 (max)	2 (max)	0.03 (max)	316L

❖ خواص مکانیکی

خواص مکانیکی گرید مورد نظر در جدول ۲ – ۹ آورده شده است.

جدول ۲ – ۹

مقدار	خواص مکانیکی
۴۸۵	استحکام کششی (Mpa)
۱۷۰	استحکام تسلیم (Mpa)
۴۰	ازدیاد طول (٪)
۲۱۷	سختی (برینل)

❖ تست نمونه

یک تست ضربه طبق استاندارد A370 بر روی سه نمونه ی برداشته شده از روی یک صفحه انجام می شود. نمونه ها در هنگام تست باید به صورت طولی قرار گیرند. یعنی محور طولانی تر نمونه موازی با محور صفحه نورد قرار گیرد و شکاف عمود بر آن باشد. هر کدام از سه نمونه نباید انبساط جانبی کمتر از ۰/۰۱۵ اینچ داشته باشند.

❖ تعمیر و ترمیم

در متن استاندارد اشاره ای به نحوه ی تعمیر یا ترمیم قطعه نشده است.

استاندارد ASTM- A276

Standard Specification for Stainless Steel Bars and Shapes

این استاندارد به معرفی شمش ها و قالب هایی از جنس فولاد های ضد زنگ می پردازد. شمش هایی که از جنس فولاد ضد زنگ بوده ولی دوباره آهنگری شده باشند جزو این استاندارد محسوب نمی شود.

❖ کاربرد در پمپ

سه گرید از این متریال در صنعت پمپ سازی کاربرد دارند. دو گرید با نام های 420 و 316L شناخته شده و دیگری به نام UNS خود یعنی S31803 معروف است. هر سه گرید در ساختن شفت پمپ مورد استفاده قرار می گیرند با این تفاوت که 420 برای ساخت شفت ٪۱۲ کروم، 316L برای ساختن شفت های آستنیتی ضدزنگ و S31803 برای ساختن شفت ها، پیچ، استاد و مهره های ضد زنگ دوبلکس مورد استفاده قرار می گیرد.

❖ ترکیب شیمیایی

ترکیب شیمیایی سه گرید از این متریال در جدول ۱-۱۰ آورده شده است.

❖ خواص مکانیکی

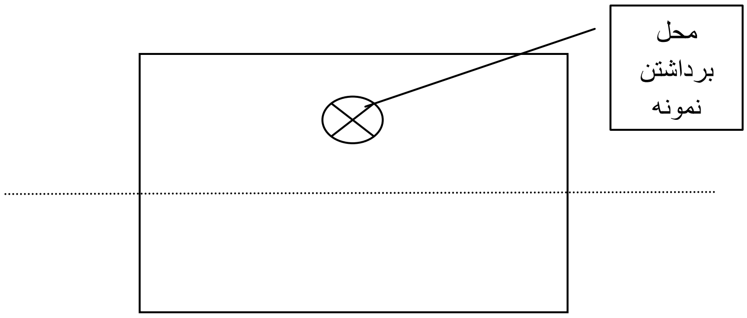
خواص مکانیکی سه گرید مزبور در جدول ۲-۱۰ آورده شده است. شایان ذکر است، خانه هایی که با علامت – نشان داده شده اند فاقد اطلاعات در متن استاندارد بوده اند.

جدول ۱- ۱۰

عنصر	420	316L	S31803
کربن (٪)	0.15 (min)	0.03 (max)	0.03 (max)
منگنز (٪)	1 (max)	2 (max)	2 (max)
فسفر (٪)	0.04 (max)	0.045 (max)	0.03 (max)
گوگرد (٪)	0.03 (max)	0.03 (max)	0.02 (max)
سیلیکون (٪)	1 (max)	1 (max)	1 (max)
کروم (٪)	12 – 14	16 - 18	21 - 23
نیکل (٪)	-	10 – 14	4.5 - 6.5
مولیبدن (٪)	-	2 -3	2.5 – 3.5
نیتروژن (٪)	-	-	0.08 – 0.2

❖ تست نمونه

برای آنالیز ترکیب شیمیایی قطعه از استاندارد A751 استفاده می شود. همچنین در صورت نیاز (اختیاری) تست سختی نیز روی قطعه انجام می شود. به همین منظور باید از قطعه نمونه ای برداشته شود. نمونه از نقطه ی میانی وسط سطح مقطع و سطح خارجی مطابق شکل ۱-۱۰ برداشته می شود.



شکل ۱-۱۰

جدول ۲- ۱۰

گرید	Finish	شرایط	قطر (in)	استحکام کششی (ksi)	استحکام تسلیم (ksi)	ازدیاد طول در ۲ اینچ (٪)	سختی برینل
420	hot finished	A	هر قطری	--	--	--	241
	cold finished		هر قطری	--	--	--	255
316L	hot finished	A	هر قطری	70	25	40	--
	cold finished		کمتر از $\frac{1}{2}$ اینچ	90	45	30	--
			بیشتر از $\frac{1}{2}$ اینچ	70	25	30	--
	cold finished	B	کمتر از $\frac{3}{4}$ اینچ	125	100	12	--
			بین $\frac{3}{4}$ و 1 اینچ	115	80	15	--
			بین 1 و $1\frac{1}{4}$ اینچ	105	65	20	--
			بین $1\frac{1}{4}$ و $1\frac{1}{2}$ اینچ	100	50	24	--
			بین $1\frac{1}{2}$ و $1\frac{3}{4}$ اینچ	95	45	28	--
	cold finished	S	تا 2 اینچ	95	75	25	--
			از 2 تا $2\frac{1}{2}$ اینچ	90	65	30	--
			از $2\frac{1}{2}$ تا 3 اینچ	80	55	30	--

استاندارد ASTM – A278

SPECIFICATION FOR GRAY IRON CASTINGS FORPRESSURE-CONTAINING PARTS FOR TEMPERATURES UP TO 650°F (350°C)

این استاندارد معرف چدن خاکستری ریخته گری شده برای ادوات ضامن فشاری است که در دمایی فراتر از ۳۵۰ درجه ی سانتیگراد کار می کنند. این متریال شامل کلاس های متفاوتی است که بر اساس استحکام کششی طبقه بندی می شوند. مثلا کلاس ۵۰ بیانگر متریالی از این استاندارد است که استحکام کششی آن ksi ۵۰ می باشد.

به منظور ریخته گری تا دمای ۲۳۰ درجه ی سانتیگراد می توان از تمام کلاس ها استفاده کرد. برای ریخته گری در دماهای بالای ۲۳۰ درجه باید از کلاس های ۴۰، ۴۵، ۵۰ ، ۵۵ و ۶۰ استفاده نمود.

❖ کاربرد در پمپ

از کلاس ۳۰ این متریال در صنعت پمپ سازی جهت ساخت اجزای چدن خاکستری ریخته گری شده که در فشار بالا کار می کنند، استفاده می شود.

❖ ترکیب شیمیایی

در رابطه با ترکیب شیمیایی کلاس های مختلف این متریال، در متن استاندارد مطلبی ذکر نشده است. تنها بحثی اجمالی پیرامون کربن معادل ارائه شده که در بخش «برخی ملاحظات» آورده شده است.

❖ خواص مکانیکی

در جدول ۱- ۱۱ استحکام کششی هر کلاس به صورت متداول و در جدول ۲ - ۱۱ استحکام کششی هر کلاس در SI از این متریال آورده شده است. در متن استاندارد اشاره ای به استحکام تسلیم، ازدیاد طول و یا سختی نشده است.

جدول ۱- ۱۱

استحکام تسلیم (ksi)	کلاس
20	No. 20
25	No. 25
30	No. 30
35	No. 35
40	No. 40
45	No. 45
50	No. 50
55	No. 55
60	No. 60

جدول ۲-۱۱

کلاس	استحکام تسلیم (MPa)
No. 150	150
No. 175	175
No. 200	200
No. 225	225
No. 250	250
No. 275	275
No. 300	300
No. 325	325
No. 350	350
No. 380	380
No. 415	415

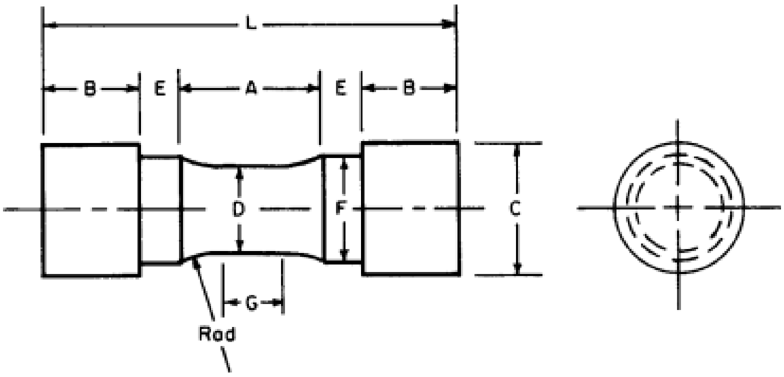
❖ تست نمونه

برای سنجش خواص مکانیکی قطعه باید یک تست کشش روی آن انجام پذیرد. اگر نتایج به دست آمده از تست بنا به هر دلیلی غیرقابل قبول باشد، باید دو تست کششی دیگر روی قطعه انجام شود. در جدول ۳-۱۱ و ۴-۱۱ انواع نمونه ها و ابعاد آنها آورده شده است.

جدول ۳ - ۱۱

طول (اینچ)		قطر (اینچ)			
ماکزیمم	مینیمم	ماکزیمم	مینیمم	نامی	شمش نمونه
6	5	0.96	0.85	0.88	A
9	6	1.32	1.14	1.2	B
10	7	2.1	1.9	2	C
*	*	*	*	*	S

* توافقی بین خریدار و فروشنده



شکل ۱-۱۱

جدول ۴ - ۱۱

دیمانسیون (inch)	A	B	C
G (min)	0.5	0.75	1.25
D	0.5 ± 0.01	0.75 ± 0.015	1.25 ± 0.025
R (min)	1	1	2
A (min)	$\frac{5}{4}$	$\frac{3}{2}$	$\frac{9}{4}$
L (min)	$\frac{15}{4}$	4	$\frac{51}{8}$
C	$\frac{7}{8}$	$\frac{5}{4}$	$\frac{15}{8}$
E (min)	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$
F	$\frac{5}{8}\pm\frac{1}{64}$	$\frac{15}{16}\pm\frac{1}{64}$	$\frac{23}{16}\pm\frac{1}{64}$
B	اختیاری	اختیاری	اختیاری

برای اینکه نوع نمونه را انتخاب کنیم از جدول ۵- ۱۱ استفاده می شود.

جدول ۵-۱۱

ضخامت دیواره ی بخش کنترل شده ی ریخته گری (in)	نوع نمونه
$t \leq 25$	S
$0.25 < t \leq 0.5$	A
$0.5 < t \leq 1$	B
$1 < t \leq 2$	C
$t > 2$	S

❖ **تعمیر و ترمیم**

در متن استاندارد اشاره ای بر الزامات تعمیر و ترمیم نشده است.

❖ **برخی ملاحظات**

کربن معادل برای این متریال از رابطه ی زیر محاسبه می شود:

$$CE = C + 0.3(SI + P)$$

برای کلاس های ۴۰، ۴۵، ۵۰، ۵۵ و ۶۰ حداکثر کربن معادل ٪۳/۸ است. همچنین میزان فسفر از ٪۰/۲۵ و میزان گوگرد از ٪۰/۱۲ نباید تجاوز کند.

استاندارد ASTM- A312

Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

این استاندارد معرف فولاد ضد زنگ آستنیتی ای است که برای ساختن لوله های یکپارچه، جوش کاری شده و کار سرد شده مناسب است. برخی از کلاس های این متریال برای کارکرد در دماهای بالا و کاربردهایی که خزش در آن حائز اهمیت است مناسب است.

❖ کاربرد در پمپ

لوله های آستنیتی ضد زنگی که در تجهیزات جانبی پمپ ها استفاده می شوند، از گرید TP316L متریال A312 می باشد.

❖ ترکیب شیمیایی

ترکیب شیمیایی گرید مورد نظر در جدول ۱-۱۲ آورده شده است.

جدول ۱-۱۲

مولیبدن (٪)	نیکل (٪)	کروم (٪)	سیلیکون (٪)	گوگرد (٪)	فسفر (٪)	منگنز (٪)	کربن (٪)	گرید
2 - 3	10 - 14	16 - 18	1 (max)	0.03 (max)	0.045 (max)	2 (max)	❋0.035 (max)	TP316L

❋ برای لوله هایی با ضخامت دیواره یا قطر کوچک ماکزیمم مقدار درصد کربن به 0.04% افزایش می یابد. منظور از لوله های مذکور، لوله هایی است با قطر خارجی کمتر از 12.7 میلیمتر و ضخامت کمتر از 1.1 میلیمتر.

❖ خواص مکانیکی

در جدول ۲- ۱۲ استحکام کششی و تسلیم گرید مورد نظر آورده شده است. شایان ذکر است که در متن اشاره ای به سختی نشده است.

جدول ۲-۱۲

مقدار	
۷۰	**استحکام کششی (ksi)**
۲۵	**استحکام تسلیم (ksi)**
۲۵	**ازدیاد طول در ۵۰ میلیمتر عرضی (٪)**
۳۵	**ازدیاد طول در ۵۰ میلیمتر طولی (٪)**

❖ تست نمونه

برای سنجش قطعه باید طبق استاندارد A999 روی آن تست هیدرو استاتیک و تست الکتریکی انجام شود. همچنین تست کشش به صورت طولی یا عرضی نیز لازم است. اگر تعداد لوله ها از ۱۰۰ عدد کمتر باشد ۱ تست کشش کافی است. در غیر این صورت ۲ تست کشش روی قطعه انجام می شود. یک گونه ی دیگر از تست ها موجود است که به صورت توزیعی نمونه را انتخاب می کند. یعنی ۵٪ لوله ها باید مورد تست قرار گیرد.

❖ تعمیر و ترمیم

برای لوله هایی با قطرهایی بزرگتر یا مساوی NPS ۶ که ضخامت نامی دیواره شان بزرگتر یا برابر با ۰/۲ است، جوشکاری مطابق با استاندارد A999 انجام می شود. گرید TP316L با الکترود ER316L جوشکاری شود.

استاندارد ASTM – A351

Standard Specification for Castings, Austenitic, for Pressure-Containing Parts

این استاندارد معرف فولاد آستنیتی ریخته گری شده ای است که برای ساخت قطعات ضامن فشار مورد استفاده قرار می گیرد. مقصود از قطعات ضامن فشار، قطعاتی مانند شیر، فلنج، فیتینگ و ... می باشد. این متریال در گرید های مختلفی موجود است.

❖ کاربرد در پمپ

از گریدهای CF3، CF3M، CF8 و CF8M این متریال در ساخت قطعات ریختگری شده ی آستنیتی ضدزنگ استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی گریدهای مذکور در جدول ۱-۱۳ آورده شده است.

جدول ۱- ۱۳

گرید	کربن (٪)	منگنز (٪)	فسفر (٪)	گوگرد (٪)	سیلیکون (٪)	کروم (٪)	نیکل (٪)	مولیبدن (٪)
CF3	0.03 (max)	1.5 (max)	2 (max)	0.04 (max)	0.04 (max)	17-21	8-12	0.5 (max)
CF3M	0.03 (max)	1.5 (max)	1.5 (max)	0.04 (max)	0.04 (max)	17-21	9-13	2-3
CF8	0.08 (max)	1.5 (max)	2 (max)	0.04 (max)	0.04 (max)	18-21	8-11	0.5 (max)
CF8M	0.08 (max)	1.5 (max)	1.5 (max)	0.04 (max)	0.04 (max)	18-21	9-12	2-3

❖ خواص مکانیکی

خواص مکانیکی گریدهای مورد نظر در جدول ۲-۱۳ ارائه شده است. شایان ذکر است که در متن استاندارد اشاره ای به سختی متریال نشده است.

جدول ۲-۱۳

	CF3	CF3M	CF8	CF8M
استحکام کششی (ksi)	۷۰	۷۰	۷۰	۷۰
استحکام تسلیم (ksi)	۳۰	۳۰	۳۰	۳۰
ازدیاد طول در ۲ اینچ (٪)	۳۰	۳۵	۳۰	۳۵

- **تست نمونه**

در متن استاندارد اشاره ای به نوع تست نمونه نشده است.

- **تعمیر و ترمیم**

تعمیر و ترمیم این متریال توسط جوشکاری طبق استاندارد A488 انجام می پذیرد. برای بازرسی جوش دو حالت در نظر گرفته می شود. حالت اول بازرسی با امواج رادیوگرافی است. از این حالت در مواقعی استفاده می شود که قطعه در تست هیدرواستاتیک نشتی داشته باشد یا حفره ای در سطح قطعه وجود داشته باشد که ضخامت آن بیشتر از ٪۲۰ ضخامت قطعه یا ۱ اینچ یا با مساحت بیشتر از ۱۰ اینچ مربع باشد. حالت دوم بازرسی نفوذ مایع است که به صورت متداول آن انجام می پذیرد.

استاندارد ASTM – A487

SPECIFICATION FOR STEEL CASTINGS SUITABLE FOR PRESSURE SERVICE

این استاندارد معرف فولاد ریخته گری شده ای است که در ساخت ادوات کاربردی در فشار بالا مورد استفاده قرار می گیرند. این متریال در گریدهایی مختلف و هر کدام در سه کلاس تعریف شده است. برخی گریدها تنها با یک عدد (مثلا گرید ۴) و برخی با ترکیبی از حروف و عدد (مثلا گریدCA15M) نشان داده می شوند. کلاس های این متریال نیز با سه حرف A، B و C مشخص می شود. برای معرفی دقیق متریال A487 باید آن را با گرید و کلاس مورد نظر مشخص کرد. (مثلا گرید ۶ کلاس B)

❖ کاربرد در پمپ

گرید CA6NM در دو کلاس A و B در ساخت قطعات تحت فشار ریخته گری شده از جنس فولاد کروم دار مورد استفاده قرار می گیرد.

❖ ترکیب شیمیایی

ترکیب شمیایی گرید مذکور در دو کلاس موجود یکسان است. تنها تفاوت این دو در عملیات حرارتی صورت گرفته روی آنهاست. در جدول ۱-۱۴ ترکیب شیمیایی این دو نشان داده شده است.

جدول ۱-۱۴

عنصر	درصد
کربن	0.06 (max)
منگنز	1 (max)
فسفر	0.04 (max)
گوگرد	0.03 (max)
سیلیکون	1 (max)
نیکل	3.5 – 4.5
کروم	11.5 – 14
مولیبدن	0.4 – 1
مس	0.5 (max)
تنگستن	0.1 (max)
ونادیوم	0.05 (max)

❖ خواص مکانیکی

به دلیل متفاوت بودن عملیات حرارتی انجام شده روی دو کلاس، تفاوت هایی در خواص مکانیکی این دو مشاهده می شود که در جدول ۲-۱۴ ارائه شده است.

جدول ۲-۱۴

سختی (HRC)	کاهش سطح (%)	ازدیاد طول (%)	استحکام تسلیم (ksi)	استحکام کششی (ksi)	کلاس	گرید
اشاره نشده است	35	15	80	110	A	**CA6MM**
23		17	75	100	B	

❖ تست نمونه

در متن استاندارد اشاره ای به نحوه ی تست نمونه نشده است.

❖ تعمیر و ترمیم

تعمیر و ترمیم این متریال توسط جوشکاری و طبق استانداردهای A488 و Boiler and Pressure Vessel ASME IX صورت می گیرد. هر قطعه ای که توسط جوشکاری ترمیم می شود، باید بعد از آن تحت عملیات حرارتی قرار گیرد. الزامات این عملیات حرارتی در جدول ۳-۱۴ نشان داده شده است. همچنین قطعاتی که حین تست هیدرواستاتیک دچار نشتی شوند باید توسط جوشکاری ترمیم شوند.

اگر حفره ای روی سطح قطعه وجود داشته باشد که عمق آن بیشتر از ٪۲۰ ضخامت قطعه و یا بیشتر از ۲۵ میلیمتر باشد و یا اگر مساحت آن بیشتر از ۶۵ سانتیمتر مربع باشد، باید به وسیله ی اصول بیان شده ی فوق ترمیم شود.

جدول ۳-۱۴

Tempering Temperature (°F)	Quenching Cool Below (°F)	Media	Austenitizing Temperature (°F)	کلاس	گرید
1050 – 1150	200	هوا یا مایع	1850	A	**CA6NM**
1225 – 1275 (میانی) 1050 – 1150 (نهایی)				B	

استاندارد ASTM- A516

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

این استاندارد معرف نوعی از فولاد کربنی است که برای ساخت صفحات فشار پر کاربرد درمصارف دمای متوسط و پایین مناسب است. این متریال در ۴ گرید موجود می باشد که نام هر گرید بیانگر استحکام کششی آن در واحد ksi است.

❖ کاربرد در پمپ

دو گرید از این متریال (گریدهای ۶۵ و ۷۰) در ساخت صفحات صفحاتی از جنس فولاد کربنی در پمپ کاربرد دارند.

❖ ترکیب شیمیایی

میزان کربن صفحات ساخته شده از متریال مذکور وابسته به ضخامت آن می باشد. اطلاعات کاملی از ترکیب شیمیایی دو گرید ۶۵ و ۷۰ در جدول ۱-۱۵ آورده شده است.

❖ خواص مکانیکی

خواص مکانیکی دو گرید مورد استفاده در جدول ۲-۱۵ آورده شده است. شایان ذکر است که در متن استاندارد اشاره ای به سختی متریال نشده است.

جدول ۱-۱۵

عنصر	ضخامت (in)	نوع آنالیز ترکیب	گرید ۶۵	گرید ۷۰
کربن	$t \leq \frac{1}{2}$	هر آنالیزی	0.24 (max)	0.27 (max)
	$\frac{1}{2} < t \leq 2$		0.26 (max)	0.28 (max)
	$2 < t \leq 4$		0.28 (max)	0.30 (max)
	$4 < t \leq 8$		0.29 (max)	0.31 (max)
	$t > 8$		0.29 (max)	0.31 (max)
منگنز	هر ضخامتی	آنالیز حرارتی	0.85 – 1.2	
		آنالیز قطعه	0.79 – 1.3	
فسفر	هر ضخامتی	هر آنالیزی	0.35 (max)	
گوگرد	هر ضخامتی	هر آنالیزی	0.35 (max)	
سیلیکون	هر ضخامتی	آنالیز حرارتی	0.15 – 0.40	
		آنالیز قطعه	0.13 -0.45	

* به ازای هر ۰/۰۱ درصد کربن کمترا ز میزان ماکزیمم ۰/۰۶ تا ۱/۵ درصد افزایش مقدار منگنز بیش از ماکزیمم تعیین شده مجاز است.

جدول ۲-۱۵

خواص مکانیکی	گرید ۶۵	گرید ۷۰
استحکام کششی (ksi)	65 – 85	70 – 90
استحکام تسلیم (ksi)	35	38
ازدیاد طول در ۲ اینچ (%)	23	21
ازدیاد طول در ۸ اینچ (%)	19	17

❖ **تست نمونه**

در متن استاندارد اشاره ای به نحوه تست نمونه نشده است.

❖ **تعمیر و ترمیم**

در متن استاندارد اشاره ای به نحوه تعمیر و ترمیم قطعه نشده است.

❖ **برخی ملاحظات**

حداقل ضخامت صفحات ساخته شده طبق این استاندارد در جدول ۳-۱۵ خلاصه شده است.

در این استاندارد کربن معادل با رابطه ی زیر تعریف می شود:

$$CE = C + \frac{Mn}{6} + \frac{(Cr+Mo+V)}{5} + \frac{(Ni+Cu)}{15}$$

که ماکزیمم مقدار آن برای صفحات با ضخامت کمتر از ۱ اینچ ۰/۴۳ و برای صفحات با ضخامت بیشتر از ۱ اینچ ۰/۴۵ است.

جدول ۳ – ۱۵

حداقل ضخامت(in)	گرید
۸	۶۵
۸	۷۰

استاندارد ASTM – A576

Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

این استاندارد معرف فولاد کربنی و با شکل دهی شده گرم شده با کیفیت مخصوص است که در ساخت انواع شفت کاربرد دارد. برای اطلاعات بیشتر در زمینه انتخاب شفت به استاندارد A400 رجوع شود. همچنین سایز انواع شفت در استاندارد A29 آورده شده است.

❖ کاربرد در پمپ

گرید ۱۰۴۵ این متریال در ساخت شفت های فولاد کربنی مورد استفاده قرار می گیرد.

❖ ترکیب شیمیایی

ترکیب شیمیایی گرید ۱۰۴۵ در جدول ۱-۱۶ آورده شده است.

جدول ۱-۱۶

گوگرد	فسفر	منگنز	کربن	گرید
0.05 (max)	0.04 (max)	0.6 – 0.9	0.43 – 0.5	۱۰۴۵

* می توان حداقل ۰/۲ درصد مس نیز به ترکیب شیمیایی فوق افزود.

❖ خواص مکانیکی

برای اطلاع از خواص مکانیکی شفتی که با متریال A576 ساخته می شود، باید به استاندارد A400 که معرف خصوصیات کامل شفت هاست رجوع شود.

❖ تست نمونه

در متن استاندارد اشاره ای به نحوه ی تست نمونه نشده است.

❖ تعمیر و ترمیم

در متن استاندارد اشاره ای به نحوه ی تعمیر و ترمیم قطعه نشده است.

استاندارد ASTM – A743

Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

این استاندارد معرف متریالی از جنس آهن-کروم و آهن-کروم-نیکل است که در کاربردهای عمومی برای مصارف ضد خوردگی به کار می رود.

❖ کاربرد در پمپ

از گرید CA15 این متریال در ساخت قطعات عمومی ریخته گری شده ی فولاد کرومی و از گرید CF3M آن در ساخت قطعات عمومی ریخته گری شده ی فولادی ضد زنگ آستنیتی استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی دو گرید مذکور در جدول ۱-۱۷ ارائه شده است.

جدول ۱-۱۷

گرید	کربن	منگنز	سیلیکون	فسفر	گوگرد	کروم	نیکل	مولیبدن
CA15	0.15 (max)	1 (max)	1.5 (max)	0.04 (max)	0.04 (max)	11.5 - 14	1 (max)	0.05 (max)
CF3M	0.03 (max)	1.5 (max)	1.5 (max)	0.04 (max)	0.04 (max)	17-21	9-13	2-3

❖ خواص مکانیکی

خواص مکانیکی در جدول ۲-۱۷ آورده شده است. شایان ذکر است که در متن استاندارد اشاره ای به سختی متریال نشده است.

جدول ۲-۱۷

گرید	استحکام کششی (ksi)	استحکام تسلیم (ksi)	ازدیاد طول (٪)	کاهش سطح (٪)
CA15	90	65	18	30
CF3M	70	30	30	اشاره نشده است

❖ تست نمونه

در متن استاندارد اشاره ای به نحوه تست نمونه نشده است.

❖ **تعمیر و ترمیم**

تعمیر و ترمیم این متریال به وسیله ی جوشکاری و با توجه به حداقل دمای دوباره گرمکاری که در جدول ۳-۱۷ آورده شده است انجام می شود.

جدول ۳-۱۷

گرید	حداقل دمای دوباره گرمکاری (فارنهایت)
CA15	۴۰۰
CF3M	۵۰

استاندارد ASTM – A790

Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe

این استاندارد معرف فولاد ضد زنگ فریت- آستنیتی (دوبلکس) است که برای ساخت لوله های یکپارچه و یا جوشکاری شده مناسب می باشد.

❖ کاربرد در پمپ

از گرید S31803 این متریال در ساخت لوله های فولادی ضد زنگ دوبلکس استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی گرید S31803 در جدول ۱ – ۱۸ آورده شده است.

جدول ۱- ۱۸

عنصر	درصد
کربن	0.03 (max)
منگنز	2 (max)
فسفر	0.03(max)
گوگرد	0.02 (max)
سیلیکون	1 (max)
نیکل	4.5 – 6.5
کروم	21 – 23
مولیبدن	2.5 – 3.5
نیتروژن	0.08 – 0.2

❖ خواص مکانیکی

خواص مکانیکی گرید S31803 در جدول ۲ – ۱۸ آورده شده است.

جدول ۲-۱۸

گرید	استحکام کششی (ksi)	استحکام تسلیم (ksi)	ازدیاد طول (٪)	سختی (HBW)	سختی (HRC)
S31803	95	65	25	290	30

❖ تست نمونه

اگر تعداد لوله های همسان تولید شده زیر ۱۰۰ عدد باشد ۱ تست و اگر بالای ۱۰۰ عدد باشد ۲ تست کشش باید روی نمونه ها انجام شود. همچنین روی ٪۵ لوله ها باید تست تخت کردن (Flattening) انجام شود. شایان ذکر است که تعداد نمونه ها برای تست فشردگی نباید از ۲ عدد کمتر باشد. برای لوله های جوشکاری شده با NPS بیشتر از ۱۰، تست خمش جانبی کنترل شده را می توان جایگزین تست فشردگی کرد. یک تست سختی نیز باید روی دو نمونه از لوله ها انجام شود. علاوه بر تست های فوق می توان تست غیرمخرب الکتریکی را نیز طبق استاندارد A999 روی لوله انجام داد.

❖ تعمیر و ترمیم

برای لوله هایی با NPS بزرگتر یا مساوی ۶ و ضخامت دیواره ی بزرگتر از ۰/۱۱۸ اینچ می توان از جوشکاری برای تعمیر استفاده کرد. الکترود مناسب برای گرید S31803 طبق AWS ، ER2209 است.

استاندارد ASTM – A890

Standard Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion Resistant, Duplex (Austenitic/Ferritic) for General Application

این استاندارد معرف متریالی از جنس آهن- کروم- نیکل- مولیبدن است که استفاده از آن در کاربردهای عمومی معمول است و قابلیت ضد خوردگی بالایی دارد.

❖ کاربرد در پمپ

از گرید 1B این متریال در ساخت قطعات ریخته گری شده ی فولادی ضد زنگ دوبلکس که در فشار بالا کار می کنند، استفاده می شود.

❖ ترکیب شیمیایی

ترکیب شیمیایی گرید مذکور در جدول ۱-۱۹ آورده شده است.

جدول ۱ – ۱۹

عنصر	درصد
کربن	0.04 (max)
منگنز	1 (max)
سیلیکون	1 (max)
فسفر	0.04 (max)
گوگرد	0.04 (max)
کروم	24.5 – 26.5
نیکل	4.7-6
مولیبدن	1.7 – 2.3
مس	2.7 – 3.3
نیتروژن	0.1 – 0.25

❖ خواص مکانیکی

خواص مکانیکی گرید مذکور در جدول ۲-۱۹ آورده شده است. شایان ذکر است که در متن استاندارد اشاره ای به سختی قطعه نشده است.

جدول ۲-۱۹

خاصیت مکانیکی	مقدار
استحکام کششی (ksi)	۱۰۰
استحکام تسلیم (ksi)	۷۰
ازدیاد طول (٪)	۱۶

❖ تست نمونه

برای آنالیز خواص مکانیکی این متریال روی آن تست کشش انجام می شود. برای اطلاعات از نحوه ی نمونه برداری و ابعاد نمونه به استاندارد A781 مراجعه شود.

❖ تعمیر و ترمیم

تعمیر و ترمیم این متریال توسط جوشکاری صورت می گیرد. اگر سطح یا عمق جوشکاری زیاد باشد، باید پس از آن عملیات حرارتی روی آن صورت گیرد در غیر این صورت نیازی به عملیات حرارتی بعد از جوش نیست. منظور از مساحت یا عمق زیاد هنگامی است که قطعه در تست هیدرواستاتیک نشتی داشته باشد یا حفره ای در سطح قطعه وجود داشته باشد که ضخامت آن بیشتر از ٪۲۰ ضخامت قطعه یا ۱ اینچ یا با مساحت بیشتر از ۱۰ اینچ مربع باشد.

عملیات حرارتی مناسب برای گرید 1B، افزایش دمای قطعه تا ۱۹۰۰ درجه ی فارنهایت، حفظ قطعه در این دما تا زمان لازم و سپس خنک کردن (کوئنچ) آن به وسیله ی آب یا هر سیالی که آن را به سرعت خنک کند، است.

جمع بندی

Material Specifications for Pump Parts

Material Class (ASTM)	Applications							
	Castings		Bar Stock	Bolts and studs	Nuts	Plate	Pipe	Fitting
	Pressure Parts	General						
CAST IRON	A 278 Class 30	A 48 Class 25/30/40	-	-	-	-	-	-
CARBON STEEL	A 216 Gr WCB	-	A 576 Gr 1045	A 193 Gr B7	A 194 Gr 2H	A 516 Gr 65/70	A 106 Gr B	A 105
4140 ALLOY STEEL	-	-	A 29 Gr 4140	A 193 Gr B7	A 194 Gr 2H	-	-	-
12 % CHROME STEEL	A 487 Gr CA6NM	A 743 Gr CA 15	A 276 Type 420	-	-	-	-	-
AUSTENITIC STAINLESS STEEL	A 351 Gr CF3 M	A 743 Gr CF3 M	A 276 grade 316 L	A 193 Gr B 8 M	A 194 Gr B 8 M	A 240 Gr 316 L	A 312 Type 316 L	A 182 Gr 316 L
DUPLEX STAINLESS STEEL	A 890 Gr 1 B	-	A 276-S31803	A 276-S31803	A 276-S31803	-	A 790-S31803	A 182 Gr F 51

ASTM Standards and Codes:

ASTM Code	Grade	Description
A29	Gr4140	Standard Specification for steel bars, carbon and alloy, hot-wrought and cold finished, general requirements for
A 48	Class 25/30/40	Standard Specification for Gray Cast Iron
A 105	-	Standard Specification for Carbon Steel Forgings for Piping Applications
A 106	Gr B	Standard Specification for Seamless Carbon Steel Pipe for High Temperature Services
A 182	Gr 316 L Gr F 51	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High temperature Services
A 193	Gr B7 Gr 8 M	Standard Specification for Alloy Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
A 194	Gr 2H Gr B 8 M	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 216	Gr WCB	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High Temperature Service
A 240	Gr 316 L	Standard Specification for Chromium and Chromium Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A 276	Type 420 Gr 316 L S31803	Standard Specification for Stainless Steel Bars and Shapes
A 278	Class 30	Standard Specification for Gray Cast Iron Castings for Pressure Containing Parts for Temperatures Up to 650 °F (350 °C)
A 312	Type 316 L	Standard Specification for Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
A 351	Gr CF3 M	Standard Specification for Castings, Austenitic, for Pressure Containing Parts
A 487	Gr CA6NM	Standard Specification for Steel Castings suitable for Pressure Services
A 516	Gr 65 / 70	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate and Lower Temperature Service
A 576	Gr 1045	Standard Specification for Steel Bars, Carbon, Hot Wrought, Special Quality
A 743	Gr CA 15 Gr CF3 M	Standard Specification for Castings, Iron Chromium, Iron Chromium Nickel, Corrosion Resistant, for General Application
A 790	S31803	Standard Specification for Seamless and Welded Ferritic / Austenitic Stainless Steel Pipe

پیوست ها

پیوست ۱ (NPS)

NPS یا همان Nominal Pipe Size معیاری برای سنجش اندازه ی لوله هاست که در متن استاندارد ها از آن بسیار استفاده می شود. در جدول A1 که در زیر آورده شده است، ابعاد دقیق لوله هایی با NPS های مختلف ارائه شده است.

جدول A1

NPS	قطر خارجی		ضخامت نامی دیواره							
	in	mm	رده 5S		رده 10S		رده 40S		رده 80S	
			in	mm	in	mm	in	mm	in	mm
$\frac{1}{8}$	0.405	10.29	-	-	0.049	1.24	0.068	1.73	0.095	2.41
$\frac{1}{4}$	0.540	13.72	-	-	0.065	1.65	0.088	2.24	0.119	3.02
$\frac{3}{8}$	0.675	17.15	-	-	0.065	1.65	0.091	2.31	0.126	3.20
$\frac{1}{2}$	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
$\frac{3}{4}$	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
$1\frac{1}{4}$	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
$1\frac{1}{2}$	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
$2\frac{1}{2}$	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
$3\frac{1}{2}$	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500	12.70
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375	9.52	0.500	12.70
14	14.000	355.60	0.156	3.96	0.188	4.78	-	-	-	-
16	16.000	406.40	0.165	4.19	0.188	4.78	-	-	-	-
18	18.000	457.20	0.165	4.19	0.188	4.78	-	-	-	-
20	20.000	508.00	0.188	4.78	0.218	5.54	-	-	-	-
22	22.000	558.80	0.188	4.78	0.218	5.54	-	-	-	-
24	24.000	609.60	0.218	5.54	0.250	6.35	-	-	-	-
30	30.000	762.00	0.250	6.35	0.312	7.92	-	-	-	-

پیوست ۲ (تبدیل واحد)

1 in = 25.4 mm

1 mm = 0.03937 in

1 ksi = 6.896 MPa

1 MPa= 0.145 ksi

پیوست ۳ (نماد عناصر شیمیایی)

نماد شیمیایی	نام عنصر
C	کربن
Mn	منگنز
P	فسفر
S	گوگرد
Si	سیلیکون
Cr	کروم
Ni	نیکل
Mo	مولیبدن
V	وانادیوم
N	نیتروژن
Nb	کلمبیوم (نبیوم)
Cu	مس

پیوست ۴ (استاندارد ASTM- A488)

این استاندارد به نحوه ی صحیح جوشکاری فولاد ریخته گری شده به روش قوس الکتریکی می پردازد. با رعایت این استاندارد خود به خود استاندارد ASME Section IX نیز ارضا می شود.

هر تولید کننده باید مطابق با شکل D۱ میزان مطلوب بودن فرآیند جوشکاری، مطابق با شکل D۲ میزان مطلوب بودن عملکرد جوشکار را ثبت کند.

موقعیت جوشکاری

موقعیت جوشکاری بسته به افقی یا عمودی بودن صفحات اصلی به چهار دسته زیر تقسیم می شود :

۱- افقی

۲- عمودی

۳- تخت[4]

۴- بالای سر[5]

در شکل D۳ و جدول D۱ اطلاعات هندسی هرکدام از این چهار دسته ارائه شده است.

موقعیت تخت : این موقعیت شامل مواردی می شود که صفحه به صورت افقی قرار گرفته و فلز جوشکاری از بالا روی آن قرار می گیرد. حالت دیگری از این موقعیت لوله هایی است که محور آنها به صورت افقی قرار گرفته است و به دور محور خود می چرخد و فلز جوشکاری از بالا روی آن قرار می گیرد.

موقعیت افقی : این موقعیت شامل مواردی است که صفحه به صورت عمودی قرار گرفته است و خط جوش در حالت افقی روی آن قرار دارد. حالت دیگر این موقعیت لوله ای است که محور آن عمودی است و خط جوش به صورت افقی روی آن قرار می گیرد.

موقعیت عمودی : این موقعیت شامل حالتی می شود که صفحه و خط جوش هر دو به صورت عمودی قرار گیرند.

موقعیت بالای سر : این موقعیت شامل حالتی است که صفحه به صورت افقی قرار گیرد و فلز جوشکاری از زیر به صفحه وارد شود.

[4] flat
[5] overhead

موقعیت ثابت افقی : این موقعیت شامل حالتی می شود که لوله ای با محور افقی قرار بگیرد و خط جوش به صورت عمودی روی آن قرار می گیرد. در این حالت لوله حرکت نمی کند و ثابت است.

جدول D۱

موقعیت	شماره شکل	انحراف محور (درجه)	گردش صفحه (درجه)
پهن	A	۰ تا ۱۵	۱۵۰ تا ۲۱۰
افقی	B	۰ تا ۱۵	۸۰ تا ۱۵۰
			۲۱۰ تا ۲۸۰
بالای سر	C	۰ تا ۸۰	۰ تا ۸۰
			۲۸۰ تا ۳۶۰
عمودی	D	۱۵ تا ۸۰	۸۰ تا ۲۸۰
	E	۸۰ تا ۹۰	۰ تا ۳۶۰

آریا سپهر کیهان	عنوان مدرک : فرم فرآیند جوشکاری (پروسه) **WPQ**	کد مدرک : QC-W-2 شماره بازنگری : 00 تاریخ بازنگری : ۹۲/۸/۱۱

شماره فرآیند .... تاریخ .... نوع فرآیند جوشکاری ....

متریال .... تا .... از دسته ی .... تا ....

ضخامت صفحه (پلیت) .... محدوده ضخامت قابل قبول ....

Filler Metal F Group No .... Weld Deposit A Group No ....

مشخصه ی روانساز(Flux) .... ترکیب گاز .... دبی حجمی گاز ....

مواد پشت بند (در صورت وجود) .... محدوده دمای پس گرمایش ....

Single/Multiple .... موقعیت شیار .... قطر سیم جوش ....

نام تجاری .... نوع پشت بند ....

Forehand/Backhand .... Amps .... Volts .... Inches/min ....

دمای پس گرمایش .... مدت زمانی که در آن دما حفظ می شود ....

نتایج تست کشش

نوع failure و موقعیت آن	تنش نهایی واحد	بار کل نهایی	مساحت	ضخامت	عرض	شماره نمونه

نتایج تست خمش

نتیجه	شماره نمونه	نتیجه	شماره نمونه

نام جوشکار .... ساعت .... مهر ....

نام تست گیر .... شماره تست ....

بدین وسیله تضمین می شود که تمامی نتایج مندرج در این فرم حقیقی است و تمامی فرآیند بر اساس ملزومات استاندارد ASTM .... انجام پذیرفته است.

	سمت :
	امضا و تاریخ:

شکل D۱

کد مدرک : QC-W-1 شماره بازنگری : 00 تاریخ بازنگری: ۹۲/۸/۱۱	عنوان مدرک : فرم فرآیند جوشکاری (عملکرد جوشکار) PQR	ARYA SEPEHR KAYHAN آریا سپهر کیهان

نام جوشکار .... ساعت .... مهر ....

شماره فرآیند .... تاریخ .... نوع فرآیند جوشکاری ....

موقعیت .... متریال .... تا .... از دسته ی .... تا ....

ضخامت صفحه (پلیت) .... محدوده ضخامت قابل قبول ....

Filler Metal F Group No ....
Filler Metal A Group No ....

قطر سیم جوش .... مشخصه روانساز (Flux) ....

ترکیب گاز .... نام تجاری ....

نوار پشت بند (در صورت وجود) ....

نتایج تست خمش

نتیجه	شماره نمونه	نتیجه	شماره نمونه

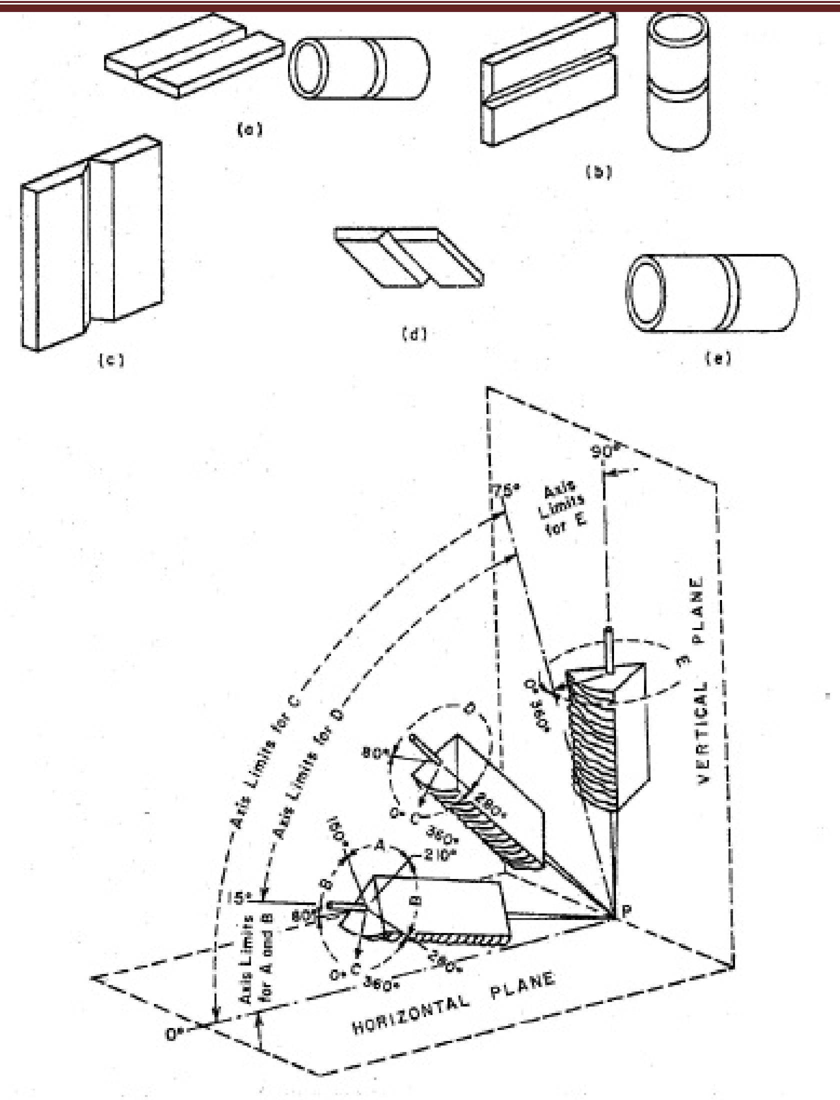
نام تست گیر .... شماره آزمایشگاه ....

بدین وسیله تضمین می شود که تمامی نتایج درج شده در این فرم حقیقی است و تمامی فرآیند بر اساس ملزومات استاندارد .... ASTM انجام پذیرفته است.

سمت :

امضاء و تاریخ:

شکل D۲



شکل D۳

<u>نحوه تهیه ی صفحات تست :</u>

نمونه ی تست حتما باید هم جنس با قطعه ی اصلی باشد و عملیات حرارتی صورت گرفته روی آن قبل و بعد از جوشکاری مشابه با قطعه ی اصلی باشد. تعداد نمونه های مورد نیاز با توجه به ابعاد نمونه ی تست تعیین شود. محل اتصال در نمونه باید با همان خط جوش قطعه اصلی جوش داده شود. ابعاد این خط جوش اهمیتی ندارد. ضخامت قطعه با توجه به جداول D۲ و D۳ تعیین می شود.

جدول D۲- نوع و تعداد نمونه های تست و محدوده ی ضخامت مورد قبول (پروسه)

نوع و تعداد تست های مورد نیاز				**محدوده ضخامت مورد قبول (اینچ)**		**ضخامت صفحه یا لوله ای که روی آن جوشکاری صورت گرفته است (t) (اینچ)**
خمش از قاعده	**خمش از رویه**	**خمش از کناره**	**کشش در سطح کاهش یافته**	**ماکزیمم**	**مینیموم**	
2	2	-	2	2t	$\frac{1}{16}$	$\frac{1}{16}$ تا $\frac{3}{8}$
2	2	-	2	2t	$\frac{3}{16}$	$\frac{3}{8}$ تا $\frac{3}{4}$
-	-	4	2	2t	$\frac{3}{16}$	$\frac{3}{4}$ تا $\frac{3}{2}$
-	-	4	2	8	$\frac{3}{16}$	بیشتر از $\frac{3}{2}$

* اگر از جوشکاری جهت ترمیم و تعمیر استفاده شود، ضخامت مینیموم اهمیتی ندارد.

* ماکزیمم ضخامت مورد قبول برای لوله هایی کوچکتر از ۵ اینچ، مینیموم دو مقدار دو برابر ضخامت آن یا $\frac{3}{4}$ اینچ است.

جدول D۳- نوع و تعداد نمونه های تست و محدوده ی ضخامت مورد قبول (عملکرد)

نوع و تعداد تست های مورد نیاز			**ضخامت مورد قبول**	**ضخامت صفحه یا لوله ای که روی آن جوشکاری صورت گرفته است (t) (اینچ)**
خمش از قاعده	**خمش از رویه**	**خمش از کناره**		
1	1	-	2t	کمتر از $\frac{3}{8}$
1	1	-	2t	$\frac{3}{8}$ تا $\frac{3}{4}$
-	-	2	2t	$\frac{3}{8}$ تا $\frac{3}{4}$
-	-	2	تا جایی که جوشکاری امکان پذیر باشد	بیشتر از $\frac{3}{4}$

شرایط اتصال باید مطابق شکل D۴ باشد.

شکل D۴

انواع تست :

چهار نوع تست برای بررسی و قبول نمونه انجام می شود:

۱- تست کشش : این تست به منظور سنجش مقاومت خط جوش مورد استفاده قرار می گیرد.

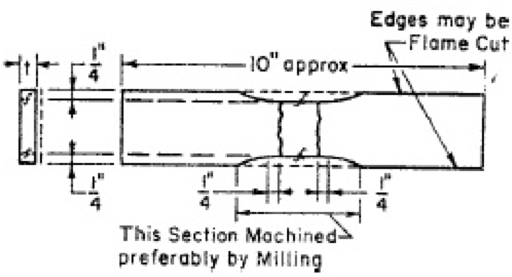
۲- تست خمش : این تست به منظور سنجش درستی و چکش خواری خط جوش مورد استفاده قرار می گیرد.

۳- تست ضربه شارپی : این تست به منظور سنجش مقاومت ضربه ای خط جوش ها شیاری مورد استفاده قرار می گیرد.

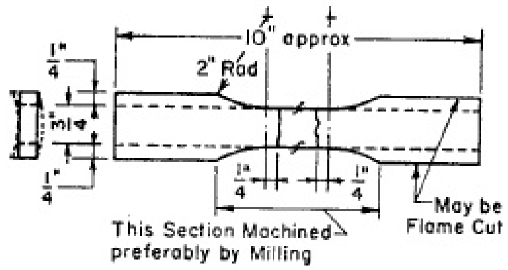
۴- تست رادیوگرافی : این تست به منظور سنجش مهارت جوشکار مورد استفاده قرار می گیرد.

تست کشش :

ضخامت صفحه یا لوله مورد تست قرار گرفته شده با توجه به شکل های D۵ و D۶ به دست می آید. شایان ذکر است که اندازه لوله ها بیشتر از ۳ اینچ است.



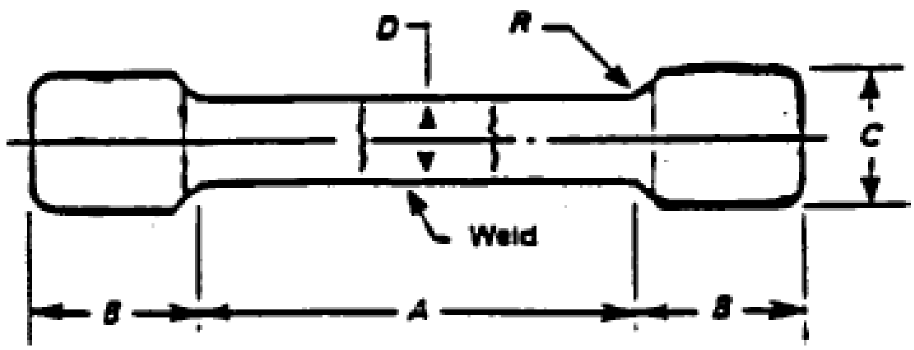
شکل D۵- تست کشش برای صفحه



شکل D۶- تست کشش برای لوله

برای صفحات و لوله هایی با ضخامت زیر یک اینچ، یک نمونه تست و برای بیشتر از ۱ اینچ، یک یا چند نمونه کافی است. هنگامی که از چند نمونه استفاده می شود، هر نمونه یک تست کشش را متحمل می شود.

برای تست کشش می توان از نمونه هایی که نمونه های واژگون نام دارند استفاده کرد که در شکل D۷ و جدول D۴ ارائه شده اند.



شکل D۷

اگر جوش نمونه ی تست شده استحکام کششی ای بیشتر از ۹۵٪ استحکام کششی تعیین شده داشت، این تست را با موفقیت پشت سر گذاشته است. برای اطلاعات بیشتر پیرامون تست کشش به استاندارد ASTM- A370 رجوع شود.

جدول D۴

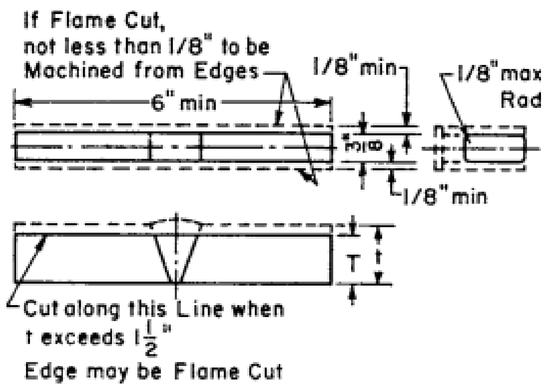
	ابعاد استاندارد (اینچ)			
	(a) نمونه ۰/۵۰۵	(b) نمونه ۰/۳۵۳	(c) نمونه ۰/۲۵۲	(d) نمونه ۰/۱۸۸
A	*	*	*	*
D	0.5 ± 0.01	0.35 ± 0.007	0.25 ± 0.005	0.188 ± 0.003
R (min)	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
B	$1\frac{3}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{2}$
C	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$

* باید بزرگتر از مجموع عرض جوش و ۲۰ باشد.

تست خمش :

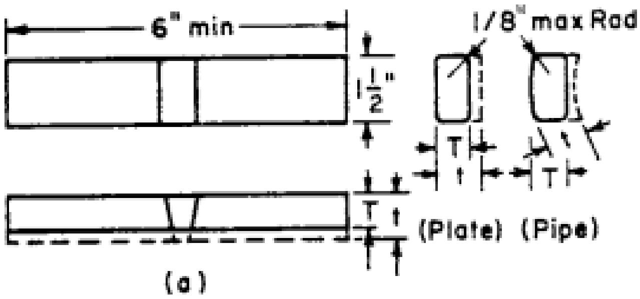
برای تهیه نمونه ی تست خمش باید صفحه یا لوله ی مورد نظر را به گونه ای برش داد که سطح مقطع آن مستطیلی شکل باشد. سطوح بریده شده وجوه جانبی و دو وجه دیگر رویه و قاعده نام دارند. گرده سطحی است که خط جوش با بیشترین ضخامت روی آن قرار دارد. بسته به اینکه کدام وجه، وجه محدب خارجی می شود سه نوع تست خمش موجود است.

خمش جانبی : خط جوش در عرض محور طولی نمونه وجود دارد و نمونه به گونه ای خم می شود که یکی از وجوه جانبی سطح محدب خمش باشد. در شکل D۸ نمونه ی این تست ارائه شده است.



شکل D۸

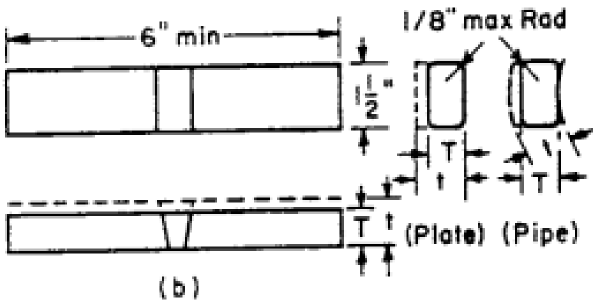
خمش گرده ای : خط جوش در عرض محور طولی نمونه وجود دارد و نمونه به گونه ای خم می شود که گرده ی آن سطح محدب خمش باشد. در شکل D۹ نمونه ی این تست ارائه شده است.



t, in. [mm]	*T*, in. [mm] (all Ferrous Materials)
1/16 to 1/8 [1.6 to 3.2]	*t*
1/8 to 3/8 [3.2 to 9.5]	*t*
> 3/8 [9.5]	3/8 [9.5]

شکل D۹

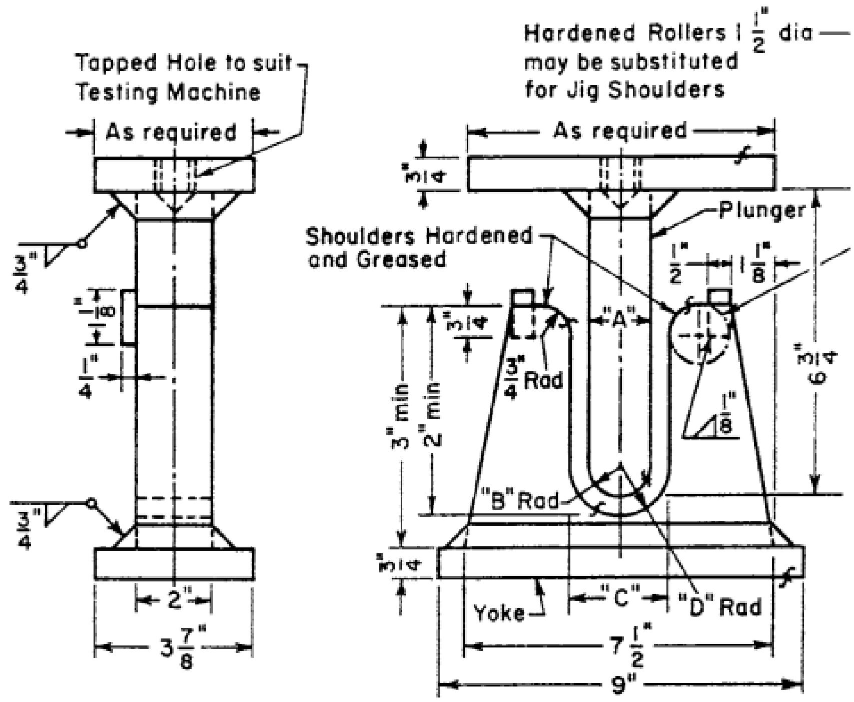
خمش ریشه ای : خط جوش در عرض محور طولی نمونه وجود دارد و نمونه به گونه ای خم می شود که ریشه ی آن سطح محدب خمش باشد. در شکل D۱۰ نمونه ی این تست ارائه شده است.



شکل D۱۰

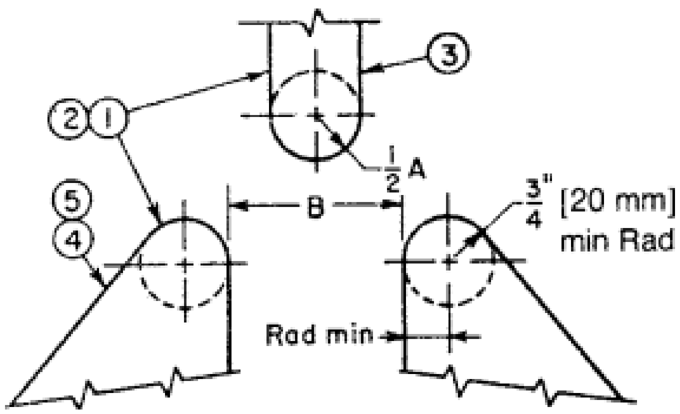
تعداد تست های خمش مورد نیاز برای نمونه های متفاوت در جداول D۲ و D۳ آورده شده است. اگر ضخامت قطعه ی اصلی بیشتر از ۱/۵ اینچ باشد، نمونه ای با ضخامتی بین ۰/۷۵ و ۱/۵ اینچ از آن برداشته می شود.

نمونه های تست خمش باید در راهنمای تست خم شوند. تعدادی از این راهنما های تست در شکل های D۱۱ تا D۱۳ ارائه شده است. بسته به نوع تست خمش، صفحه ی تحت خمش باید در مکتم خالی بین دو فک قرار گیرد.

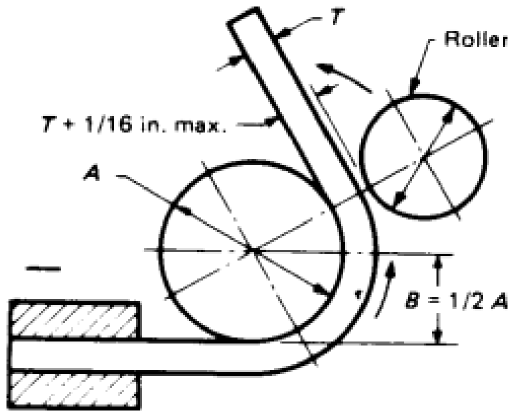


ضخامت نمونه	A (in)	B(in)	C(in)	D(in)
$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{3}{16}$
t	4t	2t	$6t+\frac{1}{8}$	$3t+\frac{1}{6}$

شکل D۱۱



شکل D۱۲



شکل D۱۳

برای سنجش نمونه به موارد زیر توجه شود :

۱- وجه محدب خمش نباید در هیچ جهتی هیچ گونه ترکی یا هر نقص دیگری بزرگتر از $\frac{1}{8}$ اینچ داشته باشد.

۲- از ترک های کناره ی وجه محدب خمش می توان صرف نظر کرد، مگر اینکه دلیل واضحی مبنی بر ارتباط این ترک با دخول سرباره به قطعه در دست باشد.

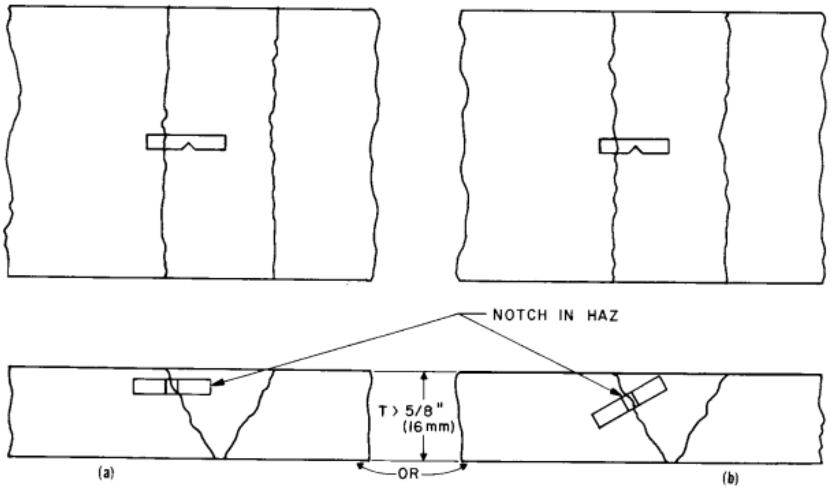
اگر میزان چکش خواری قطعه ی اصلی آنقدر بالا باشد که نتوان روی آن تست خمش را انجام داد، باید ابتدا با استفاده از عملیات حرارتی مخصوص شرایط را برای خمش آن محیا کرد. اگر قطعه طبق خمش جانبی ۵ درجه خم شد و ترکی روی سطح محدب خمش آن به وجود نیامد این تست را با موفقیت پشت سر گذاشته است.

تست ضربه ی شارپی :

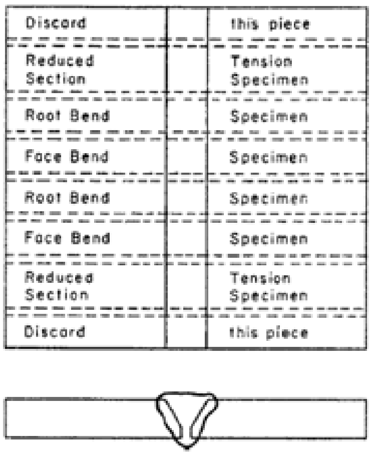
اطلاعات کاملی از این تست در استاندارد A370 آورده شده است. در این تست فاق V شکل عمود بر سطح قطعه به گونه ای قرار می گیرد که $\frac{1}{16}$ اینچ داخل یک صفحه از آن شود. در نواحی تحت تاثیر عملیات حرارتی قرار گرفته، فاق در عرض جوش بر آن عمود می شود. در شکل D۱۴ نحوه ی قرار گیری فاق نشان داده شده است.

ترتیب حذف بخش هایی از نمونه

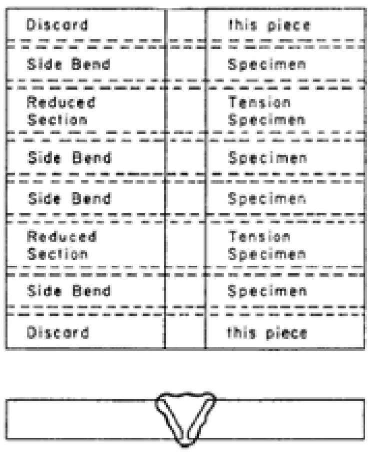
در شکل های D۱۵ و D۱۶ ترتیب حذف بخشهایی از نمونه جهت تشکیل نمونه ی تست مورد نظر نشان داده شده است.



شکل D۱۴

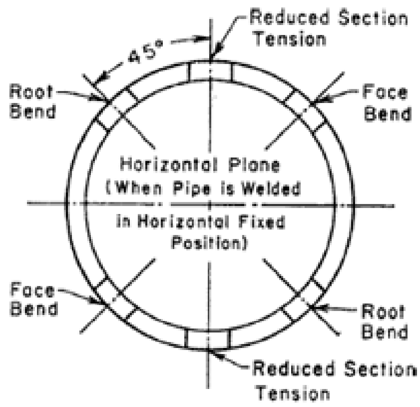


Order of Removal of Test Specimens from Test Plate 1/16 to 3/4 in. [1.6 to 19.0 mm] Thick

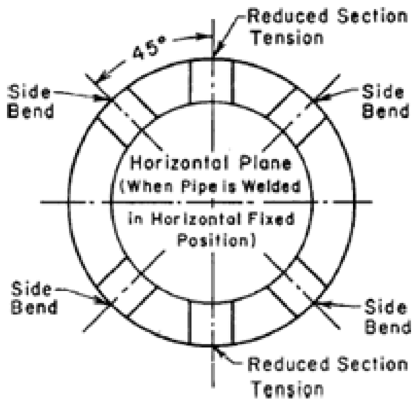


Order of Removal of Test Specimens from Welded Test Plates over 3/4 in. [19.0 mm] Thick (May be Used for Thicknesses 3/8 to 3/4 in. [9.5 to 19.0 mm])

شکل D۱۵



Order of Removal of Test Specimens from Welded Pipe or Cylindrical Castings 1/16 to 3/4 in. [1.6 to 19.0 mm] Thick



Order of Removal of Test Specimens from Welded Pipe or Cylindrical Castings over 3/4 in. [19.0 mm] Thick (May be Used for Thicknesses 3/8 to 1/4 in. [9.5 to 19.0 mm])

شکل D۱۶

<u>بررسی مطلوب بودن فرآیند</u>

۱- هر تولید کننده یا پیمانکاری باید فرآیند جوشکاری را در فرمی مشابه با فرم های ارائه شده ثبت کند.

۲- تعداد تست های خمش مورد نیازی که برای هر قطعه با توجه به ضخامت آن مورد نیاز است در جدول D۲ آورده شده است.

۳- نمونه باید مطابق شکل های D۱۵ و D۱۶ از صفحه یا لوله برداشته شود.

۴- نمونه های برداشته شده باید موارد صلاحیت اشاره شده در هر تست را با موفقیت پشت سر بگذارد.

بررسی دوباره مطلوب بودن فرآیند

در صورتی که هر یک از ۱۲ حالت زیر برای قطعه اتفاق افتاد، فرآیند جوشکاری باید به عنوان فرآیندی جدید تنظیم شده و مطلوب بودن آن بررسی شود:

۱- تغییر متریال پایه از یک دسته به دسته ی دیگر. هنگامی که دو قطعه از دو جنس مختلف به هم جوش داده می شوند، مطلوب بودن فرآیند باید برای ترکیب دو متریال بررسی شود. شایان ذکر است که دسته بندی مواد مختلف در جدول D۵ آورده شده است.

۲- هر گونه تغییر در آنالیز سرباره ی جوش یا جنس الکترود نیاز به بررسی دوباره مطلوب بودن تحت هرکدام از شرایط زیر را الزامی می کند.

۲-۱- هنگامی که *A No* متریال تغییر کند. (جدول *D۶*)

۲-۲- هنگامی که *F No* متریال تغییر کند. (جدول *D۷*)

۳- کاهش ۱۰۰ درجهی فارنهایت یا بیشتر در دمای پیش گرم سازی.

۴- تغییر در عملیات حرارتی بعد از جوشکاری یا سیکل زمانی آن.

۵- تغییر در پشتبند یا قلم افتادگی مواردی در نسخه ی قبلی.

۶- تغییر در پروسه ی جوشکاری.

۷- در جوشکاری زیر آب که نوع آلیاژ فلز جوشکاری شدیدا وابسته به جنس ذوب کننده است، هرگونه تغییر در فرآیند جوشکاریی که باعث تغییر در ترکیب شیمیایی فلز شود.

۸- در جوشکاری زیر آب هر گونه تغییر در جنس ذوب کننده.

۹- در جوشکاری زیر آب تغییر ترکیب فیلر از حالتی که بین ۱/۷۵ تا ۲/۲۵ درصد و حالتی که زیر ۱ درصد منگنز داشته باشد.

۱۰- در جوشکاری زیر آب تغییر *A No* پرکننده. (جدول *D۶*)

۱۱- در جوشکاری قوس الکتریکی فلزی و تنگستنی:

۱۱-۱- هر گونه تغییر در ترکیبات گاز مورد استفاده در جوشکاری.

۱۱-۲- تغییر بیش از ٪۱۰ در دبی حجمی گاز.

۱۲- در جوشکاری قوس الکتریکی فلزی تغییر الکترود مصرفی از نوع روکش دار به نوع زیرپودری.

جدول D۵

گریدها	ASTM	نوع متریال	شماره دسته
همه	A27	فولاد کربنی (کربن کمتر از ۰/۳۵ درصد، استحکام کششی کمتر یا مساوی ۷۰ ksi)	1
WCA, WCB	A216		
LCB, LCA	A352		
1	A356		
1A,2A	A732		
A1Q	A757		
SC1020, SC 1025, SC 1030, SC 1040, SC 1045, کلاس های : 65/35, 70/36	A958		
80-40	A148	فولاد کربنی (استحکام کششی بیش از ۷۰ksi)- فولاد کربن- منگنز (استحکام کششی بین ۷۰ ksi تا ۹۰)	2
WCC	A216		
LCC	A352		
2Q, 3A	A732		
A2Q	A757		
SC 1030, SC 1040, SC 1045 کلاس های: 80/40, 80/50	A958		
3Q, 4A, 4Q, 5N	A732	فولاد کربنی و فولاد کربن- منگنز (استحکام کششی بیش از ۹۰ksi)	3
SC 1045 کلاس های: 90/60, 105/85, 115/95	A958		
80-50	A148	فولاد کم آلیاژ (آنیل شده، نرمالیزه شده، نرمالیزه و حرارت داده شده، استحکام کششی کمتر از ۸۵ ksi)	4
WC1, WC4, WC5, WC6, WC9	A217		
LC1, LC2, LC3, LC4	A352		
2, 5, 6, 8	A356		
C23, C24	A389		
11A, 12A, 16A	A487		
B2N, B3N, B4N	A757		
SC 4130, SC 4140, SC 8620, SC 8625, SC 8630, کلاس های: 65/35, 70/36, 80/40, 80/50	A985		
90-60, 105-85	A148	فولاد کم آلیاژ (آنیل شده، نرمالیزه شده، نرمالیزه و حرارت داده شده، استحکام کششی بیشتر از ۸۵ ksi)	5
C5, C12, C12A, WC11	A217		
9, 10, 12	A356		
1A, 1C, 2A, 2C, 4A, 4C, 6A, 8A, 9A, 9C, 10A, 13A	A487		
6N, 15A	A732		
D1N1, D1N2, D1N3, E2N1,	A757		

			E2N2, E2N3
		A958	SC 4340 کلاس های: 90/60 , 105/85
6	فولاد کم آلیاژ (کوئنچ و حرارت داده شده)	A148	90-60, 105-85, 115-95, 130-115, 135-125, 150-135 ,160-145, 165-150, 165-150L, 210-180, 210-180L, 260-210, 260-210L
		A352	LC2-1, LC1, LC2, LC3, LC4, LC9
		A487	1B, 1C, 2B, 2C, 4B, 4C, 4D, 4E, 9A, 9B, 9C, 9D, ,6B, 7A, 8B, 8C 9E, 10B, 11B, 12B, 13B, 14A
		A732	7Q, 8Q, 9Q, 10Q, 11Q, 12Q, 13Q, 14Q
		A757	B2Q, B3Q, B4Q, C1Q, D1Q1, D1Q2, D1Q3, E1Q, E2Q1, E2Q2, E2Q3
		A958	SC 4140, SC 4130, SC 4340, SC 8620, SC 8625, SC 8630, کلاس های: 115/95, 130/115, 135/125, 150/ 135, 160/145, 165/150, 210/180
7	فولاد ضد زنگ فریتی	A743	CB-30, CC-50
8	فولاد ضد زنگ مارتنزیتی	A217	CA-15
		A352	CA6NM
		A356	CA6NM
		A487	CA15-A, CA15-B, CA15-C, ,CA15-D, CA15M-A CA6NM-A, CA6NM-B
		A743	CA-15, CA-15M, CA6NM, CA-40, CA6N, CB6
		A757	E3N
9	فولاد آستنیتی ضد زنگ کم کربن (کربن کمتر از ٪ ۰/۰۳)	A351	CF-3, CF-3A, CF-3M, CF-3MA, CF-3MN, CK3MCUN, CG3M, CN3MN
		A743	CF-3, CF-3M, CF-3MN, CK-,3MCUN, CN-3M,CG3M CN3MN
		A744	CF-3, CF-3M, CK-3MCUN, CG3M , CN3MN
10	فولاد آستنیتی ضد زنگ غیرپایدار (	A351	CE-8MN, CF-8, CF-8A, CF-8M,

	کربن بیشتر از ٪ ۰/۰۳)		,CF-10, CF-10M CG-8M, CH-8, CH-10, CH-20, CF10S1MNN, ,CG6MMN CE20N
		A447	Type I
		A743	CF-8, CG-12, CF-20, CF-8M, ,CF-16F, CF10SMNN CH-20, CG-8M, CE-30, CG6MMN, CH10, CF16Fa
		A744	CF-8, CF-8M, CG-8M
11	فولاد آستنیتی ضد زنگ پایدار	A351	CF-8C, CF-10MC, CK-20, HK- ,30, HK-40, HT-30 CN-7M, CT-15C
		A447	Type II
		A743	CF-8C, CN-7M, CN-7MS, CK-20
		A744	CF-8C, CN-7M, CN-7MS
12	فولاد دوبلکس (آستنیتی- فریتی) ضد زنگ	A351	CD3MWCuN, CD-4MCU
		A872	J93183, J93550
		A890	1A, 1B, 2A, 3A, 4A, 5A, 6A
		A995	1B, 2A, 3A, 4A, 5A, 6A
13	فولاد آستنیتی رسوبی – سخت کاری شده ی ضد زنگ	A747	CB7CU-1, CB7CU-2
14	آلیاژ پایه نیکل	A494	CW-12MW, CY-40 Class 1, CY- ,40 Class 2, CZ-100 M-35-1, M-35-2, M-30C, N- -12MV, N-7M, CW-6M, CW 2M, CW-6MC, CX-2MW, CU5MCUC
		A990	CW2M
15	فولاد ریخته گری، آستنیتی- منگنز	A128	A, B-1, B-2, B-3, B-4, C, D, E-1, E-2, F

جدول D۵

آنالیز							
سیلیسیم ٪	منگنز ٪	نیکل ٪	مولیبدن ٪	کروم ٪	کربن ٪	سرباره جوش	A No
max 1.00	max 1.6	-	-	-	max 0.15	فولاد نرم	۱
max 1.00	max 1.6	-	0.40 – 0.65	max 0.50	max 0.15	کربن - مولیبدن	۲
max 1.00	max 1.6	-	0.40 – 0.65	0.40 – 2.00	max 0.15	کروم (۰/۴ تا ۲ درصد) - مولیبدن	۳
max 2.00	max 1.6	-	0.40 – 1.50	2.00 – 6.00	max 0.15	کروم (۲ تا ۶ درصد) - مولیبدن	۴
max 2.00	max 1.2	-	0.40 – 1.50	6.00 – 10.50	max 0.15	کروم (۶ تا ۱۰/۵ درصد) - مولیبدن	۵
max 1.00	max 2.00	-	max 0.70	11.00 – 15.00	max 0.15	کروم – مارتنزیت	۶
max 3.00	max 1.00	-	max 1.00	11.00 – 30.00	max 0.15	کروم – فریت	۷
max 1.00	max 2.50	7.50 – 15.00	max 4.00	14.50 – 30.00	max 0.15	کروم – نیکل	۸
max 1.00	max 2.50	15.00 – 37.00	max 4.00	25.00 – 30.00	max 0.30	کروم – نیکل	۹
max 1.00	max 1.70	0.80 – 4.00	max 0.55	-	max 0.15	نیکل تا ۴ درصد	۱۰
max 1.00	1.25 – 2.25	max 0.85	0.25 – 0.75	-	max 0.17	منگنز – موایبدن	۱۱
max 1.00	0.75 – 2.25	1.25 – 2.80	0.25 – 0.80	max 1.50	max 0.15	نیکل – کروم - مولیبدن	۱۲

جدول D۷

دسته بندی ANSI/AWS	مشخصه ANSI/AWS *	F No
EXX20, EXX22, EXX24, EXX27, EXX28	SFA-5.1 & 5.5	۱
EXX25, EXX26	SFA-5.4	۱
EXX12, EXX13, EXX14, EXX19	SFA-5.1 & 5.5	۲
EXX10, EXX11	SFA-5.1 & 5.5	۳
EXX15, EXX16, EXX18, EXX48	SFA-5.1 & 5.5	۴
EXX15, EXX16, EXX17	SFA-5.4 (به جز آستنیتی و دوبلکس)	۴
EXX-15, EXX-16, EXX-17	SFA-5.4 (آستنیتی و دوبلکس)	۵
RX	SFA-5.2	۶
FXX-EXX, FXX-ECX	SFA-5.17	۶
ERXX, ECXX, EQXX	SFA-5.9	۶
ERXXS-X, EXXC-X, EXXC-XX	SFA-5.18	۶
EXXT-X	SFA-5.20	۶
EXXXT-X	SFA-5.22	۶
FXX-EXXX-X, FXX-ECXXX-X, FXX-EXXX-XN, FXX-ECXXX-XN	SFA-5.23	۶
FESXX-EXXXXX-EW	SFA-5.25	۶
EGXXS-X, EGXXT-X	SFA-5.26	۶
ERXXS-X, EXXC-X	SFA-5.28	۶
EXXTX-X	SFA-5.29	۶
INXXXX	SFA-5.30	۶
ENi-1	SFA-5.11	۴۱
ERNi-1	SFA-5.14	۴۱
IN61	SFA-5.30	۴۱
ENiCu-7	SFA-5.11	۴۲
ERNiCu-7	SFA-5.14	۴۲
ERNiCu-8	SFA-5.14	۴۲
IN60	SFA-5.30	۴۲
ENiCrFe-1	SFA-5.11	۴۳
ENiCrFe-2	SFA-5.11	۴۳
ENiCrFe-3	SFA-5.11	۴۳
ENiCrFe-4	SFA-5.11	۴۳
ENiCrFe-7	SFA-5.11	۴۳
ENiCrFe-9	SFA-5.11	۴۳
ENiCrFe-10	SFA-5.11	۴۳
ENiCrCoMo-1	SFA-5.11	۴۳

۴۳	SFA-5.11	ENiCrMo-2
۴۳	SFA-5.11	ENiCrMo-3
۴۳	SFA-5.11	ENiCrMo-6
۴۳	SFA-5.11	ENiCrMo-12
۴۳	SFA-5.14	ERNiCr-3
۴۳	SFA-5.14	ERNiCr-4
۴۳	SFA-5.14	ERNiCr-6
۴۳	SFA-5.14	ERNiCrFe-5
۴۳	SFA-5.14	ERNiCrFe-6
۴۳	SFA-5.14	ERNiCrFe-7
۴۳	SFA-5.14	ERNiCrFe-8
۴۳	SFA-5.14	ERNiCrFe-11
۴۳	SFA-5.14	ERNiCrCoMo-1
۴۳	SFA-5.14	ERNiCrMo-2
۴۳	SFA-5.14	ERNiCrMo-3
۴۳	SFA-5.30	IN82
۴۳	SFA-5.30	IN62
۴۳	SFA-5.30	IN62A
۴۴	SFA-5.11	ENiMo-1
۴۴	SFA-5.11	ENiMo-3
۴۴	SFA-5.11	ENiMo-7
۴۴	SFA-5.11	ENiMo-8
۴۴	SFA-5.11	ENiMo-9
۴۴	SFA-5.11	ENiMo-10
۴۴	SFA-5.11	ENiCrMo-4
۴۴	SFA-5.11	ENiCrMo-5
۴۴	SFA-5.11	ENiCrMo-7
۴۴	SFA-5.11	ENiCrMo-10
۴۴	SFA-5.11	ENiMo-13
۴۴	SFA-5.11	ENiMo-14
۴۴	SFA-5.14	ERNiMo-1
۴۴	SFA-5.14	ERNiMo-2, ERNiMo-3
۴۴	SFA-5.14	ERNiMo-7 (Alloy B-2)
۴۴	SFA-5.14	ERNiMo-8
۴۴	SFA-5.14	ERNiMo-9
۴۴	SFA-5.14	ERNiMo-10
۴۴	SFA-5.14	ERNiCrMo-4
۴۴	SFA-5.14	ERNiCrMo-5

۴۴	SFA-5.14	ERNiCrMo-7 (Alloy C-4)
۴۴	SFA-5.14	ERNiCrMo-10
۴۴	SFA-5.14	ERNiCrMo-13
۴۴	SFA-5.14	ERNiCrMo-14
۴۴	SFA-5.14	ERNiCrWMo-1
۴۵	SFA-5.11	ENiCrMo-1
۴۵	SFA-5.11	ENiCrMo-9
۴۵	SFA-5.11	ENiCrMo-11
۴۵	SFA-5.14	ERNiCrMo-1
۴۵	SFA-5.14	ERNiFeCr-1
۴۵	SFA-5.14	ERNiCrMo-8
۴۵	SFA-5.14	ERNiCrMo-9
۴۵	SFA-5.14	ERNiCrMo-11
۷۱	SFA-5.13	EFeMn-A, EFeMn-B, EFeMn-C, EFeMn-D, EFeMn-E, EFeMn-F, EFeMnCr

❋ موضوع هرکدام از *SFA* ها به شرح زیر است:

* *SFA-5.1=* الکترود های فولاد کربنی مناسب برای جوشکاری قوس الکتریکی فلزی

* *SFA-5.2=* میله های فولاد کربنی و کم آلیاژ مناسب برای جوشکاری استیلن

* *SFA-5.3=* الکترود های آلمینیومی و آلیاژ آن مناسب برای جوشکاری قوس الکتریکی فلزی

* *SFA-5.4=* الکترود های فولاد ضد زنگ مناسب برای جوشکاری قوس الکتریکی فلزی

* *SFA-5.6=* الکترود های فولاد کم آلیاژ مناسب برای جوشکاری قوس الکتریکی فلزی

* *SFA-5.7=* الکترود های با پوشش مسی و آلیاژ های مس مناسب برای جوشکاری

* *SFA-5.8=* فلزات پر کننده ی مناسب برای لحیم کاری و جوش های لحیمی

* *SFA-5.9=* الکترود ها و میله های فولاد ضد زنگ بدون روکش مناسب برای جوشکاری

* *SFA-5.10=* الکترود ها و میله های آلمینیوم و آلیاژ آلمینیومی مناسب برای جوشکاری

* *SFA-5.11=* الکترود ها و میله های نیکل و آلیاژ نیکلی بدون روکش مناسب برای جوشکاری قوس الکتریکی فلزی

* *SFA-5.12=* الکترود ها و میله های تنگستن و آلیاژ تنگستنی بدون روکش مناسب برای جوشکاری و برشکاری قوس الکتریکی فلزی

* *SFA-5.13=solid surfacing* الکترود ها و میله های مناسب برای

* *SFA-5.14=* الکترودها و میله های نیکل و آلیاژ نیکلی مناسب برای جوشکاری روکشی

* *SFA-5.15=*الکترودها و میله های مناسب برای جوشکاری آهن ریخته گری

* *SFA-5.16=*الکترودها و میله های جوشکاری تیتانیوم و آلیاژهای تیتانیوم

* *SFA-5.17=*الکترودهای فولاد کربنی مناسب برای جوشکاری زیر آب

* *SFA-5.18=*الکترود های فولاد کربنی مناسب برای جوشکاری قوس الکتریکی گازی

* *SFA-5.20=*الکترود های فولاد کربنی مناسب برای جوشکاری قوس الکتریکی توپودری

* *SFA-5.21=* surfacing الکترود های روکش دار فولاد کربنی مناسب برای

* *SFA-5.22=* الکترودهای فولاد ضد زنگ مناسب برای جوشکاری قوس الکتریکی زیر پودری و میله های زیر پودری فولاد ضد زنگی مناسب برای جوشکاری قوس الکتریکی گاز تنگستن

* *SFA-5.23=*الکترودهای فولاد کم آلیاژ مناسب برای جوشکاری زیر آب

* *SFA-5.24=*الکترودها و میله های مناسب برای جوشکاری زیرکونیوم و آلیاژهای آن

* *SFA-5.25=* الکترودهای فولاد کربنی و کم آلیاژ مناسب برای جوشکاری الکترو گازی

* *SFA-5.26=*الکترودهای فولاد کربنی و کم آلیاژ مناسب برای جوشکاری الکتریکی

* *SFA-5.28=* الکترود ها و میله های فولاد کم آلیاژ مناسب برای جوشکاری قوس الکتریکی

* *SFA-5.29=*الکترود ها و میله های فولاد کم آلیاژ مناسب برای جوشکاری زیرپودری

* *SFA-5.30=*مواد پرکننده مصرفی

* *SFA-5.31=*سیم لحیم کاری

* *SFA-5.32=*گازهای جوشکاری

* *SFA-5.34=*الکترودهای آلیاژ نیکل مناسب برای جوشکاری قوس الکتریکی زیرپودری

پیوست ۵ (استاندارد ASTM- A400)

این استاندارد پیرامون انتخاب شفت های فولادی با توجه به سطح مقطع و خواص مکانیکی مورد انتظار از آنهاست. شفت ها به سه کلاس تقسیم می شوند:

۱- کلاس P (P-1 to P-7) : این دسته از شفت ها مناسب برای کاربردهای سنگین است. به همین دلیل شفت های این کلاس خصوصیات زیر را دارند :

I. استحکام کششی بالا (بیشتر از ۵۲۱ مگا پاسکال)
II. قابلیت چکش خواری بالا
III. سختی بالا

شماره ی گریدهای مناسب برای ساخت شفت هایی با خصوصیت ذکر شده در جداول E۱ و E۲ (به ترتیب برای حالات خنک کاری ملایم و خنک کاری سریع) ارائه شده است.

۲- کلاس Q (Q-1 to Q-7) : این دسته از شفت ها مناسب برای کاربردهای متوسط است. به همین دلیل شفت های این کلاس خصوصیات زیر را دارند :

I. استحکام کششی متوسط (۵۱۷ تا ۱۲۷۶ مگا پاسکال)
II. قابلیت چکش خواری خوب

شماره ی گریدهای مناسب برای ساخت شفت هایی با خصوصیت ذکر شده در جداول E۳ و E۴ (به ترتیب برای حالات خنک کاری ملایم و خنک کاری سریع) ارائه شده است.

۳- کلاس R (R-1 to R-7) : این دسته از شفت ها مناسب برای کاربردهای سبک است. به همین دلیل شفت های این کلاس خصوصیات زیر را دارند :

I. استحکام کششی پایین (۲۰۷ تا ۸۲۷ مگا پاسکال)
II. قابلیت چکش خواری نسبتا خوب

شماره ی گریدهای مناسب برای ساخت شفت هایی با خصوصیت ذکر شده در جداول E۵ و E۶ (به ترتیب برای حالات نورد گرم و نورد سرد) ارائه شده است.

جدول E۱

سختی مطلوب		استحکام کششی معادل psi	استحکام تسلیم معادل psi	سختی بعد از کوئنچ (مینیموم)		کلاس						
						P-1	P-2	P-3	P-4	P-5	P-6	P-7
						قطر شفت (اینچ)						
						≤ 0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5
						ضخامت سطح مقطع قطعه Flat (اینچ)						
HB	HRC			HB	HRC	≤ 0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	2-2.3
229-293	20 -33	110000-145000	90000- 125000	388	42	1330	-	-	-	-	-	-
						4130						
						5132						
						8630						
						50B30						
293-341	33 -38	145000-170000	125000-150000	409	44	1335	3140	4137	-	4142	9840	4337
						3135	4135					
						4042	4640					
						5135	8640					
						94B30	8740					
341-388	38 - 42	170000 - 190000	150000 - 170000	455	48	1340	4137	4140	-	4145	4147	4340
						3140	6145	TS4140		9840	4337	-
						4047	8642	94B40		-	86B45	-
						4135	8645	-		-	-	-
						5140	8742	-		-	-	-
						8637	-	-		-	-	-
						TS14B50	-	-		-	-	-
						50B40	-	-		-	-	-
388-429	42-45	190000-205000	170000 - 185000	496	51	1345	5147	4142	8660	4147	4150	E4340
						4063	5155	4145	9840	4161	4161	9850
						4068	5160	4337	-	4340	TS4150	-
						4140	6150	8650	-	86B45	-	-
						4640	9262	8655	-	-	-	-
						5145	94B40	50B60	-	-	-	-
						5150	-	51B60	-	-	-	-
						8640	-	81B45	-	-	-	-
						8642	-	-	-	-	-	-
						8645	-	-	-	-	-	-
						8740	-	-	-	-	-	-
						8742	-	-	-	-	-	-
						9260	-	-	-	-	-	-
						9261	-	-	-	-	-	-
						TS4140	-	-	-	-	-	-
						50B46	-	-	-	-	-	-
						50B44	-	-	-	-	-	-
						50B50	-	-	-	-	-	-

جدول E۲

سختی مطلوب		استحکام کششی معادل psi	استحکام تسلیم معادل psi	سختی بعد از کوئنچ (مینیموم)		کلاس						
						P-1	P-2	P-3	P-4	P-5	P-6	P-7
						قطر شفت (اینچ)						
						≤ 0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5
						ضخامت سطح مقطع قطعه Flat (اینچ)						
HB	HRC			HB	HRC	≤ 0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	2-2.3
229- 293	20 -33	110000-145000	90000- 125000	388	42	8625	4130	94B30	-	-	-	-
						8627	5130	-	-	-	-	-
						-	8630	-	-	-	-	-
						-	50B30	-	-	-	-	-
293-341	33 -38	145000-170000	125000-150000	409	44	4032	1330	1335	-	1340	3140	4137
						4037	5132	5135	-	3135	4135	4337
						4130	94B30	5140	-	4640	-	9840
						5130	-	50B40	-	8637	-	-
						8630	-	-	-	8640	-	-
						TS14B35	-	-	-	8740	-	-
						508B30	-	-	-	-	-	-

جدول E۳

سختی مطلوب		استحکام کششی معادل psi	استحکام تسلیم معادل psi	سختی بعد از کوئنچ (مینیموم)		کلاس						
						Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7
						قطر شفت (اینچ)						
						≤ 0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5
						ضخامت سطح مقطع قطعه Flat (اینچ)						
HB	HRC			HB	HRC	≤ 0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	2-2.3
187-293	20-33	95000-145000	75000-125000	388	42	1330	8637	3140	4140	-	4142	-
						4130	-	8740	TS4140	-	-	-
						5132	-	-	94B40	-	-	-
						8630	-	-	-	-	-	-
						50B30	-	-	-	-	-	-
293-341	23-38	145000-170000	125000-150000	409	44	1335	3140	4137	81B45	4142	4145	4147
						4042	4135	4140	-	-	-	4337
						5135	4640	8642	-	-	-	9840
						50B30	8640	8645	-	-	-	86B45
						94B30	8740	8742	-	-	-	-
						-	-	TS4140	-	-	-	-
341-388	38-42	170000-190000	150000-170000	455	48	1340	1345	4142	51B60	4145	4147	4150
						3140	4137	5147	-	8655	4337	4340
						3135	4140	5155	-	9840	86B45	TS4150
						4047	5150	6150	-	-	-	-
						4135	8642	94B40	-	-	-	-
						5140	8645	-	-	-	-	-
						8637	8742	-	-	-	-	-
						TS14B50	TS4140	-	-	-	-	-
						50B40	50B50	-	-	-	-	-
388-429	42-45	190000-205000	170000-185000	496	51	1345	4142	4145	9840	4147	4150	E4340
						4047	5147	4337	-	4340	TS4150	9850
						4063	5155	5160	-	8660	-	-
						4068	6150	8650	-	86B45	-	-
						4140	9261	8655	-	-	-	-
						4640	94B40	9262	-	-	-	-
						5145	-	50B60	-	-	-	-
						5150	-	51B60	-	-	-	-
						8640	-	81B45	-	-	-	-
						8642	-	-	-	-	-	-
						8645	-	-	-	-	-	-
						8740	-	-	-	-	-	-
						8742	-	-	-	-	-	-
						9260	-	-	-	-	-	-
						TS4140	-	-	-	-	-	-
						50B46	-	-	-	-	-	-
						50B44	-	-	-	-	-	-
						50B50	-	-	-	-	-	-

ARYA SEPEHR KAYHAN

جدول E۴

سختی مطلوب		استحکام کششی معادل psi	استحکام تسلیم معادل psi	سختی بعد از کوئنچ (مینیموم)		کلاس						
						Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7
						قطر شفت (اینچ)						
						≤ 0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5
						ضخامت سطح مقطع قطعه Flat (اینچ)						
HB	HRC			HB	HRC	≤ 0.3	0.3-0.6	0.6-1	1-1.3	1.3-1.6	1.6-2	2-2.3
187-293	20-33	95000-145000	75000-125000	388	42	سری 1000 از 1024 تا 1040	4037	5135	-	5140	4640	3140
							4130	94B30	-	8637	-	8740
							5130	-	-	50B40	-	-
						8625	5132	-	-	-	-	-
						8627	8630	-	-	-	-	-
						-	50B30	-	-	-	-	-
293-341	23-38	145000-170000	125000-150000	409	44	از 1036 تا 1045	1330	1335	-	1340	4135	4137
							5046	-	-	3135	8640	4140
						4032	5135	-	-	3140	8740	8642
						8630	94B30	-	-	8637	-	8645
						-	-	-	-	-	-	8742
						-	-	-	-	-	-	TS4140
341-388	38-42	170000-190000	150000-170000	455	48	1335	3135	1340	-	1345	4140	4142
						4037	4042	3140	-	4137	8645	4337
						4130	4047	4135	-	4640	8742	5147
						5046	-	5140	-	5145	TS4140	6150
						5130	-	8637	-	5150	-	8650
						5132	-	50B40	-	8640	-	9840
						5135	-	-	-	8642	-	81B45
						8635	-	-	-	8740	-	94B40
						TS14B35	-	-	-	50B44	-	-
						50B30	-	-	-	50B50	-	-
						94B30	-	-	-	-	-	-

جدول E۵

حداقل استحکام کششی مورد نیاز (psi)	کلاس			
	R-1	R-2	R-3/R-4	R-5/R-6
	قطر شفت (اینچ)			
	≤ 0.5	0.5-1	1-2	2-3
	ضخامت سطح مقطع قطعه Flat (اینچ)			
	≤ 0.3	0.3-0.6	0.6-1.3	1.3-2
30000-35000	HR1016 HR1020	HR1016 HR1020	HR1018	HR1018
	HR1018	HR1018 HR1022	HR1019	HR1022
	HR1019	HR1019	HR1021	HR1030
35000-40000	HR1022	HR1030	HR1030	HR1035
	HR1030	HR1035	HR1035	-
40000-45000	HR1035	HR1040	CD1010	CD1010 HR1045
	-	-	HR1040	CD1015
	-	-	-	HR1040
45000-50000	CD1010	CD1010	CD1015	CD1020 HR1137
	HR1040	CD1015	HR1045	CD1115
	HR1045	HR1045	HR1137	HR1050
50000-55000	CD1015	CD1020 HR1137	CD1018 CD1115	CD1018 HR1141
	HR1040	CD1115 HR1141	CD1020 HR1050	CD1019 HR1141
	HR1045	HR1050	HR 1141	CD1025
	-	-	CD1025 HR 1144	-
55000-60000	CD1018 CD1015	CD1018 HR1141	CD1019 CD1120	CD1022 CD1120
	CD1025	CD1019	CD1022	CD1117
	CD1019 HR1141	CD1025	CD1117	CD1118
	CD1020 HR1144	-	-	-

جدول E۶

حداقل استحکام کششی مورد نیاز (psi)	کلاس			
	R-1	R-2	R-3/R-4	R-5/R-6
	قطر شفت (اینچ)			
	≤ 0.5	0.5-1	1-2	2-3
	ضخامت سطح مقطع قطعه Flat (اینچ)			
	≤ 0.3	0.3-0.6	0.6-1.3	1.3-2
60000-65000	CD1022	CD1022	CD1030	CD1030
	CD1117	CD1117	CD1118	-
	CD1020	CD1118	-	-
	-	CD1020	-	-
65000-70000	CD1030	CD1030	CD1035	CD1035
	CDT1040	CD1035	CDT1137	CD1050
	CD1118	CDT1045	CDT1040	CDT1141
	-	-	CDT1050	CDT1045
70000-75000	CD1035	CDT1137	CD1040	CD1045
	CDT1045	CDT1040	CDT1141	CDT1040
	-	CDT1050	CDT1045	CDT1137
	-	-	-	CDT1144
	-	-	-	CDT1050
75000-80000	CDT1137	CD1040	CD1045	CD1137
	CDT1040	CDT1141	CDT1040	CDT1045
	CDT1050	CDT1045	CDT1137	CDT1040
	-	-	CDT1144	CDT1141
	-	-	CDT1050	CD1050
80000-85000	CD1040	CD1045	CD1137	CD1141
	CDT1141	CDT1040	CDT1045	CDT1137
	CDT1045	CDT1137	CDT1040	CDT1045
	-	CDT1144	CDT1141	CDT1040
	-	CDT1050	CD1050	CDT1144
	-	-	-	CDT1050
85000-90000	CD1045	CD1137	CD1141	CD1144
	CDT1040	CDT1045	CDT1137	CDT1141
	CDT1137	CDT1040	CDT1045	CDT1137
	CDT1144	CDT1141	CDT1040	CDT1045
	CDT1050	CD1050	CDT1144	CDT1050
	-	-	CDT1050	-
90000-95000	CD1137	CD1141	CD1144	CDT1144
	CDT1045	CDT1137	CDT1141	CDT1141
	CDT1040	CDT1045	CDT1137	CDT1137
	CDT1141	CDT1040	CDT1045	CDT1050
	CD1050	CDT1144	CDT1050	-
	-	CDT1050	-	-
95000-100000	CD1141	CD1144	CDT1144	CDT1144
	CDT1137	CDT1141	CDT1141	CDT1141
	CDT1045	CDT1137	CDT1137	-
	CDT1040	CDT1045	CDT1050	-
	CDT1144	CDT1050	-	-
	CDT1050	-	-	-
100000-105000	CD1144	CDT1144	CDT1144	CDT1144
	CDT1141	CDT1141	CDT1141	-
	CDT1137	CDT1137	-	-
	CDT1045	CDT1050	-	-
	CDT1050	-	-	-
105000-110000	CDT1144	CDT1144	CDT1144	-
	CDT1141	CDT1141	-	-
	CDT1137	-	-	-
	CDT1050	-	-	-
110000-115000	CDT1144	CDT1144	-	-
	CDT1141	-	-	-
115000-120000	CDT1144	-	-	-

SPECIFICATION FOR STEEL BARS, CARBON AND ALLOY, HOT-WROUGHT AND COLD-FINISHED, GENERAL REQUIREMENTS FOR

SA-29/SA-29M

(Identical with ASTM Specification A 29/A 29M-93a)

1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to carbon and alloy steel bars under each of the following ASTM specifications (or under any other ASTM specification which invokes this specification or portions thereof):

Title of Specification	ASTM Designation
Hot-Rolled Carbon Steel Bars:	
Steel Bars, Carbon, Quenched and Tempered	A 321
Steel Bars and Shapes, Carbon Rolled from "T" Rails	A 499
Steel Bars, Carbon, Merchant Quality, M-Grades	A 575
Steel Bars, Carbon, Hot-Wrought, Special Quality	A 576
Steel Bars, Carbon, Merchant Quality, Mechanical Properties	A 663
Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	A 675
Steel Bars for Springs, Carbon and Alloy	A 689
Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications	A 695
Cold-Finished Carbon Steel Bars:	
Steel Bars, Carbon, Cold-Finished, Standard Quality	A 108
Stress-Relieved Steel Bars Subject to Mechanical Property Requirements, Cold-Drawn Carbon	A 311/A 311M
Hot-Rolled Alloy Steel Bars:	
Steel Bars, Alloy, Standard Grades	A 322
Steel Bars, Alloy, Subject to End-Quench Hardenability Requirements	A 304
Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered	A 434
Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	A 739
Cold-Finished Alloy Steel Bars:	
Steel Bars, Alloy, Cold-Finished	A 331
Steel Bars, Alloy, Hot-Rolled or Cold-Finished, Quenched and Tempered	A 434
Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	A 696

1.2 In case of any conflict in requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 For purposes of determining conformance to this specification and the various material specifications referenced in 1.1, dimensional values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 112 Test Methods for Determining the Average Grain Size

2.2 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.3 *Military Standard:*

MIL-STD-163 Steel Mill Products — Preparation for Shipment and Storage

2.4 *Other Standards:*

AIAG B-1 Bar Code Symbology Standard for 3-of-9 Bar Codes

AIAG B-5 02.00 Primary Metals Tag Application Standard

3. Terminology

3.1 *Descriptions of Terms Specific To This Standard:*

3.1.1 *Hot-Wrought Steel Bars* — Steel bars produced by hot forming ingots, blooms, billets, or other semifinished forms to yield straight lengths (or coils, depending upon size, section, and mill equipment) in sections which are uniform throughout their length, and in the following sections and sizes:

3.1.1.1 *Rounds,* $^7/_{32}$ to 10.0 in. [5.5 to 250 mm], inclusive,

3.1.1.2 *Squares,* $^7/_{32}$ to 6.0 in. [6 to 160 mm], inclusive

3.1.1.3 *Round-Cornered Squares,* $^7/_{32}$ to 8.0 in. [6 to 200 mm], inclusive,

3.1.1.4 *Flats,* $^1/_4$ to 8 in. inclusive, in width: $^{12}/_{64}$ in. in minimum thickness up to 6 in. in width; and 0.230 in. in minimum thickness for over 6 to 8 in. in width, inclusive [over 5 mm in thickness up to 150 mm in width; and over 6 mm in thickness for over 150 mm through 200 mm in width]. Maximum thickness for all widths is 4 in. [100 mm].

3.1.1.5 *Hexagons and Octagons,* $^1/_4$ to $4^1/_{16}$ in. [6 to 103 mm], inclusive, between parallel surfaces,

3.1.1.6 *Bar Size Shapes* — Angles, channels, tees, zees, when their greatest cross-sectional dimension is under 3 in. [75 mm], and

3.1.1.7 *Special Bar Sections* — Half-rounds, ovals, half-ovals, other special bar size sections.

3.1.2 *Cold-Finished Steel Bars* — Steel bars produced by cold finishing previously hot-wrought bars by means of cold drawing, cold forming, turning, grinding, or polishing (singly or in combination) to yield straight lengths or coils in sections which are uniform throughout their length and in the following sections and sizes:

3.1.2.1 *Rounds,* 9 in. [230 mm] and under in diameter,

3.1.2.2 *Squares,* 6 in. [150 mm] and under between parallel surfaces,

3.1.2.3 *Hexagons,* 4 in. [100 mm] and under between parallel surfaces,

3.1.2.4 *Flats,* $^1/_8$ in. [3 mm] and over in thickness and not over 12 in. [300 mm] in width, and

3.1.2.5 *Special Bar Sections.*

3.1.3 *Lot* — Unless otherwise specified in the contract or order, a lot shall consist of all bars submitted for inspection at the same time of the same heat, condition, finish, size, or shape. For bars specified in the quenched and tempered condition, when heat treated in batch-type furnaces, a lot shall consist of all bars from the same heat, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge. For bars specified in the quenched and tempered condition, when heat treated without interruption in a continuous-type furnace, a lot shall consist of all bars from the same heat, of the same prior condition, of the same size, and subjected to the same heat treatment.

4. Chemical Composition

4.1 *Limits:*

4.1.1 The chemical composition shall conform to the requirements specified in the purchase order or the individual product specifications. For convenience the grades commonly specified for carbon steel bars are shown in Table 1 and for alloy steel bars in Table 2. Bars may be ordered to these grade designations and when so ordered shall conform to the specified limits by heat analysis.

4.1.2 When compositions other than those shown in Tables 1 and 2 are required, the composition limits shall be prepared using the ranges and limits shown in Table 3 for carbon steel and Table 4 for alloy steel.

4.2 *Heat or Cast Analysis:*

4.2.1 The chemical composition of each heat or cast shall be determined by the manufacturer in accordance with Test Methods, Practices, and Terminology A 751.

4.2.2 The heat or cast analysis shall conform to the requirements specified in the product specification or purchase order. These can be the heat chemical range and limit for a grade designated in Tables 1 or 2, or another range and limit in accordance with 4.1.2, or with requirements of the product specification.

NOTE 1 — Heat analysis for lead is not determinable since lead is added to the ladle stream while each ingot is poured. When specified as an added element to a standard steel, the percentage of lead is reported as 0.15 to 0.33 incl, which is the range commonly specified for this element.

4.2.3 If requested or required, the heat analysis shall be reported to the purchaser or his representative.

4.2.4 Reporting of significant figures and rounding shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.3 *Product Analysis:*

4.3.1 Merchant quality carbon bar steel is not subject to rejection for product analysis unless misapplication of a heat is clearly indicated.

4.3.2 Analyses may be made by the purchaser from finished bars other than merchant quality representing each heat of open-hearth, basic-oxygen, or electric-furnace steel. The chemical composition thus determined shall not vary from the limits specified in the applicable specification by more than the amounts prescribed in Tables 5 and 6, but the several determinations of any element, excluding lead, in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur; therefore, when rimmed or capped steel is specified or required, the limitations for these elements shall not be applicable. Because of the degree to which phosphorus and sulfur segregate, the limitations for these elements shall not be applicable to rephosphorized or resulfurized steels.

4.3.3 Samples for product analysis shall be taken by one of the following methods:

4.3.3.1 Applicable to small sections whose cross-sectional area does not exceed 0.75 in.^{2} [500 mm^2] such as rounds, squares, hexagons, etc. Chips are taken by milling or machining the full cross section of the piece. Drilling is not a feasible method for sampling sizes 0.75 in.^{2} and smaller.

4.3.3.2 Applicable to products where the width of the cross section greatly exceeds the thickness, such as bar size shapes and light flat bars. Chips are taken by drilling entirely through the steel at a point midway between the edge and the middle of the section, or by milling or machining the entire cross section.

4.3.3.3 Applicable to large rounds, squares semi-finished, etc. Chips are taken at any point midway between the outside and the center of the piece by drilling parallel to the axis or by milling or machining the full cross section in cases where these methods are not practicable, the piece may be drilled on the side, but chips are not taken until they represent the portion midway between the outside and the center.

4.3.3.4 When the steel is subject to tension test requirements, the tension test specimen can also be used for product analysis. In that case, chips for product analysis can be taken by drilling entirely through the tension test specimens or by the methods described in 4.3.3.1.

4.3.4 When chips are taken by drilling, the diameter of the drill used shall conform to the following:

Area of Sample Cross Section, in.^{2} (cm^2)	Approximate Drill Diameter, in. (mm)
16 [100] or less	½ [12.5]
Over 16 [100]	1 [25.0]

4.3.5 The minimum number of samples to be taken from material representing the same heat or lot before rejection by the purchaser shall be as follows:

	Minimum Number of Samples
15 tons [15 Mg] and under	4
Over 15 tons [15 Mg]	6

4.3.6 In case the number of pieces in a heat is less than the number of samples required, one sample from each piece shall be considered sufficient.

4.3.7 In the event that product analysis determinations are outside the permissible limits as prescribed in 4.3.2, additional samples shall be analyzed and the acceptability of the heat negotiated between the purchaser and the producer.

4.4 *Referee Analysis* — In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the referee analysis shall be performed in accordance with the latest issue of Test Methods, Practices, and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

5. Grain Size Requirement

5.1 *Austenitic Grain Size*

5.1.1 When a coarse austenitic grain size is specified, the steel shall have a grain size number of 1 to 5 exclusive as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made.

5.1.2 When a fine austenitic grain size is specified, the steel shall have a grain size number of 5 or higher as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the area examined shall constitute the basis of acceptance. One test per heat shall be made unless the provision of 5.1.2.1 is exercised.

5.1.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternately, 0.015% acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 5.1.2 shall be the referee test.

5.1.2.2 If specified on the order, one grain size test per heat shall be made and the austenitic grain size of the steel, as represented by the test, shall be number 5 or higher.

5.1.2.3 By agreement between purchaser and supplier, columbium or vanadium or both may be used for grain refining instead of or with aluminum. The maximum contents shall be:

Cb	0.05 max.
V	0.08 max.
Cb + V	0.06 max.

The content of the elements shall be reported with the heat analysis.

5.1.2.4 The austenitic grain size test shall be required.

6. Mechanical Property Requirements

6.1 *Test Specimens:*

6.1.1 *Selection* — Test specimens shall be selected in accordance with the requirements of the applicable product specification or in accordance with Supplement I of the latest issue of Test Methods and Definitions A 370, in the sequence named.

6.1.2 *Preparation* — Unless otherwise specified in the applicable product specification, test specimens shall be prepared in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof.

6.2 *Methods of Mechanical Testing* — All mechanical tests shall be conducted in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof, on steel bar products.

6.3 *Retests:*

6.3.1 If any test specimen shows defective machining or develops flaws, the specimen may be discarded and another substituted.

6.3.2 If the percentage elongation of any tension specimen is less than that specified and any part of the fracture is more than $^3\!/_4$ in. [20 mm] from the center of a 2 in. [50 mm] specimen, or is outside the middle half of the gage length of an 8 in. [200 mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

6.3.3 For "as-wrought" material, if the results for any original tension specimen are within 200 psi [14 MPa] of the required tensile strength, within 1000 psi [7 MPa] of the required yield point, or within 2% of the required elongation, retesting shall be permitted. If the original testing required only one test, the retest shall consist of two random tests from the heat or lot involved. If the original testing required two tests of which one failed by the amounts listed in this paragraph, the retest shall be made on one random test from the heat or lot. If the results on the retest specimen or specimens meet the specified requirements, the heat or test lot will be accepted. If the results of one retest specimen do not meet the specified requirements, the material is subject to rejection.

6.3.4 For thermally treated bars, if the results of the mechanical tests do not conform to the requirements specified, two more tests may be selected for each bar failing, and each of these retests shall conform to the requirements of the product specification.

6.3.5 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted from the heat or test lot involved for which one random specimen for each original specimen showing failure shall be used. If the results on the retest specimen meet the requirements of the specification, the heat or test lot will be accepted.

7. Dimensions, Mass, and Permissible Variations

7.1 *Hot-Wrought Bars* — The permissible variations for dimensions of hot-wrought carbon and alloy steel bars shall not exceed the applicable limits stated in Tables A1.1 to A1.10 for inch-pound values and Tables A2.1 to A2.10 and S1.1 for metric values.

7.2 *Cold-Finished Bars* — The permissible variations for dimensions of cold-finished carbon and alloy steel bars shall not exceed the applicable limits stated in Tables A1.11 to A1.14 for inch-pound values and Tables A2.11 to A2.14 for metric values.

8. Workmanship, Finish, and Appearance

8.1 The material shall be free of injurious defects and shall have a workmanlike finish.

9. Rework and Retreatment

9.1 For thermally treated bars only, the manufacturer may retreat a lot one or more times, and retests shall be made in the same manner as the original tests. Each such retest shall conform to the requirements specified.

10. Inspection

10.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10.2 All required tests and inspection shall be made by the manufacturer prior to shipment.

11. Rejection

11.1 Unless otherwise specified, any rejection because of noncompliance to the requirements of the specification shall be reported by the purchaser to the manufacturer within 30 working days after receipt of samples.

11.2 Material that shows imperfections capable of adversely affecting processability subsequent to its acceptance at the purchaser's works will be rejected, and the manufacturer shall be notified.

12. Rehearing

12.1 Samples that represent rejected material shall be preserved for two weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Product Marking

13.1 *Civilian Procurement* — Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser's name and order number, the ASTM designation (year date is not required), grade number where appropriate, size and length, weight of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and may be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars.

13.1.1 Bar code marking may be used as an auxiliary method of identification. Such bar-code markings shall be of the 3-of-9 type and shall conform to AIAG B1. When bar-coded tags are used, they shall conform to AIAG B5.

13.2 *Government Procurement:*

13.2.1 Marking for shipment shall be in accordance with the requirements specified in the contract or order and shall be in accordance with MIL-STD-163 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

13.2.2 For government procurement by the Defense Supply Agency, the bars shall be continuously marked for identification in accordance with Fed. Std. No. 183.

14. Packaging

14.1 *Civilian Procurement* — Unless otherwise specified, the bars shall be packaged and loaded in accordance with Practices A 700.

14.2 *Government Procurement* — MIL-STD-163 shall apply when packaging is specified in the contract or order, or when Level A for preservation, packaging, and packing is specified for direct procurement by or direct shipment to the government.

15. Keywords

15.1 alloy steel bars; carbon steel bars; cold finished steel bars; general delivery requirement; hot wrought steel bars; steel bars

TABLE 1
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF CARBON STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, % Carbon	Manganese	Phosphorus, max	Sulfur, max[A]
	Nonresulfurized Carbon Steels[B,C,D,G,H]			
1005	0.06 max	0.35 max	0.040	0.050
1006	0.08 max	0.25–0.40	0.040	0.050
1008	0.10 max	0.30–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1011	0.08–0.13	0.60–0.90	0.040	0.050
1012	0.10–0.15	0.30–0.60	0.040	0.050
1013	0.11–0.16	0.50–0.80	0.040	0.050
1015	0.13–0.18	0.30–0.60	0.040	0.050
1016	0.13–0.18	0.60–0.90	0.040	0.050
1017	0.15–0.20	0.30–0.60	0.040	0.050
1018	0.15–0.20	0.60–0.90	0.040	0.050
1019	0.15–0.20	0.70–1.00	0.040	0.050
1020	0.18–0.23	0.30–0.60	0.040	0.050
1021	0.18–0.23	0.60–0.90	0.040	0.050
1022	0.18–0.23	0.70–1.00	0.040	0.050
1023	0.20–0.25	0.30–0.60	0.040	0.050
1025	0.22–0.28	0.30–0.60	0.040	0.050
1026	0.22–0.28	0.60–0.90	0.040	0.050
1029	0.25–0.31	0.60–0.90	0.040	0.050
1030	0.28–0.34	0.60–0.90	0.040	0.050
1034	0.32–0.38	0.50–0.80	0.040	0.050
1035	0.32–0.38	0.60–0.90	0.040	0.050
1037	0.32–0.38	0.70–1.00	0.040	0.050
1038	0.35–0.42	0.60–0.90	0.040	0.050
1039	0.37–0.44	0.70–1.00	0.040	0.050
1040	0.37–0.44	0.60–0.90	0.040	0.050
1042	0.40–0.47	0.60–0.90	0.040	0.050
1043	0.40–0.47	0.70–1.00	0.040	0.050
1044	0.43–0.50	0.30–0.60	0.040	0.050
1045	0.43–0.50	0.60–0.90	0.040	0.050
1046	0.43–0.50	0.70–1.00	0.040	0.050
1049	0.46–0.53	0.60–0.90	0.040	0.050
1050	0.48–0.55	0.60–0.90	0.040	0.050
1053	0.48–0.55	0.70–1.00	0.040	0.050
1055	0.50–0.60	0.60–0.90	0.040	0.050
1059	0.55–0.65	0.50–0.80	0.040	0.050
1060	0.55–0.65	0.60–0.90	0.040	0.050
1064	0.60–0.70	0.50–0.80	0.040	0.050
1065	0.60–0.70	0.60–0.90	0.040	0.050
1069	0.65–0.75	0.40–0.70	0.040	0.050
1070	0.65–0.75	0.60–0.90	0.040	0.050
1071	0.65–0.70	0.75–1.05	0.040	0.050
1074	0.70–0.80	0.50–0.80	0.040	0.050
1075	0.70–0.80	0.40–0.70	0.040	0.050
1078	0.72–0.85	0.30–0.60	0.040	0.050
1080	0.75–0.88	0.60–0.90	0.040	0.050
1084	0.80–0.93	0.60–0.90	0.040	0.050
1086	0.80–0.93	0.30–0.50	0.040	0.050
1090	0.85–0.98	0.60–0.90	0.040	0.050
1095	0.90–1.03	0.30–0.50	0.040	0.050
	Resulfurized Carbon Steels[B,D,H]			
1108	0.08–0.13	0.60–0.80	0.040	0.08–0.13
1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13
1110	0.08–0.13	0.30–0.60	0.040	0.08–0.13
1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23
1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13
1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33
1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13
1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
1139	0.35–0.43	1.35–1.65	0.040	0.13–0.20
1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13
1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33
1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07
1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13
1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13

TABLE 1 (CONT'D)
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF CARBON STEEL BARS

Grade Designation	Rephosphorized and Resulfurized Carbon Steels[D,E,H] Carbon	Manganese	Phosphorus	Sulfur	Lead
1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15	. . .
1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	. . .
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	. . .
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	. . .
12L13	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	0.15–0.35
12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35
12L15	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	0.15–0.35

Grade Designation	High-Manganese Carbon Steels[B,C,D,G,H] Former Designation	Carbon	Manganese	Phosphorus, max	Sulfur, max
1513	. . .	0.10–0.16	1.10–1.40	0.040	0.050
1518	. . .	0.15–0.21	1.10–1.40	0.040	0.050
1522	. . .	0.18–0.24	1.10–1.40	0.040	0.050
1524	1024	0.19–0.25	1.35–1.65	0.040	0.050
1525	. . .	0.23–0.29	0.80–1.10	0.040	0.050
1526	. . .	0.22–0.29	1.10–1.40	0.040	0.050
1527	1027	0.22–0.29	1.20–1.50	0.040	0.050
1536	1036	0.30–0.37	1.20–1.50	0.040	0.050
1541	1041	0.36–0.44	1.35–1.65	0.040	0.050
1547	. . .	0.43–0.51	1.35–1.65	0.040	0.050
1548	1048	0.44–0.52	1.10–1.40	0.040	0.050
1551	1051	0.45–0.56	0.85–1.15	0.040	0.050
1552	1052	0.47–0.55	1.20–1.50	0.040	0.050
1561	1061	0.55–0.65	0.75–1.05	0.040	0.050
1566	1066	0.60–0.71	0.85–1.15	0.040	0.050
1572	1072	0.65–0.76	1.00–1.30	0.040	0.050

Grade Designation	Heat Chemical Ranges and Limits, percent — Merchant Quality M Series Carbon Steel Bars — Carbon	Manganese[F]	Phosphorus, max	Sulfur, max
M 1008	0.10 max	0.25–0.60	0.04	0.05
M 1010	0.07–0.14	0.25–0.60	0.04	0.05
M 1012	0.09–0.16	0.25–0.60	0.04	0.05
M 1015	0.12–0.19	0.25–0.60	0.04	0.05
M 1017	0.14–0.21	0.25–0.60	0.04	0.05
M 1020	0.17–0.24	0.25–0.60	0.04	0.05
M 1023	0.19–0.27	0.25–0.60	0.04	0.05
M 1025	0.20–0.30	0.25–0.60	0.04	0.05
M 1031	0.26–0.36	0.25–0.60	0.04	0.05
M 1044	0.40–0.50	0.25–0.60	0.04	0.05

[A] Maximum unless otherwise indicated.

[B] When silicon is required, the following ranges and limits are commonly specified: 0.10%, max, 0.10% to 0.20%, 0.15% to 0.35%, 0.20% to 0.40%, or 0.30% to 0.60%.

[C] Copper can be specified when required as 0.20% minimum.

[D] When lead is required as an added element to a standard steel, a range of 0.15 to 0.35% inclusive is specified. Such a steel is identified by inserting the letter "L" between the second and third numerals of the grade designation, for example, 10 L 45. A cast or heat analysis is not determinable when lead is added to the ladle stream.

[E] It is not common practice to produce these steels to specified limits for silicon because of its adverse effect on machinability.

[F] Unless prohibited by the purchaser, the manganese content may exceed 0.60% on heat analysis to a maximum of 0.75%, provided the carbon range on heat analysis has the minimum and maximum reduced by 0.01% for each 0.05% manganese over 0.60%.

[G] When boron treatment for killed steels is specified, the steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

[H] The elements bismuth, calcium, selenium, or tellurium may be added as agreed upon between purchaser and supplier.

TABLE 2
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS

NOTE 1 — Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35%; nickel, 0.25%; chromium, 0.20%; and molybdenum, 0.06%.

NOTE 2 — Where minimum and maximum sulfur content is shown it is indicative of resulfurized steel.

NOTE 3 — The chemical ranges and limits shown in Table 2 are produced to product analysis tolerances shown in Table 6.

NOTE 4 — Standard alloy steels can be produced with a lead range of 0.15–0.35%. Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, for example, 41 L 40. A cast or heat analysis is not determinable when lead is added to the ladle stream.

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon[A]	Nickel	Chromium	Molybdenum
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	. . .	0.15–0.25
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	. . .	. . .	0.20–0.30
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	. . .	. . .	0.20–0.30
4032	0.30–0.35	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4042	0.40–0.45	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	0.08–0.15
4120	0.18–0.23	0.90–1.20	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	0.13–0.20
4121	0.18–0.23	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.45–0.65	0.20–0.30
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4135	0.33–0.38	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4137	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4142	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4145	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4147	0.45–0.50	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4150	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4161	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	0.25–0.35
4320	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	0.40–0.60	0.20–0.30
4340	0.38–0.43	0.60–0.80	0.035	0.040	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
E4340	0.38–0.43	0.65–0.85	0.025	0.025	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.15 to 0.35	. . .	. . .	0.45–0.60
4422	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.35–0.45
4427	0.24–0.29	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.35–0.45
4615	0.13–0.18	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	. . .	0.20–0.30
4620	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	. . .	0.20–0.30
4621	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	1.65–2.00	. . .	0.20–0.30
4626	0.24–0.29	0.45–0.65	0.035	0.040	0.15 to 0.35	0.70–1.00	. . .	0.15–0.25
4715	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.70–1.00	0.45–0.65	0.45–0.60
4718	0.16–0.21	0.70–0.90	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.30–0.40
4720	0.17–0.22	0.50–0.70	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.15–0.25
4815	0.13–0.18	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	. . .	0.20–0.30
4817	0.15–0.20	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	. . .	0.20–0.30
4820	0.18–0.23	0.50–0.70	0.035	0.040	0.15 to 0.35	3.25–3.75	. . .	0.20–0.30
5015	0.12–0.17	0.30–0.50	0.035	0.040	0.15 to 0.35	. . .	0.30–0.50	. . .
5046	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.20–0.35	. . .
5115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5120	0.17–0.22	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	. . .
5132	0.30–0.35	0.60–0.80	0.035	0.040	0.15 to 0.35	. . .	0.75–1.00	. . .
5135	0.33–0.38	0.60–0.80	0.035	0.040	0.15 to 0.35	. . .	0.80–1.05	. . .
5140	0.38–0.43	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .

TABLE 2 (CONT'D)
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon[A]	Nickel	Chromium	Molybdenum
5145	0.43–0.48	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5147	0.46–0.51	0.70–0.95	0.035	0.040	0.15 to 0.35	. . .	0.85–1.15	. . .
5150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5155	0.51–0.59	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5160	0.56–0.61	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
E50100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	. . .	0.40–0.60	. . .
E51100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	. . .	0.90–1.15	. . .
E52100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	. . .	1.30–1.60	. . .
6118	0.16–0.21	0.50–0.70	0.035	0.040	0.15 to 0.35	. . .	0.50–0.70	(0.10–0.15 V)
6150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	(0.15 min V)
8115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.20–0.40	0.30–0.50	0.08–0.15
8615	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8617	0.15–0.20	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8622	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8625	0.23–0.28	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8627	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8637	0.35–0.40	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8640	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8642	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8645	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8650	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8655	0.51–0.59	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8660	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8720	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8740	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8822	0.20–0.25	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.30–0.40
9254	0.51–0.59	0.60–0.80	0.035	0.040	1.20–1.60	. . .	0.60–0.80	. . .
9255	0.51–0.59	0.70–0.95	0.035	0.040	1.80–2.20	. . .	. . .	. . .
9259	0.56–0.64	0.75–1.00	0.035	0.040	0.70–1.10	. . .	0.45–0.65	. . .
9260	0.56–0.64	0.75–1.00	0.035	0.040	1.80–2.20	. . .	. . .	. . .
E9310	0.08–0.13	0.45–0.65	0.025	0.025	0.15 to 0.30	3.00–3.50	1.00–1.40	0.08–0.15
Standard Boron Steels[B]								
50B44	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.20–0.60	. . .
50B46	0.44–0.49	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.20–0.35	. . .
50B50	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	. . .
50B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	. . .
51B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
81B45	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.20–0.40	0.35–0.55	0.08–0.15
94B17	0.15–0.20	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.80–0.15
94B30	0.28–0.33	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.08–0.15

[A] Silicon may be specified by the purchaser as 0.10% maximum. The need for 0.10% maximum generally relates to severe cold-formed parts.

[B] These steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

TABLE 3
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF CARBON STEEL BARS

Element	Chemical Ranges and Limits, %: When Maximum of Specified Elements is:	Range	Lowest Maximum
Carbon[A]	. . .	. . .	0.06
	to 0.12, incl	. . .	. . .
	over 0.12 to 0.26, incl	0.05	. . .
	over 0.25 to 0.40, incl	0.06	. . .
	over 0.40 to 0.55, incl	0.07	. . .
	over 0.55 to 0.80, incl	0.10	. . .
	over 0.80	0.13	. . .
Manganese	. . .	. . .	0.35
	to 0.40, incl	0.15	. . .
	over 0.40 to 0.50, incl	0.20	. . .
	over 0.50 to 1.65, incl	0.30	. . .
Phosphorus	to 0.040, incl	. . .	0.040[D]
	over 0.040 to 0.08, incl	0.03	. . .
	over 0.08 to 0.13, incl	0.05	. . .
Sulfur	to 0.050, incl	. . .	0.050[D]
	over 0.050 to 0.09, incl	0.03	. . .
	over 0.09 to 0.15, incl	0.05	. . .
	over 0.15 to 0.23, incl	0.07	. . .
	over 0.23 to 0.50, incl	0.09	. . .
Silicon[B]	. . .	. . .	0.10
	to 0.10, incl	. . .	. . .
	over 0.10 to 0.15, incl	0.08	. . .
	over 0.15 to 0.20, incl	0.10	. . .
	over 0.20 to 0.30, incl	0.15	. . .
	over 0.30 to 0.60, incl	0.20	. . .
Copper	When copper is required 0.20 min is generally used		
Lead[C]	When lead is required, a range of 0.15 to 0.35 is specified		
Bismuth[E]			
Calcium[E]			
Selenium[E]			
Tellurium[E]			

[A] The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.10%. When the maximum manganese limit exceeds 1.10%, add 0.01 to the carbon ranges shown above.

[B] It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.

[C] A cast or heat analysis is not determinable when lead is added to the ladle stream.

[D] For steels produced in merchant quality the phosphorus maximum is 0.04% and the sulfur maximum is 0.05%.

[E] Element specification range as agreed upon between purchaser and supplier.

TABLE 4
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF ALLOY STEEL BARS

NOTE 1 — Boron steels can be expected to have 0.0005% minimum boron content.

NOTE 2 — Alloy steels can be produced with a lead range of 0.15–0.35%. A cast or heat analysis is not determinable when lead is added to the ladle stream.

Element	Chemical Ranges and Limits, %: When Maximum of Specified Element is:	Open-Hearth or Basic- Oxygen Steel	Electric Furnace Steel	Maximum Limit, %[A]
Carbon	To 0.55, incl	0.05	0.05	
	Over 0.55–0.70, incl	0.08	0.07	
	Over 0.70 to 0.80, incl	0.10	0.09	
	Over 0.80–0.95, incl	0.12	0.11	
	Over 0.95–1.35, incl	0.13	0.12	
Manganese	To 0.60, incl	0.20	0.15	
	Over 0.60–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.90, incl	0.30	0.30	
	Over 1.90–2.10, incl	0.40	0.35	
Phosphorus	Basic open-hearth or basic-oxygen steel			0.035
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
	Acid electric-furnace steel			0.050
Sulfur	To 0.050, incl	0.015	0.015	
	Over 0.050–0.07, incl	0.02	0.02	
	Over 0.07–0.10, incl	0.04	0.04	
	Over 0.10–0.14, incl	0.05	0.05	
	Basic open-hearth or basic-oxygen steel			0.040
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
	Acid electric-furnace steel			0.050
Silicon	To 0.20, incl	0.08	0.08	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.60, incl	0.20	0.20	
	Over 0.60–1.00, incl	0.30	0.30	
	Over 1.00–2.20, incl	0.40	0.35	
	Acid steels[B]			
Nickel	To 0.50, incl	0.20	0.20	
	Over 0.50–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	
	Over 2.00–3.00, incl	0.40	0.40	
	Over 3.00–5.30, incl	0.50	0.50	
	Over 5.30–10.00, incl	1.00	1.00	
Chromium	To 0.40, incl	0.15	0.15	
	Over 0.40–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.60, incl	0.30	0.30	
	Over 1.60–1.75, incl	[C]	0.35	
	Over 1.75–2.10, incl	[C]	0.40	
	Over 2.10–3.99, incl	[C]	0.50	
Molybdenum	To 0.10, incl	0.05	0.05	
	Over 0.10–0.20, incl	0.07	0.07	
	Over 0.20–0.50, incl	0.10	0.10	
	Over 0.50–0.80, incl	0.15	0.15	
	Over 0.80–1.15, incl	0.20	0.20	
Tungsten	To 0.50, incl	0.20	0.20	
	Over 0.50–1.00, incl	0.30	0.30	
	Over 1.00–2.00, incl	0.50	0.50	
	Over 2.00–4.00, incl	0.60	0.60	
Vanadium	To 0.25, incl	0.05	0.05	
	Over 0.25–0.50, incl	0.10	0.10	
Aluminum	Up to 0.10, incl	0.05	0.05	
	Over 0.10–0.20, incl	0.10	0.10	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.80, incl	0.25	0.25	
	Over 0.80–1.30, incl	0.35	0.35	
	Over 1.30–1.80, incl	0.45	0.45	
Copper	To 0.60, incl	0.20	0.20	
	Over 0.60–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	

[A] Applies to only nonrephosphorized and nonresulfurized steels.

[B] Minimum silicon limit for acid open-hearth or acid electric-furnace alloy steels is 0.15%.

[C] Not normally produced in open-hearth.

TABLE 5
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS OF CARBON STEEL

Element	Limit, or Maximum of Specified Range, %	Over Maximum Limit, %	Under Minimum Limit, %
Carbon[A]	0.25 and under	0.02	0.02
	over 0.25 to 0.55, incl	0.03	0.03
	over 0.55	0.04	0.04
Manganese	0.90 and under	0.03	0.03
	over 0.90 to 1.65, incl	0.06	0.06
Phosphorus[A,B]	basic steels	0.008	. . .
	acid bessemer steel	0.01	0.01
Sulfur[A,B]		0.008	. . .
Silicon	0.35 and under	0.02	0.02
	over 0.35 to 0.60, incl	0.05	0.05
Copper	under minimum only	. . .	0.02
Lead[C]	0.15 to 0.35, incl	0.03	0.03

[A] Rimmed and capped steels are not subject to rejection on product analysis unless misapplication is clearly indicated.
[B] Resulfurized or rephosphorized steels are not subject to rejection on product analysis for these elements unless misapplication is clearly indicted.
[C] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

TABLE 6
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS OF ALLOY STEEL

Elements	Limit, or Maximum of Specified Range, %	Permissible Variations Over Maximum Limit or Under Minimum Limit, %
Carbon	0.30 and under	0.01
	over 0.30 to 0.75, incl	0.02
	over 0.75	0.03
Manganese	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.04
Phosphorus	over maximum only	0.005
Sulfur	0.060 and under	0.005
Silicon	0.40 and under	0.02
	over 0.40 to 2.20, incl	0.05
Nickel	1.00 and under	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.30, incl	0.07
	over 5.30 to 10.00, incl	0.10
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.05
	over 2.10 to 3.99, incl	0.10
Molybdenum	0.20 and under	0.01
	over 0.20 to 0.40, incl	0.02
	over 0.40 to 1.15, incl	0.03
Vanadium	0.10 and under	0.01
	over 0.10 to 0.25, incl	0.02
	over 0.25 to 0.50, incl	0.03
	minimum value specified, under minimum limit only	0.01
Tungsten	1.00 and under	0.04
	over 1.00 to 4.00, incl	0.08
Aluminum	0.10 and under	0.03
	over 0.10 to 0.20, incl	0.04
	over 0.20 to 0.30, incl	0.05
	over 0.30 to 0.80, incl	0.07
	over 0.80 to 1.80, incl	0.10
Lead[A]	0.15 to 0.35, incl	0.03
Copper	to 1.00 incl	0.03
	over 1.00 to 2.00, incl	0.05

[A] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Flat Bar Thickness Tolerances

S1.1 When flat bars are specified in metric units to a thickness under tolerance of 0.3 mm, the thickness tolerance of Table S1.1 shall apply.

TABLE S1.1
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS ORDERED TO 0.3 MM UNDER TOLERANCE[A]

	Tolerances over Specified Thickness for Thickness Given, mm					Tolerance from Specified Width, mm	
Specified Width, mm	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75, incl	Over 75	Over	Under
To 25, incl	. . .	. . .	. . .	. . .	. . .	0.5	0.5
Over 25 to 50, incl	. . .	0.5	1.3	. . .	. . .	1.0	1.0
Over 50 to 100, incl	0.5	0.7	1.3	2.1	2.1	1.5	1.0
Over 100 to 150, incl	0.5	0.7	1.3	2.1	2.1	2.5	1.5
Over 150 to 200, incl	0.5	1.0	1.3	2.1	2.9	3.0	2.5

[A] When a square is held against a face and an edge of a square-edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

NOTE — Tolerance under specified thickness 0.3 mm.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions expressed in inch-pound units of measurements.

TABLE A1.1
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR HOT-WROUGHT ROUND, SQUARE, AND ROUND-CORNERED SQUARE BARS OF STEEL

Specified Size, in.	Permissible Variation from Specified Size, in.[A]		Out-of-Round or Out-of-Square, in.[B]
	Over	Under	
To 5/16, incl	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 5/8, incl	0.007	0.007	0.010
Over 5/8 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1 1/8, incl	0.010	0.010	0.015
Over 1 1/8 to 1 1/4, incl	0.011	0.011	0.016
Over 1 1/4 to 1 3/8, incl	0.012	0.012	0.018
Over 1 3/8 to 1 1/2, incl	0.014	0.014	0.021
Over 1 1/2 to 2, incl	1/64	1/64	0.023
Over 2 to 2 1/2, incl	1/32	0	0.023
Over 2 1/2 to 3 1/2, incl	3/64	0	0.035
Over 3 1/2 to 4 1/2, incl	1/16	0	0.046
Over 4 1/2 to 5 1/2, incl	5/64	0	0.058
Over 5 1/2 to 6 1/2, incl	1/8	0	0.070
Over 6 1/2 to 8 1/4, incl	5/32	0	0.085
Over 8 1/4 to 9 1/2, incl	3/16	0	0.100
Over 9 1/2 to 10, incl	1/4	0	0.120

[A] Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.
[B] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

TABLE A1.2
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR HOT-WROUGHT HEXAGONAL BARS OF STEEL

Specified Sizes Between Opposite Sides, in.	Permissible Variations from Specified Size, in.[A]		Out-of-Hexagon (Carbon Steel and Alloy Steel) or Out-of-Octagon (Alloy Steel), in.[B]
	Over	Under	
To 1/2, incl	0.007	0.007	0.011
Over 1/2 to 1, incl	0.010	0.010	0.015
Over 1 to 1 1/2, incl	0.021	0.013	0.025
Over 1 1/2 to 2, incl	1/32	1/64	1/32
Over 2 to 2 1/2, incl	3/64	1/64	3/64
Over 2 1/2 to 3 1/2, incl	1/16	1/64	1/16
Over 3 1/2 to 4 1/16, incl	5/64	1/64	5/64

[A] Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.
[B] Out-of-hexagon or out-of-octagon is the greatest difference between any two dimensions at the same cross section between opposite faces.

TABLE A1.3
PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-WROUGHT SQUARE EDGE AND ROUND EDGE FLAT BARS[A]

Specified Width, in.	Permissible Variations in Thickness, for Thickness Given, Over and Under, in.[B]							Permissible Variations in Width, in.	
	0.203 to 0.230, excl	0.230 to $\frac{1}{4}$, excl	$\frac{1}{4}$ to $\frac{1}{2}$, incl	Over $\frac{1}{2}$ to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	. . .	. . .	. . .	$\frac{1}{64}$	$\frac{1}{64}$
Over 1 to 2, incl	0.007	0.007	0.012	0.015	$\frac{1}{32}$	. . .	. . .	$\frac{1}{32}$	$\frac{1}{32}$
Over 2 to 4, incl	0.008	0.008	0.015	0.020	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{1}{32}$
Over 4 to 6, incl	0.009	0.009	0.015	0.020	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{32}$	$\frac{1}{16}$
Over 6 to 8, incl	[C]	0.015	0.016	0.025	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{32}$

[A] When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

[B] Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

[C] Flats over 6 to 8 in., incl, in width, are not available as hot-wrought steel bars in thickness under 0.230 in.

TABLE A1.4
PERMISSIBLE VARIATIONS IN THICKNESS, LENGTH, AND OUT-OF-SQUARE FOR HOT-WROUGHT BAR SIZE ANGLES OF CARBON STEEL

Specified Length of Leg, in.[A]	Permissible Variations in Thickness, for Thicknesses Given, Over and Under, in.			Permissible Variations for Length of Leg, Over and Under, in.
	To $\frac{3}{16}$, incl	Over $\frac{3}{16}$ to $\frac{3}{8}$, incl	Over $\frac{3}{8}$	
To 1, incl	0.008	0.010	. . .	$\frac{1}{32}$
Over 1 to 2, incl	0.010	0.010	0.012	$\frac{3}{64}$
Over 2 to 3, excl	0.012	0.015	0.015	$\frac{1}{16}$

[A] The longer leg of an unequal angle determines the size for tolerance. The out-of-square tolerance in either direction is $1\frac{1}{2}$°.

TABLE A1.5
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE CHANNELS OF CARBON STEEL

Specified Size of Channel, in.	Permissible Variations in Size, Over and Under, in.				Out-of-Square if Either Flange, in./in. of Flange Width
	Depth of Section[A]	Width of Flanges[A]	Thickness of Web for Thickness Given: To $\frac{3}{16}$, incl	Over $\frac{3}{16}$	
To $1\frac{1}{2}$, incl	$\frac{1}{32}$	$\frac{1}{32}$	0.010	0.015	$\frac{1}{32}$
Over $1\frac{1}{2}$ to 3, excl	$\frac{1}{16}$	$\frac{1}{16}$	0.015	0.020	$\frac{1}{32}$

[A] Measurements for depth of section and width of flanges are over-all.

[B] For channels $\frac{5}{8}$ in. and under in depth, the out-of-square tolerance is $\frac{3}{64}$ in./in. of depth.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE TEES OF CARBON STEEL

Specified Size of Tee, in.[A]	Permissible Variations in Size, in.						
	Width or Depth[B]		Thickness of Flange		Thickness of Stem		Stem out-of-Square[C]
	Over	Under	Over	Under	Over	Under	
To $1\frac{1}{4}$, incl	$\frac{3}{64}$	$\frac{3}{64}$	0.010	0.010	0.005	0.020	$\frac{1}{32}$
Over $1\frac{1}{4}$ to 2, incl	$\frac{1}{16}$	$\frac{1}{16}$	0.012	0.012	0.010	0.020	$\frac{1}{16}$
Over 2 to 3, excl	$\frac{3}{32}$	$\frac{3}{32}$	0.015	0.015	0.015	0.020	$\frac{3}{32}$

[A] The longer member of the unequal tee determines the size for tolerances.

[B] Measurements for both width and depth are over-all.

[C] Step out-of-square is the variation from its true position of the center line of the stem measured at the point.

TABLE A1.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HALF-ROUND, OVALS, HALF-OVALS, AND OTHER SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, half-ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A1.8
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, FLATS, AND BAR SIZE SECTIONS OF STEEL

Specified Size of Rounds, Squares, and Hexagons, in.	Specified Size of Flats, in.		Permissible Variations Over Specified Length, in.[A]				
	Thickness	Width	5 to 10 ft, excl	10 to 20 ft, excl	20 to 30 ft, excl	30 to 40 ft, excl	40 to 60 ft, excl
Mill Shearing							
To 1, incl	to 1, incl	to 3, incl	1/2	3/4	1 1/4	1 3/4	2 1/4
Over 1 to 2, incl	over 1	to 3, incl	5/8	1	1 1/2	2	2 1/2
	to 1, incl	over 3 to 6, incl	5/8	1	1 1/2	2	2 1/2
Over 2 to 5, incl	over 1	over 3 to 6, incl	1	1 1/2	1 3/4	2 1/4	2 3/4
Over 5 to 10, incl	. . .	. . .	2	2 1/2	2 3/4	3	3 1/4
	0.230 to 1, incl	over 6 to 8, incl	3/4	1 1/4	1 3/4	3 1/2	4
	over 1 to 3, incl	over 6 to 8, incl	1 1/4	1 3/4	2	3 1/2	4
Bar Size Sections	. . .	. . .	5/8	1	1 1/2	2	2 1/2
Hot Sawing							
2 to 5, incl	1 and over	3 and over	[B]	1 1/2	1 3/4	2 1/4	2 3/4
Over 5 to 10, incl	. . .	. . .	[B]	2 1/2	2 3/4	3	3 1/4

[A] No permissible variations under.
[B] Smaller sizes and shorter lengths are not hot sawed.

TABLE A1.9
PERMISSIBLE VARIATIONS IN LENGTH FOR RECUTTING OF BARS MEETING SPECIAL STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in.[A]	Tolerances Over Specified Length, in.[A]	
	To 12 ft, incl	Over 12 ft
To 3, incl	1/4	5/16
Over 3 to 6, incl	5/16	7/16
Over 6 to 8, incl	7/16	9/16
Rounds over 8 to 10, incl	9/16	11/16

[A] No tolerance under.

TABLE A1.10
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR HOT-WROUGHT BARS AND BAR SIZE SECTIONS OF STEEL[A]

Standard tolerances	1/4 in. in any 5 ft or (1/4 in. × length in ft)/5
Special tolerances	1/8 in. in any 5 ft or (1/8 in. × length in ft)/5

[A] Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

TABLE A1.11
SIZE TOLERANCES FOR COLD-FINISHED CARBON STEEL BARS, COLD DRAWN OR TURNED AND POLISHED[A]

Size, in.[B]	Maximum of Carbon Range 0.28% or less	Maximum of Carbon Range Over 0.28% to 0.55%, incl	Maximum of Carbon Range to 0.55%, incl, Stress Relieved or Annealed after Cold Finishing	Maximum of Carbon Range Over 0.55% or All Grades Quenched and Tempered or Normalized and Tempered before Cold Finishing
	All tolerances are in inches[B] and are minus[C]			
Rounds — Cold Drawn (to 4 in.) or Turned and Polished				
To 1½, incl	0.002	0.003	0.004	0.005
Over 1½ to 2½, incl	0.003	0.004	0.005	0.006
Over 2½ to 4, incl	0.004	0.005	0.006	0.007
Over 4 to 6, incl	0.005	0.006	0.007	0.008
Over 6 to 8, incl	0.006	0.007	0.008	0.009
Over 8 to 9, incl	0.007	0.008	0.009	0.010
Hexagons				
To ¾, incl	0.002	0.003	0.004	0.006
Over ¾ to 1½, incl	0.003	0.004	0.005	0.007
Over 1½ to 2½, incl	0.004	0.005	0.006	0.008
Over 2½ to 3⅛, incl	0.005	0.006	0.007	0.009
Over 3⅛ to 4, incl	0.005	0.006	...	...
Squares[C]				
To ¾, incl	0.002	0.004	0.005	0.007
Over ¾ to 1½, incl	0.003	0.005	0.006	0.008
Over 1½ to 2½, incl	0.004	0.006	0.007	0.009
Over 2½ to 4, incl	0.006	0.008	0.009	0.011
Over 4 to 5, incl	0.010	...	...	...
Over 5 to 6, incl	0.014	...	...	...
Flats[D]				
Width,[B] in.				
To ¾, incl	0.003	0.004	0.006	0.008
Over ¾ to 1½, incl	0.004	0.005	0.008	0.010
Over 1½ to 3, incl	0.005	0.006	0.010	0.012
Over 3 to 4, incl	0.006	0.008	0.011	0.016
Over 4 to 6, incl	0.008	0.010	0.012	0.020
Over 6	0.013	0.015		

[A] This table includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. This table does not include tolerances for bars that are annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing; the producer should be consulted for tolerances for such bars.

[B] Width governs the tolerances for both width and thickness of flats. For example, when the maximum of carbon range is 0.28% or less, for a flat 2 in. wide and 1 in. thick, the width tolerance is 0.005 in. and the thickness tolerance is the same, namely, 0.005 in.

[C] Standard manufacturing practice is a shear cut for cold drawn bars (size limits vary by producer) which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

[D] Tolerances may be ordered all plus, or distributed plus and minus with the sum equivalent to the tolerances listed.

TABLE A1.12
SIZE TOLERANCES FOR COLD FINISHED ROUND BARS COLD DRAWN, GROUND AND POLISHED OR TURNED, GROUND AND POLISHED

Size, in. Cold Drawn, Ground and Polished	Turned, Ground and Polished	Tolerances from Specified Size, Minus Only, in.
To 1½, incl	To 1½, incl	0.001
Over 1½ to 2½, excl	Over 1½ to 2½, excl	0.0015
2½ to 3, incl	2½ to 3, incl	0.002
Over 3 to 4, incl	Over 3 to 4, incl	0.003
. . .	Over 4 to 6, incl	0.004[A]
. . .	Over 6	0.005[A]

[A] For non-resulfurized steels (steels specified to maximum sulphur limits under 0.08%), or for steels thermally treated, the tolerance is increased by 0.001 in.

TABLE A1.13
SIZE TOLERANCE FOR COLD-FINISHED ALLOY STEEL BARS, COLD DRAWN, OR TURNED AND POLISHED

Size in.[A]	Maximum of Carbon Range 0.28% or less	Maximum of Carbon Range Over 0.28% to 0.55%, incl	Maximum of Carbon Range to 0.55%, incl, Stress Relieved or Annealed after Cold Finishing	Maximum of Carbon Range Over 0.55% With or Without Stress Relieving or Annealing after Cold Finishing. Also all Carbons, Quenched and Tempered (Heat Treated), or Normalized and Tempered, before Cold Finishing
	All tolerances are in inches and are minus[B]			
	Rounds — Cold Drawn (to 4 in.) or Turned and Polished			
To 1, incl, in coils	0.002	0.003	0.004	0.005
Cut Lengths:				
To 1½, incl	0.003	0.004	0.005	0.006
Over 1½ to 2½, incl	0.004	0.005	0.006	0.007
Over 2½ to 4, incl	0.005	0.006	0.007	0.008
Over 4 to 6, incl	0.006	0.007	0.008	0.009
Over 6 to 8, incl	0.007	0.008	0.009	0.010
Over 8 to 9, incl	0.008	0.009	0.010	0.011
	Hexagons			
To ¾, incl	0.003	0.004	0.005	0.007
Over ¾ to 1½, incl	0.004	0.005	0.006	0.008
Over 1½ to 2½, incl	0.005	0.006	0.007	0.009
Over 2½ to 3⅛, incl	0.006	0.007	0.008	0.010
Over 3⅛ to 4, incl	0.006	. . .	. . .	. . .
	Squares			
To ¾, incl	0.003	0.005	0.006	0.008
Over ¾ to 1½, incl	0.004	0.006	0.007	0.009
Over 1½ to 2½, incl	0.005	0.007	0.008	0.010
Over 2½ to 4, incl	0.007	0.009	0.010	0.012
Over 4 to 5, incl	0.011	. . .	. . .	. . .
	Flats[A]			
To ¾, incl	0.004	0.005	0.007	0.009
Over ¾ to 1½, incl	0.005	0.006	0.009	0.011
Over 1½ to 3, incl	0.006	0.007	0.011	0.013
Over 3 to 4, incl	0.007	0.009	0.012	0.017
Over 4 to 6, incl	0.009	0.011	0.013	0.021
Over 6	0.014	. . .	. . .	. . .

[A] Width governs the tolerances for both width and thickness of flats. For example, when the maximum of carbon range is 0.28% or less, for a flat 2 in. wide and 1 in. thick, the width tolerance is 0.006 in. and the thickness tolerance is the same, namely 0.006 in.

[B] Standard manufacturing practice is a shear cut for cold drawn bars (size limits vary by producer) which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

TABLE A1.14
STRAIGHTNESS TOLERANCES FOR COLD FINISHED BARS[A,B]

		Straightness Tolerances, in. (Maximum Deviation) from Straightness in any 10-ft Portion of the Bar			
		Maximum of Carbon Range, 0.28% or Less		Maximum of Carbon Range Over 0.28% and All Grades Thermally Treated	
Size, in.	Length, ft	Rounds	Squares, Hexagons, and Octagons	Rounds	Squares, Hexagons, and Octagons
Less than 5/8	less than 15	1/8	3/16	3/16	1/4
Less than 5/8	15 and over	1/8	5/16	5/16	3/8
5/8 and over	less than 15	1/16	1/8	1/8	3/16
5/8 and over	15 and over	1/8	3/16	3/16	1/4

[A] The foregoing tolerances are based on the following method of measuring straightness: Departure from straightness is measured by placing the bar on a level table so that the arc or departure from straightness is horizontal, and the depth of the arc is measured with a feeler gage and a straightedge.

[B] It should be recognized that straightness is a perishable quality and may be altered by mishandling. The preservation of straightness in cold-finished bars requires the utmost care in subsequent handling. Specific straightness tolerances are sometimes required for carbon and alloy steels in which case the purchaser should inform the manufacturer of the straightness tolerances and the methods to be used in checking the straightness.

A2. DIMENSIONAL TOLERANCES — SI UNITS

A2.1 Listed herein are dimensional tolerances expressed in SI units.

TABLE A2.1
TOLERANCES IN SECTIONAL DIMENSIONS FOR ROUND AND SQUARE BARS AND ROUND-CORNERED SQUARE BARS

Size, mm	Tolerance from Specified Size, Over and Under, mm or %[B]	Out-of-Round, or Out-of-Square Section,[A] mm or %[B]
To 7, incl	0.13 mm	0.20 mm
Over 7 to 11, incl	0.15 mm	0.22 mm
Over 11 to 15, incl	0.18 mm	0.27 mm
Over 15 to 19, incl	0.20 mm	0.30 mm
Over 19 to 250, incl	1%	1.5%

[A] Out-of-round is the difference between the maximum and the minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

[B] The tolerance shall be rounded to the nearest tenth of a millimetre after calculation.

TABLE A2.2
TOLERANCES IN CROSS SECTION FOR HOT-WROUGHT HEXAGONAL AND OCTAGONAL STEEL BARS

Specified Size Between Opposite Sides, mm	Tolerance from Specified Size, mm		Out of Hexagon or Out of Octagon, mm[A]
	Over	Under	
To 13, incl	0.18	0.18	0.3
Over 13 to 25, incl	0.25	0.25	0.4
Over 25 to 40, incl	0.55	0.35	0.6
Over 40 to 50, incl	0.8	0.40	0.8
Over 50 to 65, incl	1.2	0.40	1.2
Over 65 to 80, incl	1.6	0.40	1.6
Over 80 to 100, incl	2.0	0.40	2.0

[A] Out of hexagon or out of octagon is the greatest difference between any two dimensions at the cross section between opposite faces.

TABLE A2.3
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS[A,B]

	Tolerances from Specified Thickness for Thickness Given Over and Under, mm						Tolerances from Specified Width, mm	
Specified Width, mm	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
To 25, incl	0.18	0.20	0.25	. . .	. . .	. . .	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	. . .	. . .	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	[A]	0.40	0.65	0.8	1.2	1.6	3.0	2.5

[A] When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.
[B] Flats over 150 to 200 mm, incl in width are not available as hot-wrought bars in thickness 6 mm and under.

TABLE A2.4
THICKNESS, LENGTH, AND OUT-OF-SQUARE TOLERANCES FOR HOT-WROUGHT BAR SIZE ANGLES

	Tolerances in Thickness for Thickness Given, Over and Under, mm			
Specified Length of Leg, mm[A,B]	To 5, incl	Over 5 to 10, incl	Over 10	Tolerances for Length of Leg Over and Under, mm
To 50, incl	0.2	0.2	0.3	1
Over 50 to 75, excl	0.3	0.4	0.4	2

[A] The longer leg of an unequal angle determines the size for tolerance.
[B] Out of square tolerances in either direction is $1\frac{1}{2}° = 0.026$ mm/mm.

TABLE A2.5
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR SIZE CHANNELS

	Tolerances in Size, Over and Under, mm				
			Thickness of Web		
Specified Size of Channel, mm	Depth of Section[A]	Width of Flanges[A]	To 5, incl	Over 5	Out of Square of Either Flange per mm of Flange Width,[B] mm
To 40, incl	1	1	0.2	0.4	0.03
Over 40 to 75, excl	2	2	0.4	0.5	0.03

[A] Measurements for depth of section and width of flanges are overall.
[B] For channels 16 mm and under in depth, out of square tolerance is 0.05 mm/mm.

TABLE A2.6
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR SIZE TEES

	Tolerances in Size, mm						
	Width or Depth,[B]		Thickness of Flange		Thickness of Stem		
Specified Size of Tee,[A] mm	Over	Under	Over	Under	Over	Under	Stem Out of Square[C]
To 30, incl	1	1	0.2	0.2	0.1	0.5	1
Over 30 to 50, incl	2	2	0.3	0.3	0.2	0.5	2
Over 50 to 75, excl	2	2	0.4	0.4	0.4	0.5	2

[A] The longer member of the unequal tee determines the size for tolerances.
[B] Measurements for width and depth are over all.
[C] Stem out of square is the tolerance from its true position of the center line of the stem measured at the point.

TABLE A2.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HALF-ROUNDS, OVALS, HALF-OVALS, AND OTHER SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A2.8
LENGTH TOLERANCES FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, OCTAGONS, FLATS, AND BAR SIZE SECTIONS

Specified Size of Rounds, Squares, Hexagons and Octagons, mm	Specified Size of Flats, mm		Tolerances over Specified Length, mm[A]				
	Thickness	Width	1500 to 3000, excl	3000 to 6000, excl	6000 to 9000, excl	9000 to 12 000, excl	12 000 to 18 000, excl
Hot Shearing							
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	. . .	. . .	50	65	70	75	85
Bar Size Sections	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
	. . .	. . .	15	25	40	50	65
Hot Sawing							
50 to 125, incl	25 and over	75 and over	[B]	40	45	60	70
Over 125 to 250, incl	. . .	. . .	[B]	65	70	75	85

[A] No tolerance under.
[B] Smaller sizes and shorter lengths are not hot sawed.

TABLE A2.9
LENGTH TOLERANCES FOR RECUTTING OF BARS MEETING SPECIAL STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Octagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Tolerances over Specified Length, mm[A]	
	To 3700 mm, incl	Over 3700 mm
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

[A] No tolerance under.

TABLE A2.10
STRAIGHTNESS TOLERANCES FOR HOT-WROUGHT BARS AND BAR SIZE SECTIONS[A]

Standard tolerances	6 mm if any 1500 mm or (length in mm/250)[B]
Special tolerances	3 mm in any 1500 mm or (length in mm/500)[B]

[A] Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.
[B] Round to the nearest whole millimetre.

TABLE A2.11
SIZE TOLERANCES FOR COLD-FINISHED CARBON STEEL BARS, COLD DRAWN OR TURNED AND POLISHED[A]

Size, mm	Tolerances from Specified Size, Under Only, mm: Maximum of Carbon Range 0.28 or Less	Maximum of Carbon Range Over 0.28 to 0.55, incl	Maximum of Carbon Range to 0.55%, incl Stress Relief or Annealed After Cold Finishing	Maximum of Carbon Range Over 0.55% or All Grades Quenched and Tempered or Normalized Before Cold Finishing
Rounds — Cold Drawn (to 100 mm in size) or Turned and Polished				
To 40, incl	0.05	0.08	0.10	0.13
Over 40 to 60, incl	0.08	0.10	0.13	0.15
Over 60 to 100, incl	0.10	0.13	0.15	0.18
Over 100 to 150, incl	0.13	0.15	0.18	0.20
Over 150 to 200, incl	0.15	0.18	0.20	0.23
Over 200 to 230, incl	0.18	0.20	0.23	0.25
Hexagons — Cold Drawn				
Up to 20, incl	0.05	0.08	0.10	0.15
Over 20 to 40, incl	0.08	0.10	0.13	0.18
Over 40 to 60, incl	0.10	0.13	0.15	0.20
Over 60 to 80, incl	0.13	0.15	0.18	0.23
Over 80 to 100, incl	0.13	0.15	. . .	
Squares— Cold Drawn[C]				
Up to 20, incl	0.05	0.10	0.13	0.18
Over 20 to 40, incl	0.08	0.13	0.15	0.20
Over 40 to 60, incl	0.10	0.15	0.18	0.23
Over 60 to 100, incl	0.15	0.20	0.23	0.28
Over 100 to 130, incl	0.25	. . .	. . .	. . .
Over 130 to 150, incl	0.36	. . .	. . .	. . .
Flats — Cold Drawn[B,C]				
To 20, incl	0.08	0.10	0.15	0.20
Over 20 to 40, incl	0.10	0.13	0.20	0.25
Over 40 to 80, incl	0.13	0.15	0.25	0.30
Over 80 to 100, incl	0.15	0.20	0.28	0.40
Over 100 to 150, incl	0.20	0.25	0.30	0.50
Over 150	0.33	0.38	. . .	. . .

[A] This table includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. This table does not include tolerances for bars that are annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing; the producer should be consulted for tolerances for such bars.

[B] Width governs the tolerance for both width and thickness of flats, for example, when the maximum of carbon range is 0.28% or less for a flat 50 mm wide and 25 mm thick, the width tolerance is 0.13 mm and the thickness is the same, namely, 0.13 mm.

[C] Tolerances may be ordered all plus, or distributed plus and minus with the sum equivalent to the tolerances listed.

TABLE A2.12
SIZE TOLERANCES FOR COLD-FINISHED ROUND BARS, COLD DRAWN, GROUND AND POLISHED, OR TURNED, GROUND AND POLISHED

Size, mm		Tolerances from, Specified Size, Minus Only, mm
Cold Drawn, Ground, and Polished	Turned, Ground, and Polished	
To 40, incl	To 40, incl	0.03
Over 40 to 60, incl	Over 40 to 60, incl	0.04
Over 60 to 80, incl	Over 60 to 80, incl	0.05
Over 80 to 100, incl	Over 80 to 100, incl	0.08
. . .	Over 100 to 150, incl	0.10[A]
. . .	Over 150	0.13[A]

[A] For nonresulphurized steels (steels specified to maximum sulfur limits under 0.08%) or for steels thermally treated, the tolerance is increased by 0.03 mm.

TABLE A2.13
SIZE TOLERANCES FOR COLD-FINISHED ALLOY STEEL BARS, COLD DRAWN OR TURNED AND POLISHED[A]

	Tolerances from Specified Size, Under Only, mm			
Size, mm	Maximum of Carbon Range 0.28 or less	Maximum of Carbon Range Over 0.28 to 0.55, incl	Maximum of Carbon Range to 0.55%, incl Stress Relief or Annealed After Cold Finishing	Maximum of Carbon Range Over 0.55% or All Grades Quenched and Tempered or Normalized Before Cold Finishing
Rounds — Cold Drawn (to 100 mm in size) or Turned and Polished				
To 25, incl, in coils	0.05	0.08	0.10	0.13
Cut Lengths				
To 40, incl	0.08	0.10	0.13	0.15
Over 40 to 60, incl	0.10	0.13	0.15	0.18
Over 60 to 100, incl	0.13	0.15	0.18	0.20
Over 100 to 150, incl	0.15	0.18	0.20	0.23
Over 150 to 200, incl	0.18	0.20	0.23	0.25
Over 200 to 230, incl	0.20	0.23	0.25	0.28
Hexagons — Cold Drawn				
Up to 20, incl	0.08	0.10	0.13	0.18
Over 20 to 40, incl	0.10	0.13	0.15	0.20
Over 40 to 60, incl	0.13	0.15	0.18	0.23
Over 60 to 80, incl	0.15	0.18	0.20	0.25
Over 80 to 100, incl	0.15	. . .	. . .	. . .
Squares — Cold Drawn				
Up to 20, incl	0.08	0.13	0.15	0.20
Over 20 to 40, incl	0.10	0.15	0.18	0.23
Over 40 to 60, incl	0.13	0.18	0.20	0.25
Over 60 to 100, incl	0.18	0.23	0.25	0.30
Over 100 to 130, incl	0.28	0.23	0.25	0.30
Flats — Cold Drawn[B]				
Width[B]				
To 20, incl	0.10	0.13	0.18	0.23
Over 20 to 40, incl	0.13	0.15	0.23	0.28
Over 40 to 80, incl	0.15	0.18	0.28	0.33
Over 80 to 100, incl	0.18	0.23	0.30	0.43
Over 100 to 150, incl	0.23	0.28	0.33	0.52
Over 150	0.36	. . .	. . .	. . .

[A] This table includes tolerances for bars that have been annealed, spheriodize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. This table does not include tolerances for bars that are annealed, spheriodize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing; the producer should be consulted for tolerances for such bars.

[B] Width governs the tolerance for both width and thickness of flats. For example, when the maximum of carbon range is 0.28% or less for a flat 50 mm wide and 25 mm thick, the width tolerance is 0.13 mm and the thickness tolerance is the same, namely 0.13 mm.

TABLE A2.14
STRAIGHTNESS TOLERANCES FOR COLD-FINISHED BARS[A,B]

Note — All grades quenched and tempered or normalized and tempered to Brinnell 302 maximum *before* cold finishing and all grades stress relieved or annealed *after* cold finishing. Straightness tolerances are not applicable to bars having Brinnell hardness exceeding 302.

		Straightness Tolerances, mm (Maximum Deviation) from Straightness in any 3000 mm Portion of the Bar			
		Maximum of Carbon Range, 0.28% or less		Maximum of Carbon Range over 0.28% and all Grades Thermally Treated	
Size, mm	Length, mm	Rounds	Squares, Hexagons, and Octagons	Rounds	Squares, Hexagons, and Octagons
Less than 16	Less than 4500	3	5	5	6
Less than 16	4500 and over	3	8	8	10
16 and over	Less than 4500	2	3	3	5
16 and over	4500 and over	3	5	5	6

[A] The foregoing tolerances are based on the following method of measuring straightness; departure from straightness is measured by placing the bar on a level table so that the arc or departure from straightness is horizontal, and the depth of the arc is measured with a feeler gage and a straightedge.

[B] It should be recognized that straightness is a perishable quality and may be altered by mishandling. The preservation of straightness in cold-finished bars requires the utmost care in subsequent handling. Specific straightness tolerances are sometimes required for carbon and alloy steels in which case the purchaser should inform the manufacturer of the straightness tolerances and the methods to be used in checking the straightness.

Designation: A 48/A 48M – 03

Standard Specification for Gray Iron Castings[1]

This standard is issued under the fixed designation A 48/A 48M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. This specification replaces Federal Specification QQ-I-652.

1. Scope

1.1 This specification covers gray iron castings intended for general engineering use where tensile strength is a major consideration. Castings are classified on the basis of the tensile strength of the iron in separately cast test bars.

1.1.1 This specification subordinates chemical composition to tensile strength.

1.2 Castings produced to this specification are graded on the basis of minimum tensile strength obtained in special test coupons designed to standardize cooling rate. The tensile strength developed in certain casting sections may vary from test coupon values (see X1.2).

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings

E 8 Test Methods for Tension Testing of Metallic Materials

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[2]

2.3 *Federal Standard:*

Federal Standard No. 123 Marking for Shipment (Civil Agencies)[2]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions for many terms common to gray iron castings are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced in accordance with this specification are classified into a number of grades based on the properties of separately cast test bars (Table 1, Table 2). Each class is designated by a number followed by a letter. The number indicates the minimum tensile strength of the separately cast test bar, and the letter indicates the size of the test bar. Examples of proper designations are as follows:

Gray Iron Castings, ASTM Specification A 48, Class 30B.

Gray Iron Castings, ASTM Specification A 48, Class 40C.

5. Ordering Information

5.1 Orders for material to this specification shall include the following information:

5.1.1 ASTM designation number and year of issue,

5.1.2 Class of iron required (see 4.1, Table 1, and Table 2),

5.1.3 The size of the separately cast test bar (letter classification—A, B, C, or S) that best represents the thickness of the controlling section of the casting (see Table 3),

5.1.4 The tension test specimen (B or C) to be machined from test bar C (see 13.3, Table 4, and Fig. 1),

5.1.5 The tension test specimen to be machined from test bar S (see 13.4, Table 4, and Fig. 1),

5.1.6 Lot size (see Section 10),

5.1.7 Special requirements (see Section 6),

5.1.8 Saving tested specimens or unbroken test bars (see 15.1), and

5.1.9 Special preparation for delivery (see Section 19).

6. Special Requirements

6.1 When agreed upon in writing between the manufacturer and the purchaser, it may be necessary for the castings to meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, dimensions, surface finish, and so forth.

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray Iron Castings.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1905. Last previous edition approved in 2000 as A 48 – 00.

[2] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Requirements for Tensile Strength of Gray Cast Irons in Separately Cast Test Bars (Inch-Pound)

Class	Tensile Strength, min, ksi	Nominal Test Bar Diameter, in.
No. 20 A	20	0.8
No. 20 B		1.2
No. 20 C		2.0
No. 20 S		Bars S[A]
No. 25 A	25	0.88
No. 25 B		1.2
No. 25 C		2.0
No. 25 S		Bars S[A]
No. 30 A	30	0.88
No. 30 B		1.2
No. 30 C		2.0
No. 30 S		Bars S[A]
No. 35 A	35	0.88
No. 35 B		1.2
No. 35 C		2.0
No. 35 S		Bars S[A]
No. 40 A	40	0.88
No. 40 B		1.2
No. 40 C		2.0
No. 40 S		Bars S[A]
No. 45 A	45	0.88
No. 45 B		1.2
No. 45 C		2.0
No. 45 S		Bars S[A]
No. 50 A	50	0.88
No. 50 B		1.2
No. 50 C		2.0
No. 50 S		Bars S[A]
No. 55 A	55	0.88
No. 55 B		1.2
No. 55 C		2.0
No. 55 S		Bars S[A]
No. 60 A	60	0.88
No. 60 B		1.2
No. 60 C		2.0
No. 60 S		Bars S[A]

[A] All dimensions of test bar S shall be as agreed upon between the manufacturer and the purchaser.

7. Tensile Requirements

7.1 Test bars representing castings conforming to this specification shall meet the requirements for tensile strength as described in Table 1 and Table 2.

8. Dimensional Requirements

8.1 The castings shall conform to the dimensions or drawings furnished by the purchaser, or, if there are no drawings, to the dimensions predicted by the pattern equipment supplied by the purchaser.

9. Workmanship and Finish

9.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears, as determined by visual examination.

9.2 No repairing by plugging or welding of any kind shall be permitted unless written permission is granted by the purchaser.

TABLE 2 Requirements for Tensile Strength of Gray Cast Irons in Separately Cast Test Bars (Metric)

Class	Tensile Strength, min, ksi [MPa]	Nominal Test Bar Diameter, in. [mm]
No. 150A	150	20 to 22
No. 150B		30
No. 150C		50
No. 150S		Bars S[A]
No. 175A	175	20 to 22
No. 175B		30
No. 175C		50
No. 175S		Bars S[A]
No. 200A	200	20 to 22
No. 200B		30
No. 200C		50
No. 200S		Bars S[A]
No. 225A	225	20 to 22
No. 225B		30
No. 225C		50
No. 225S		Bars S[A]
No. 250A	250	20 to 22
No. 250B		30
No. 250C		50
No. 250S		Bars S[A]
No. 275A	275	20 to 22
No. 275B		30
No. 275C		50
No. 275S		Bars S[A]
No. 300A	300	20 to 22
No. 300B		30
No. 300C		50
No. 300S		Bars S[A]
No. 325A	325	20 to 22
No. 325B		30
No. 325C		50
No. 325S		Bars S[A]
No. 350A	350	20 to 22
No. 350B		30
No. 350C		50
No. 350S		Bars S[A]
No. 375A	375	20 to 22
No. 375B		30
No. 375C		50
No. 375S		Bars S[A]
No. 400A	400	20 to 22
No. 400B		30
No. 400C		50
No. 400S		Bars S[A]

[A] All dimensions of test bar S shall be as agreed upon between the manufacturer and the purchaser.

10. Sampling

10.1 A lot shall consist of one of the following:

10.1.1 All the metal poured from a single heating in a batch type melting furnace.

10.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or a single casting.

10.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

TABLE 3 Separately Cast Test Bars for Use When a Specific Correlation Has Not Been Established Between the Test Bar and the Casting

Thickness of the Wall of the Controlling Section of the Casting, in. [mm]	Test Bar
Under 0.25 [under 5]	S
0.25 to 0.50 [5 to 14]	A
0.51 to 1.00 [15 to 25]	B
1.01 to 2 [26 to 50]	C
Over 2 [over 50]	S

10.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

11. Cast Test Bars

11.1 Test bars shall be separate castings poured from the same lot as the castings they represent and shall have dimensions as shown in Table 4. Allowance may be made for reasonable pattern draft within the tolerances shown in Table 4. Test bars A, B, and C are all standard test bars in the form of simple cylinders. Test bar S is special and is intended for use where the standard bars are not satisfactory.

11.2 The test bars shall be cast in dried, baked, or chemically bonded molds made mainly of an aggregate of siliceous sand with appropriate binders. The average grain size of the sand shall approximate that of the sand in which the castings are poured. Molds for the test bars shall be approximately at room temperature when poured. More than one test bar may be cast in a single mold, but each bar in the mold shall be surrounded by a thickness of sand which is not less than the diameter of the bar. A suitable design for a mold is shown in Fig. 2.

NOTE 1—The intent of these provisions is as follows: to prohibit the casting of test bars in molds of metal, graphite, zircon, light-weight aggregates, or other materials which would significantly affect the tensile strength of the iron; to prohibit control of tensile strength of the test bars by manipulation of the grain size of the sand; and to prohibit the casting of test bars in molds preheated substantially above room temperature.

11.3 Test bars that are intended to represent castings that are cooled in the mold to less than 900°F [480°C], before shakeout, shall be cooled in their molds to a temperature less than 900°F [480°C]. They then may be cooled in still air to room temperature.

11.4 Test bars that are intended to represent castings that are hotter than 900°F [480°C], when shaken out of their molds, shall be cooled as described in 11.3 or (by agreement between the manufacturer and the purchaser) may be shaken out of their molds at approximately the same temperature as the castings they represent.

11.5 When castings are stress-relieved, annealed, or otherwise heat-treated, test bars shall receive the same thermal treatment and shall be treated adjacent to the castings they represent.

12. Number of Tests and Retests

12.1 The tension test shall be conducted in accordance with Test Method E 8.

12.2 One tension test shall be performed on each lot and shall conform to the tensile requirements specified.

12.3 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected. A valid test is one wherein the specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

12.4 If sufficient separately cast test pieces are not available, the manufacturer shall have the option of removing a test specimen from a location of representative casting, as agreed upon between the manufacturer and purchaser.

12.5 If the first test results indicate that a heat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be heat treated together. Testing shall proceed in accordance with 12.1-12.3.

12.6 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

13. Tension Test Specimens

13.1 For test Bar A, the tension-test specimen A, as shown in Fig. 1, shall be machined concentric with the axis of the test bar.

13.2 For test Bar B, the tension test specimen B, as shown in Fig. 1, shall be machined concentric with the axis of the test bar.

13.3 For test Bar C, tension test specimens B or C, as shown in Fig. 1, shall be machined concentric with the axis of the test bar. Unless the size of the tension test specimen to be machined from test bar C is specified in writing by the purchaser, the decision whether to use tension test specimen B or C shall be made by the manufacturer of the castings.

13.4 For test bar S, the nature and dimensions of the tension test specimen shall be determined by agreement between the manufacturer and purchaser.

14. Tension Test

14.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial.

14.2 The elapsed time from the beginning of loading in the tension test to the instant of fracture shall be not less than 15 s for test specimen A and not less than 20 s for specimens B and C.

15. Inspection

15.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

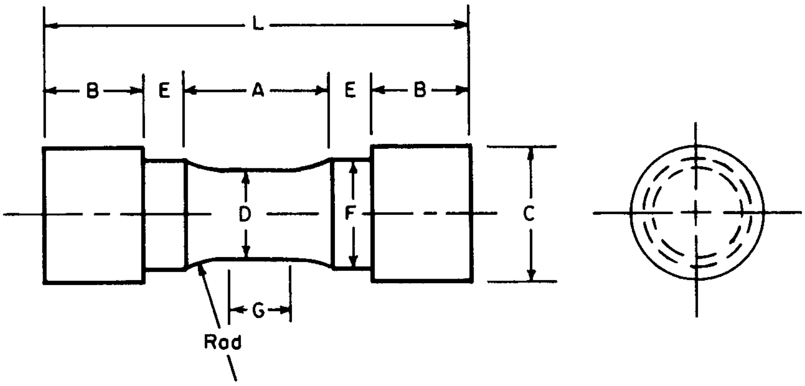
15.1.1 When agreed upon between the manufacturer and purchaser, tested specimens or unbroken test bars from the same lot shall be saved for a period of three months after the date of the test report.

15.2 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections

TABLE 4 Diameters and Lengths of Cast Test Bars

Test Bar	As-Cast Diameter, in. [mm]			Length, in. [mm]	
	Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)
A	0.88 [22.4]	0.85 [21.6]	0.96 [24.4]	5.0 [125]	6.0 [150]
B	1.20 [30.5]	1.14 [29.0]	1.32 [33.5]	6.0 [150]	9.0 [230]
C	2.00 [50.8]	1.90 [48.3]	2.10 [53.3]	7.0 [175]	10.0 [255]
S[A]	. . .	. . .	. . .	. . .	. . .

[A]All dimensions of test bar S shall be as agreed upon by the manufacturer and the purchaser.



Dimensions, in. [mm]	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50 [13]	0.75 [19]	1.25 [32]
D—Diameter	0.500 ± 0.010 [13 ± 0.25]	0.750 ± 0.015 [20 ± 0.4]	1.25 ± 0.025 [30 ± 0.6]
R—Radius of fillet, min	1 [25]	1 [25]	2 [50]
A—Length of reduced section, min	1¼ [32]	1½ [38]	2¼ [57]
L—Over-all length, min	3¾ [95]	4 [100]	6⅜ [160]
C—Diameter of end section, approx	⅞ [20]	1¼ [20]	1⅞ [47]
E—Length of shoulder, min	¼ [6]	¼ [6]	5/16 [8]
F—Diameter of shoulder	⅝ ± 1/64 [16 ± 0.4]	15/16 ± 1/64 [24 ± 0.4]	1 7/16 ± 1/64 [36 ± 0.4]
B—Length of end section	[A]	[A]	[A]

[A]Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 1 Tension-Test Specimens

are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

16. Rejection and Resubmission

16.1 Any castings or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

16.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly the basis for rejection.

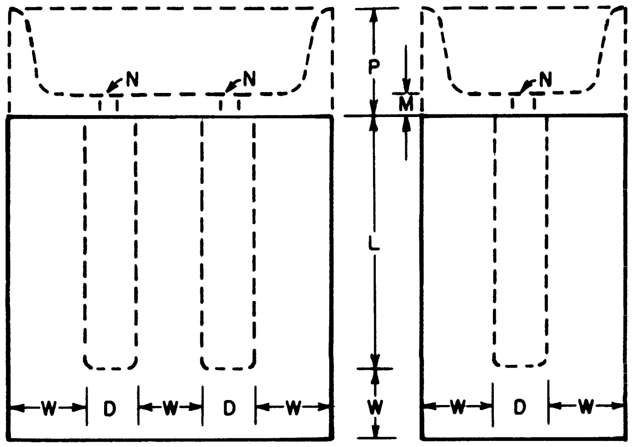
17. Certification

17.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

17.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

18. Product Marking

18.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing or, if not shown on the drawing, at a location at the discretion of the producer.



Required Features:

1. Material—Aggregate of dry siliceous sand.
2. Position—Bars vertical.
3. *L*—See Table 4.
4. *D*—See Table 4.
5. *W*—Not less than diameter *D*.

Optional Features:

1. Number of test bars in a single mold—Two suggested.
2. Design of pouring cup.
3. *P*—2 in. [50 mm], suggested.
4. *N*—5⁄16 in. [8 mm] in diameter, suggested.

f5. *M* = 1.5 *N*, suggested.

FIG. 2 Suitable Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars for Gray Iron

19. Preparation for Delivery

19.1 Unless otherwise stated in the contract or order, the cleaning, preservation and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

19.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

20. Keywords

20.1 gray iron castings

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition (particularly carbon equivalent), by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, hence, the properties developed in any particular section are influenced by the presence of cores; chills and chaplets; changes in section thickness; and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specification application, it may be determined by appropriate experimentation.

X1.3 Gray iron castings in Classes 20, 25, 30 and 35 are characterized by excellent machinability, high damping capacity, low modulus of elasticity, and comparative ease of manufacture.

X1.3.1 Castings in Classes 40, 45, 50, 55 and 60 are usually more difficult to machine, have lower damping capacity and a higher modulus of elasticity, and are more difficult to manufacture.

X1.4 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

X1.5 If iron castings are welded (see 9.2), the microstructure of the iron is usually altered, particularly in the vicinity of the weldment. Therefore, the properties of the casting may be adversely affected by welding. Where practical, appropriate post weld heat treatment may reduce this effect of welding.

SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING APPLICATIONS 98

SA-105/SA-105M

(Identical with ASTM Specification A 105/A 105M-96) 98

1. Scope

1.1 This specification covers forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the ANSI and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products, (see 4.4) it does not cover raw material produced in these product forms.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675, A 695, and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 266/A 266M Specification for Forgings, Carbon Steel, for Pressure Vessel Components

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 675 Specification for Steel Bars, Carbon, Hot Wrought, Special Quality, Mechanical Properties

A 695 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications

A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 165 Practice for Liquid Penetrant Inspection Method

E 340 Test Method for Macroetching Metals and Alloys

2.2 *MSS Standards:*

SP25 Standard Marking System for Valves, Fittings, Flanges and Unions

SP44 Standard for Steel Pipe Line Flanges

2.3 *ASME Standard:*

Section IX, Welding Qualifications, ASME Boiler and Pressure Vessel Code

2.4 *ANSI Standards:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings

B16.9 Wrought Steel Buttwelding Fittings

B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves

B16.11 Forged Steel Fittings, Socket Weld, and Threaded

B16.34 Valves-Flanged, Threaded and Welding End

2.5 *API Standards:*

API-600 Flanged and Butt-Welding-End Steel Gate Valves

API-602 Compact Design Carbon Steel Gate Valves for Refinery Use

2.6 *AWS Standard:*

AWS A5.1 Mild Steel Covered Arc-Welding Electrodes

98 3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information as necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (See Table 1 footnotes, 12.1, and 16.2).

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process and shall be fully killed.

4.2 A sufficient discard shall be made from source material to secure freedom from injurious piping and undue segregation.

4.3 The material shall be forged as close as practicable to the specified shape and size.

4.4 Except for flanges of all types, hollow cylindrically shaped parts may be machined from hot-rolled bar, forged bar, or seamless tubular material provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts (up to and including NPS 4) not including flanges may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as permitted by 4.4, the finished product shall be a forging as defined in the Terminology Section of Specification A 788.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure–temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

5.1.4 Piping components other than flanges which meet both of the following criteria: *(1)* over NPS 4 and *(2)* above Class 300, and

5.1.5 Piping components of Special Class other than flanges which meet both of the following criteria: *(1)* over NPS 4 and *(2)* when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or quenching and tempering.

5.2.1 *Annealing* — The procedure for annealing shall consist of allowing the forgings immediately after forging or rolling, to cool to a temperature below 1000°F [538°C]. They shall then be reheated to a temperature between 1550°F [843°C] and 1700°F [927°C] to refine the grain (a group thus reheated being known as an "annealing charge") and allowed to cool uniformly in the furnace.

5.2.2 *Normalizing* — The procedure for normalizing shall consist of allowing the forgings, immediately after forging or rolling, to cool to a temperature below 1000°F [538°C]. They shall then be uniformly reheated to a temperature between 1550°F [843°C] and 1700°F [927°C] to refine the grain (a group thus reheated being known as a "normalizing charge") and allowed to cool in air.

5.2.3 *Tempering* — The procedure for tempering shall consist of heating the forgings to a temperature between 1100°F [593°C] and the lower transformation temperature for a minimum of $\frac{1}{2}$ h/in. [$\frac{1}{2}$ h/25.4 mm] of maximum section thickness.

5.2.4 *Quenching* — The procedure for quenching shall consist of either *(1)* fully austenitizing the forgings followed by quenching in a suitable liquid medium or *(2)* using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered as prescribed in 5.2.3.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 1. Test Methods, Practices and Terminology A 751 shall apply.

6.2 Steels to which lead has been added shall not be used.

7. Cast or Heat (Formerly Ladle) Analysis

7.1 An analysis of each heat of steel shall be made from samples taken, preferably during the pouring of the heat, and the results shall conform with Table 1.

8. Product Analysis

8.1 The purchaser may make a product analysis on forgings supplied to this specification. Samples for analysis may be taken from midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 within the tolerances stated in Table 2.

9. Mechanical Properties

9.1 The material shall conform to the mechanical property requirements prescribed in Tables 3 and 4.

9.2 For the purpose of determining conformance with Tables 3 and 4, specimens shall be obtained from production forgings after heat treatment, when heat treatment is required, or from separately forged test blanks prepared from the stock used to make the finished product. Such test blanks shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product.

9.3 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the $\frac{1}{4}$ T plane or deeper position, where T is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

9.4 *Tension Tests:*

9.4.1 One tension test shall be made for each heat of as-forged components.

9.4.2 One tension test shall be made from each **98**
heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested.

9.4.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

9.4.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

9.4.4 Forgings too small to permit obtaining a subsize specimen of 0.250 in. [6.35 mm] diameter or larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for production of a separately forged test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2 — A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

98 **9.5** *Hardness Tests* **—** Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 9.4.2.1 to ensure that forgings are within the hardness limits given in Table 3. When only one forging is produced, it shall be hardness tested as defined in 9.4.2.1 to ensure it is within the hardness limits given in Table 3. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

10. Hydrostatic Tests

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S7 is specified.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 9.

12. Workmanship, Finish, and Appearance

12.1 The forgings shall be free of injurious imperfections, as defined below, and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 12.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish. Unless otherwise specified in the purchase order, the fittings shall be cleaned to remove all scale and processing compounds prior to final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure. The cleaned fittings shall be protected to prevent recontamination. Protective coatings on socket weld and butt welding fittings shall be suitable for subsequent welding without removal of the coating. When specified in the purchase order, parts may be furnished in the as-formed or as-forged condition.

12.2 *Depth of Injurious Imperfection* — Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

12.3 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

12.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal, they shall be removed by machining or grinding.

12.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 12.2 and if not deeper than $\frac{1}{16}$ in. [1.6 mm]. If such imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm], but do not encroach on the minimum wall thickness of the forging, they shall be removed by grinding to sound metal.

12.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of forging, and the remainder shall not be less than the minimum specified or required wall thickness.

13. Repair by Welding

13.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ANSI or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

13.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.3 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

13.4 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle inspection prior to welding.

13.5 After repair welding, the area welded shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection.

13.6 All forgings repaired by welding shall be post-weld heat treated between 1100°F [593°C] and the lower transformation temperature for a minimum of $\frac{1}{2}$ h/in. [$\frac{1}{2}$ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 9 on completion of the cycle.

13.7 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 3 for the thermal condition of repair-welded forgings.

13.8 Repair by welding shall not exceed 10% of the surface area of the forging nor $33\frac{1}{3}$% of the wall thickness of the finished forging or $\frac{3}{8}$ in. [10 mm] whichever is less, without prior approval of the purchaser.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

15. Rejection and Rehearing

15.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

15.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

16. Certification

16.1 *Identification Marking* — For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in 17.1 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

16.2 *Test Reports* — When test reports are required, the manufacturer shall also provide the following, where applicable:

16.2.1 Type heat treatment, Section 5,

16.2.2 Tensile property results, Section 9 (Table 2), report the yield strength and ultimate strength in ksi [MPa], elongation and reduction in area, in percent,

16.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02%, then the analysis for that element may be reported as "<0.02%,"

16.2.4 Hardness results, Section 9 (Table 3), and

16.2.5 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 Identification marks consisting of the manufacturer's symbol or name (see Note 3), the heat number or manufacturer's heat identificaion, designation of service rating, this specification number, and size shall be forged or legibly stamped on each forging, and in such a position as not to injure the usefullness of the forging.

The Standard Marking System of Valves, Fittings, Flanges, and Unions (SP-25-1978) of the Manufacturers' Standardization Society of the Valve and Fittings Industry may be followed except the word "Steel" shall not be substituted for this specification number.

NOTE 3 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

17.1.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following this specification number.

17.2 When test reports are required for larger products, the markings shall consist of the manufacturer's symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply). The specification number marked on the forgings need not include specification year of issue and revision letter.

17.3 *Bar Coding*—In addition to the requirements in 17.1 and 17.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag. **98**

98 TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon	0.35 max
Manganese	0.60–1.05
Phosphorus	0.035 max
Sulfur	0.040 max
Silicon	0.10–0.35
Copper	0.40 max [Note (1)]
Nickel	0.40 max [Note (1)]
Chromium	0.30 max [Notes (1)(2)]
Molybdenum	0.12 max [Notes (1)(2)]
Vanadium	0.05 max
Columbium	0.02 max

General Note—For each reduction of 0.01% below the specified carbon maximum (0.35%), an increase of 0.06% manganese above the specified maximum (1.05%) will be permitted up to a maximum of 1.35%.

NOTES:
(1) The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00%.
(2) The sum of chromium and molybdenum shall not exceed 0.32%.

TABLE 2
PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS

	Permissible Variations over the Maximum Limit or Under the Minimum Limit, %				
	200 in.^{2} [1290 cm^2] and Under	Over 200 to 400 in.^{2} [1290 to 2580 cm^2], incl	Over 400 to 800 in.^{2} [2580 to 5160 cm^2], incl	Over 800 to 1600 in.^{2} [5160 to 10 320 cm^2] incl	Over 1600 in.^{2} [10 320 cm^2]
Carbon	0.02	0.03	0.04	0.05	0.05
Manganese:					
Up to and including 0.90	0.04	0.05	0.06	0.07	0.08
0.91 and over	0.06	0.07	0.08	0.08	0.09
Phosphorus	0.008	0.010	0.010	0.015	0.015
Sulfur	0.010	0.010	0.010	0.015	0.015
Silicon	0.03	0.04	0.04	0.05	0.06
Copper	0.03	0.03	0.03	0.03	0.03
Nickel	0.03	0.03	0.03	0.03	0.03
Chromium	0.04	0.04	0.04	0.04	0.04
Molybdenum	0.01	0.01	0.01	0.01	0.01
Vanadium	0.01	0.01	0.01	0.01	0.01
Colombium	0.01	0.01	0.01	0.01	0.01

General Notes—Product cross-sectional area (taken at right angles to the axis of the original ingot or billet) is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging, or
(c) maximum cross-sectional area of the billet, bloom or slab.

TABLE 3
MECHANICAL REQUIREMENTS [Note (1)]

Tensile strength, min, psi [MPa]	70 000 [485]
Yield strength, min, psi [MPa] [Note (2)]	36 000 [250]
Elongation in 2 in. or 50 mm, min, %:	
Basic minimum elongation for walls $5/16$ in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4D is used	22
For strip tests, a deduction for each $1/32$ in. [0.8 mm] decrease in wall thickness below $5/16$ in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 4	1.50 [Note (3)]
Reduction of area, min, % [Note (4)]	30
Hardness, HB, max	187

NOTES:
(1) For small forgings, see 9.4.4.
(2) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
(3) See Table 4 for computed minimum values.
(4) For round specimens only.

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TABLE 4
COMPUTED MINIMUM VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, %
in.	mm	
$^{5}/_{16}$ (0.312)	7.9	30.00
$^{9}/_{32}$ (0,281)	7.1	28.50
$^{1}/_{4}$ (0.250)	6.4	27.00
$^{7}/_{32}$ (0.219)	5.6	25.50
$^{3}/_{16}$ (0.188)	4.8	24.00
$^{5}/_{32}$ (0.156)	4.0	22.50
$^{1}/_{8}$ (0.125)	3.2	21.00
$^{3}/_{32}$ (0.094)	2.4	19.50
$^{1}/_{16}$ (0.062)	1.6	18.00

General Note:
The above table gives the computed minimum elongation values for each $^{1}/_{32}$-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

where:

E = elongation in 2 in. or 50 mm, %, and
T = actual thickness of specimen, in. [mm].

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis shall be made from one randomly selected forging representing each size and shape of forging on the order, and the results shall comply with Table 1. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S3. Hardness

S3.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S4. Tension Tests

S4.1 In addition to the requirements of Section 9, the heat identification shall be marked on each forging and one tensile specimen shall be obtained from a representative forging at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S5. Magnetic-Particle Examination

S5.1 All accessible surfaces of the finished forging shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the manufacturer and purchaser.

S6. Liquid-Penetrant Examination

S6.1 All surfaces shall be examined by a liquid-penetrant method. The method shall be in accordance with Practice E 165. Acceptance limits shall be as agreed upon by the manufacturer and the purchaser.

S7. Hydrostatic Testing

S7.1 A hydrostatic test at a pressure agreed upon by the manufacturer and the purchaser shall be applied by the manufacturer.

S8. Repair Welding

S8.1 No repair welding shall be permitted without prior approval of the purchaser.

S9. Heat Treatment

S9.1 All forgings shall be heat treated as specified **98**
by the purchaser.

S9.2 When forgings not requiring heat treatment by **98**
5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 3 and Table 4 shall be hardness testing per 9.5 and either (*1*) tensile testing of heat treated forgings per 9.2, or (*2*) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser.

S9.3 When test reports are required, and tensile test **98**
results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report.

S9.4 In addition to the marking required by Section **98**
17, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered as appropriate.

S10. Marking Small Forgings

S10.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with the test reports.

S10.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S11. Carbon Equivalent

S11.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S11.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S11.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

Designation: A 106/A 106M – 08

Used in USDOE-NE standards

Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 106/A 106M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS ⅛ to NPS 48 [DN 6 to DN 1200] (Note 2) inclusive, with nominal (average) wall thickness as given in ASME B 36.10M. It shall be permissible to furnish pipe having other dimensions provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized.

NOTE 1—It is suggested, consideration be given to possible graphitization.

NOTE 2—The dimensionless designator NPS (nominal pipe size) [DN (diameter nominal)] has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.2 Supplementary requirements of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The following precautionary caveat pertains only to the test method portion, Sections 11, 12, and 13 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Standard:*

ASME B 36.10M Welded and Seamless Wrought Steel Pipe[4]

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[5]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[5]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[5]

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[5]

2.5 *Other Standards:*

SSPC-SP 6 Surface Preparation Specification No. 6[6]

3. Ordering Information

3.1 The inclusion of the following, as required will describe the desired material adequately, when ordered under this specification:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1),

[1] This specification is under the jurisdiction of Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products.

Current edition approved July 15, 2008. Published August 2008. Originally approved in 1926. Last previous edition in 2006 as A 106/A 106M – 06a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SA-106 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[6] Available from Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656, http://www.sspc.org.

***A Summary of Changes section appears at the end of this standard.**

TABLE 1 Chemical Requirements

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max[B]	0.40	0.40	0.40
Copper, max[B]	0.40	0.40	0.40
Molybdenum, max[B]	0.15	0.15	0.15
Nickel, max[B]	0.40	0.40	0.40
Vanadium, max[B]	0.08	0.08	0.08

[A] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.
[B] These five elements combined shall not exceed 1 %.

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size (NPS [DN] and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),

3.1.6 Special outside diameter tolerance pipe (16.2.2),

3.1.7 Inside diameter tolerance pipe, over 10 in. [250 mm] ID (16.2.3),

3.1.8 Length (specific or random, Section 17),

3.1.9 Optional requirements (Section 9 and S1 to S8),

3.1.10 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.11 Specification designation (A 106 or A 106M, including year-date),

3.1.12 End use of material,

3.1.13 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.14 Special requirements.

4. Process

4.1 The steel shall be killed steel, with the primary melting process being open-hearth, basic-oxygen, or electric-furnace, possibly combined with separate degassing or refining. If secondary melting, using electroslag remelting or vacuum-arc remelting is subsequently employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel cast in ingots or strand cast is permissible. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 For pipe NPS 1½ [DN 40] and under, it shall be permissible to furnish hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 [DN 50] and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, it is permissible to furnish cold-drawn pipe.

5. Heat Treatment

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200 °F (650 °C) or higher.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (see 20.1) shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties given in Table 2.

11. Bending Requirements

11.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter (as shown in ASME B 36.10M) of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ASME B 36.10M) of the pipe, without failure.

11.2 For pipe whose diameter exceeds 25 in. [635 mm] and whose diameter to wall thickness ratio, where the diameter to wall thickness ratio is the specified outside diameter divided by the nominal wall thickness, is 7.0 or less, the bend test shall be conducted. The bend test specimens shall be bent at room temperature through 180° with the inside diameter of the bend being 1 in. [25 mm] without cracking on the outside portion of the bent portion.

Example: For 28 in. [711 mm] diameter 5.000 in. [127 mm] thick pipe the diameter to wall thickness ratio = 28/5 = 5.6 [711/127 = 5.6].

TABLE 2 Tensile Requirements

	Grade A		Grade B		Grade C	
Tensile strength, min, psi [MPa]	48 000 [330]		60 000 [415]		70 000 [485]	
Yield strength, min, psi [MPa]	30 000 [205]		35 000 [240]		40 000 [275]	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. [50 mm], min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2-in. [50-mm] gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	[A]		[A]		[A]	
For transverse strip tests, a deduction for each 1⁄32-in. [0.8-mm] decrease in wall thickness below 5⁄16 in. [7.9 mm] from the basic minimum elongation of the following percentage shall be made		1.25		1.00		1.00

[A] The minimum elongation in 2 in. [50 mm] shall be determined by the following equation:

$$e = 625\ 000 A^{0.2} / U^{0.9}$$

for inch-pound units, and

$$e = 1\ 940 A^{0.2} / U^{0.9}$$

for SI units,

where:

e = minimum elongation in 2 in. [50 mm], %, rounded to the nearest 0.5 %,

A = cross-sectional area of the tension test specimen, in.^{2} [mm^2], based upon specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 0.01 in.^{2} [1 mm^2]. (If the area thus calculated is equal to or greater than 0.75 in.^{2} [500 mm^2], then the value 0.75 in.^{2} [500 mm^2] shall be used.), and

U = specified tensile strength, psi [MPa].

12. Flattening Tests

12.1 Although testing is not required, pipe shall be capable of meeting the flattening test requirements of Supplementary Requirement S3, if tested.

13. Hydrostatic Test

13.1 Except as allowed by 13.2, 13.3, and 13.4, each length of pipe shall be subjected to the hydrostatic test without leakage through the pipe wall.

13.2 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order, it shall be permissible for the full body of each pipe to be tested with a nondestructive electric test described in Section 14.

13.3 Where specified in the purchase order, it shall be permissible for pipe to be furnished without the hydrostatic test and without the nondestructive electric test in Section 14; in this case, each length so furnished shall include the mandatory marking of the letters "NH." It shall be permissible for pipe meeting the requirements of 13.1 or 13.2 to be furnished where pipe without either the hydrostatic or nondestructive electric test has been specified in the purchase order; in this case, such pipe need not be marked with the letters "NH." Pipe that has failed either the hydrostatic test of 13.1 or the nondestructive electric test of 13.2 shall not be furnished as "NH" pipe.

13.4 Where the hydrostatic test and the nondestructive electric test are omitted and the lengths marked with the letters "NH," the certification, where required, shall clearly state "Not Hydrostatically Tested," and the letters "NH" shall be appended to the product specification number and material grade shown on the certification.

14. Nondestructive Electric Test

14.1 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order as an alternative or addition to the hydrostatic test, the full body of each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570. In such cases, the marking of each length of pipe so furnished shall include the letters "NDE." It is the intent of this nondestructive electric test to reject pipe with imperfections that produce test signals equal to or greater than that produced by the applicable calibration standard.

14.2 Where the nondestructive electric test is performed, the lengths shall be marked with the letters "NDE." The certification, where required, shall state "Nondestructive Electric Tested" and shall indicate which of the tests was applied. Also, the letters "NDE" shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

14.3.1 The reference standards defined in 14.4 through 14.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

14.3.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short abrupt type.

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific applications of these examinations is directed to discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 *Drilled Hole*—The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
≤ ½	≤ 15	0.039 in. [1 mm]
> ½ ≤ 1¼	> 15 ≤ 32	0.055 in. [1.4 mm]
> 1¼ ≤ 2	> 32 ≤ 50	0.071 in. [1.8 mm]
> 2 ≤ 5	> 50 ≤ 125	0.087 in. [2.2 mm]
>5	> 125	0.106 in. [2.7 mm]

14.5.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12 ½ % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12 ½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 *Compatibility*—The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thicknesses under ½ in. [12.7 mm], outside and inside notches shall be used; for wall thicknesses equal to and above ½ in. [12.7 mm], only an outside notch shall be used. Notch depth shall not exceed 12½ % of the specified wall thickness, or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

14.7.2 Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 18:

14.7.2.1 Dinges,

14.7.2.2 Straightener marks,

14.7.2.3 Cutting chips,

14.7.2.4 Scratches,

14.7.2.5 Steel die stamps,

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes, a condition referred to as "end effect." The length of such end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Mass, and Permissible Variations

16.1 *Mass*—The mass of any length of pipe shall not vary more than 10 % over and 3.5 % under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 [DN 100] and smaller may be weighed in convenient lots; pipe larger than NPS 4 [DN 100] shall be weighed separately.

16.2 *Diameter*—Except as provided for thin-wall pipe in paragraph 11.2 of Specification A 530/A 530M, the tolerances for diameter shall be in accordance with the following:

16.2.1 Except for pipe ordered as special outside diameter tolerance pipe or as inside diameter tolerance pipe, variations in outside diameter shall not exceed those given in Table 3.

16.2.2 For pipe over 10 in. [250 mm] OD ordered as special outside diameter tolerance pipe, the outside diameter shall not vary more than 1 % over or 1 % under the specified outside diameter.

16.2.3 For pipe over 10 in. [250 mm] ID ordered as inside diameter tolerance pipe, the inside diameter shall not vary more than 1 % over or 1 % under the specified inside diameter.

16.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under the specified wall thickness.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

TABLE 3 Variations in Outside Diameter

NPS [DN Designator]	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
1⁄8 to 11⁄2 [6 to 40], incl	1⁄64 (0.015)	0.4	1⁄64 (0.015)	0.4
Over 11⁄2 to 4 [40 to 100], incl	1⁄32 (0.031)	0.8	1⁄32 (0.031)	0.8
Over 4 to 8 [100 to 200], incl	1⁄16 (0.062)	1.6	1⁄32 (0.031)	0.8
Over 8 to 18 [200 to 450], incl	3⁄32 (0.093)	2.4	1⁄32 (0.031)	0.8
Over 18 to 26 [450 to 650], incl	1⁄8 (0.125)	3.2	1⁄32 (0.031)	0.8
Over 26 to 34 [650 to 850], incl	5⁄32 (0.156)	4.0	1⁄32 (0.031)	0.8
Over 34 to 48 [850 to 1200], incl	3⁄16 (0.187)	4.8	1⁄32 (0.031)	0.8

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft [4.8 to 6.7 m] with 5 % 12 to 16 ft [3.7 to 4.8 m], or in double random lengths with a minimum average of 35 ft [10.7 m] and a minimum length of 22 ft [6.7 m] with 5 % 16 to 22 ft [4.8 to 6.7 m].

18. Workmanship, Finish and Appearance

18.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but consideration should be given to the necessity of exploring all surface imperfections to assure compliance with 18.2.

18.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

18.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within the limits specified in 16.3.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

18.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks and abrasions—such as cable marks, dinges, guide marks, roll marks, ball scratches, scores, and die marks—and pits, any of which imperfections are deeper than 1⁄16 in. [1.6 mm].

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5 % of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding is permitted to be reduced by the amount so removed.

18.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

19. End Finish

19.1 The Pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 *NPS 1½ [DN 40] and Smaller*—All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 *NPS 2 [DN 50] and Larger*—Walls through extra strong weights, shall be plain-end-beveled.

19.1.3 *NPS 2 [DN 50] and Larger*—Walls over extra strong weights, shall be plain-end square cut.

19.2 Plain-end beveled pipe shall be plain-end pipe having a bevel angle of 30°, + 5° or - 0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of 1⁄16 ± 1⁄32 in. [1.6 ± 0.8 mm]. Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Sampling

20.1 For product analysis (see 9.1) and tensile tests (see 21.1), a lot is the number of lengths of the same size and wall thickness from any one heat of steel; of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6 [DN 150]; and of 200 lengths or fraction thereof of each size NPS 6 [DN 150] and over.

20.2 For bend tests (see 21.2), a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof, of each size.

20.3 For flattening tests, a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

21. Number of Tests

21.1 The tensile requirements specified in Section 10 shall be determined on one length of pipe from each lot (see 20.1).

21.2 For pipe NPS 2 [DN 50] and under, the bend test specified in 11.1 shall be made on one pipe from each lot (see 20.2). The bend test, where used as required by 11.2, shall be made on one end of 5 % of the pipe from each lot. For small lots, at least one pipe shall be tested.

21.3 If any test specimen shows flaws or defective machining, it shall be permissible to discard it and substitute another test specimen.

22. Retests

22.1 If the percentage of elongation of any tension test specimen is less than that given in Table 1 and any part of the fracture is more than ¾ in. [19 mm] from the center of the gage length of a 2-in. [50-mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

23. Test Specimens and Test Methods

23.1 On NPS 8 [DN 200] and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8 [DN 200], the longitudinal test only shall be used.

23.2 When round tension test specimens are used for pipe wall thicknesses over 1.0 in. [25.4 mm], the mid–length of the longitudinal axis of such test specimens shall be from a location midway between the inside and outside surfaces of the pipe.

23.3 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

23.4 Test specimens for the bend test specified in 11.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over 1⁄16 in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

23.5 All routine check tests shall be made at room temperature.

24. Certification

24.1 When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

25. Product Marking

25.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 4, an additional symbol "S" if one or

TABLE 4 Marking

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

more of the supplementary requirements apply; the length, OD 1 %, if ordered as special outside diameter tolerance pipe; ID 1 %, if ordered as special inside diameter tolerance pipe; the schedule number, weight class, or nominal wall thickness; and, for sizes larger than NPS 4 [DN 100], the weight. Length shall be marked in feet and tenths of a foot [metres to two decimal places], depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS 1½ , 1¼ , 1, and ¾ [DN 40, 32, 25, and 20], each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag; individual lengths of pipe need not be marked with footage. For sizes less than NPS ¾ [DN 20], all the required markings shall be on the bundle tag or on each length of pipe and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

25.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

25.3 *Bar Coding*—In addition to the requirements in 25.1 and 25.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

26. Government Procurement

26.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

26.2 *Inspection*—Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer shall use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

27. Keywords

27.1 carbon steel pipe; seamless steel pipe; steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 [DN 200] and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test, Standard

S3.1 For pipe over NPS 2 [DN 50], a section of pipe not less than 2½ in. [63.5 mm] in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the "H" value, the following "e" constants shall be used:

0.08 for Grade A
0.07 for Grades B and C

S3.2 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than ten.

S3.3 The flattening test shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and from each lot of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

S3.4 Should a crop end of a finished pipe fail in the flattening test, one retest is permitted to be made from the failed end. Pipe shall be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

S4. Flattening Test, Enhanced

S4.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S5. Metal Structure and Etching Test

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Carbon Equivalent

S6.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S6.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S6.3 The CE shall be reported on the test report.

S7. Heat Treated Test Specimens

S7.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen from each heat of steel furnished which has been either stress relieved at 1250 °F or normalized at 1650 °F, as specified by the purchaser. Other stress relief or annealing temperatures, as appropriate to the analysis, may be specified by agreement between the purchaser and the manufacturer. The results of this test shall meet the requirements of Table 1.

S8. Internal Cleanliness–Government Orders

S8.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP 6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

S9. Requirements for Carbon Steel Pipe for Hydrofluoric Acid Alkylation Service

S9.1 Pipe shall be provided in the normalized heat-treated condition.

S9.2 The carbon equivalent (CE), based upon heat analysis, shall not exceed 0.43 % if the specified wall thickness is equal to or less than 1 in. [25.4 mm] or 0.45 % if the specified wall thickness is greater than 1 in. [25.4 mm].

S9.3 The carbon equivalent (CE) shall be determined using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S9.4 Based upon heat analysis in mass percent, the vanadium content shall not exceed 0.02 %, the niobium content shall not exceed 0.02 %, and the sum of the vanadium and niobium contents shall not exceed 0.03 %.

S9.5 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15 %.

S9.6 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18 %.

S9.7 Welding consumables of repair welds shall be of low hydrogen type. E60XX electrodes shall not be used and the resultant weld chemical composition shall meet the chemical composition requirements specified for the pipe.

S9.8 The designation "HF-N" shall be stamped or marked on each pipe to signify that the pipe complies with this supplementary requirement.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 106/A 106M – 06a, that may impact the use of this specification. (Approved July 15, 2008)

(*1*) Revised 16.2 to permit OD tolerance for thin-wall pipe to default to Specification A 530/A 530M.

Endorsed by Manufacturers Standardization
Society of the Valve and Fittings Industry
Used in USDOE-NE Standards

Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service[1]

This standard is issued under the fixed designation A 182/A 182M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards, such as the ASME specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar (other than those directly addressed by this specification; see 5.4), refer to Specifications A 479/A 479M and A 739 for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications, refer to Specifications A 336/A 336M and A 965/A 965M for the similar ferritic and austenitic grades, respectively, available in those specifications.

1.3 Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic-austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 In addition to the referenced documents listed in Specification A 961/A 961M, the following list of standards apply to this specification.

2.2 *ASTM Standards:* [3]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings
A 336/A 336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 479/A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
A 788/A 788M Specification for Steel Forgings, General Requirements
A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications
A 965/A 965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
E 112 Test Methods for Determining Average Grain Size

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved May 1, 2008. Published June 2008. Originally approved in 1935. Last previous edition approved in 2008 as A 182/A 182M – 08.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-182 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

E 165 Test Method for Liquid Penetrant Examination
E 340 Test Method for Macroetching Metals and Alloys

2.3 *ASME Boiler and Pressure Vessel Codes:*[4]

Section IX Welding Qualifications
SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification A 961/A 961M, orders should include the following information:

3.1.1 Additional requirements (see 6.2.1, Table 2 footnotes, 8.3, and 17.2), and

3.1.2 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 8.3.1).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961/A 961M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961/A 961M, this specification shall prevail.

5. Manufacture

5.1 The low-alloy ferritic steels shall be made by the open-hearth, electric-furnace, or basic-oxygen process with the option of separate degassing and refining processes in each case.

5.2 The stainless steels shall be melted by one of the following processes: *(a)* electric-furnace (with the option of separate degassing and refining processes); *(b)* vacuum-furnace; or *(c)* one of the former followed by vacuum or electroslag-consumable remelting. Grade F XM-27Cb may be produced by electron-beam melting.

5.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.4 The material shall be forged as close as practicable to the specified shape and size.

5.4.1 Flanges of any type, elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.4.2 Cylindrically-shaped parts may be machined from forged or rolled solution-annealed austenitic stainless steel bar without additional hot working.

5.4.3 Small cylindrically-shaped low alloy and martensitic stainless steel parts, NPS-4 [DN 100] and under, may be machined from forged or rolled bar, without additional hot working.

5.5 Except as provided for in 5.4, the finished product shall be a forging as defined in the Terminology section of Specification A 788/A 788M.

6. Heat Treatment[5]

6.1 After hot working, forgings shall be cooled to a temperature below 1000 °F [538 °C] prior to heat treating in accordance with the requirements of Table 1.

6.2 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—The low alloy steels and ferritic and martensitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.2.1 *Liquid Quenching*—When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are utilized.

6.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT."

6.2.2 Alternatively, Grade F 1, F 2, and F 12, Classes 1 and 2 may be given a heat treatment of 1200 °F [650 °C] minimum after final hot or cold forming.

6.3 *Austenitic and Ferritic-Austenitic Stainless Steels*—The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solution annealing temperature specified in Table 1, forgings made from austenitic grades (except grades F 304H, F 309H, F 310, F 310H, F 316H, F 321, F 321H, F 347, F 347H, F 348, F 348H, F 45, and F 56) may be individually rapidly quenched in accordance with the requirements of Table 1.

6.3.2 See Supplementary Requirement S8 if a particular heat treatment method is to be employed.

6.4 *Time of Heat Treatment*—Heat treatment of forgings may be performed before machining.

6.5 *Forged or Rolled Bar*—Forged or rolled austenitic stainless bar from which cylindrically shaped parts are to be machined, as permitted by 5.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification A 479/A 479M or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S3 if annealing must be the final operation).

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in F 321, F 321H, F 347, F 347H, F 348, and F 348H. When specified by the purchaser, a lower temperature stabilization or resolution annealing shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S10).

TABLE 1 Heat Treating Requirements

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C][A]	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
		Low Alloy Steels			
F 1	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 2	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 9	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 91	normalize and temper	1900-1975 [1040-1080]	air cool	[B]	1350–1470 [730–800]
F 92	normalize and temper	1900-1975 [1040-1080]	air cool	[B]	1350–1470 [730–800]
F 122	normalize and temper	1900-1975 [1040-1080]	air cool	[B]	1350–1470 [730–800]
F 911	normalize and temper	1900-1975 [1040-1080]	air cool or liquid	[B]	1365–1435 [740-780]
F 11, Class 1, 2, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 12, Class 1, 2	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 22, Class 1, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1250 [675]
F 22V	normalize and temper or quench and temper	1650 [900]	air cool or liquid	[B]	1250 [675]
F 23	normalize and temper	1900-1975 [1040-1080]	air cool accelerated cool	[B]	1350–1470 [730–800]
F 24	normalize and temper	1800-1975 [980-1080]	air cool or liquid	[B]	1350–1470 [730–800]
FR	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize	1750 [955]	air cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 36, Class 1	normalize and temper	1650 [900]	air cool	[B]	1100 [595]
F 36, Class 2	normalize and temper	1650 [900]	air cool	[B]	1100 [595]
	quench and temper	1650 [900]	accelerated air cool or liquid		1100 [595]
		Martensitic Stainless Steels			
F 6a Class 1	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[B]	[B]	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[B]	[B]	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040-1120 [560-600]
		Ferritic Stainless Steels			
F XM-27 Cb	anneal	1850 [1010]	furnace cool	[B]	[B]
F 429	anneal	1850 [1010]	furnace cool	[B]	[B]
F 430	anneal	not specified	furnace cool	[B]	[B]

TABLE 1 *Continued*

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C][A]	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
		Austenitic Stainless Steels			
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 309H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310MoLN	solution treat and quench	1900–2010 [1050–1100]	liquid	500 [260]	[B]
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316Ti	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 347H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 348H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 321H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 20	solution treat and quench	1700-1850 [925-1010]	liquid	500 [260]	[B]
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	[B]
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 46	solution treat and quench	2010-2140 [1100-1140]	liquid	500 [260]	[B]
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	[B]
F 56	solution treat and quench	2050-2160 [1120-1180]	liquid	500 [260]	[B]
F 58	solution treat and quench	2085 [1140]	liquid	500 [260]	[B]
F 62	solution treat and quench	2025 [1105]	liquid	500 [260]	[B]
F 63	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 64	solution treat and quench	2010-2140 [1100-1170]	liquid	500 [250]	[B]
F 904L	solution treat and quench	1920-2100 [1050-1150]	liquid	500 [260]	[B]
		Ferritic-Austenitic Stainless Steels			
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	[B]
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
F 52[C]			liquid	500 [260]	[B]
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	[B]
F 54	solution treat and quench	1920-2060 [1050-1125]	liquid	500 [260]	[B]
F 55	solution treat and quench	2010-2085 [1100-1140]	liquid	500 [260]	[B]
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	[B]
F 59	solution treat and quench	1975-2050 [1080-1120]	liquid	500 [260]	[B]
F 60	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
F 61	solution treat and quench	1920-2060 [1050-1125]	liquid	500 [260]	[B]
F 65	solution treat and quench	1830-2100 [1000-1150]	liquid[D]	500 [260]	[B]
F 66	solution treat and quench	1800–1975 [980–1080]	liquid	500 [260]	[B]

[A] Minimum unless temperature range is listed.

[B] Not applicable.

[C] Grade F 52 shall be solution treated at 1825 to 1875 °F [995 to 1025 °C] 30 min/in. of thickness and water quenched.

[D] The cooling media for Grade F 65 shall be quenching in water or rapidly cooling by other means.

7. Chemical Composition

7.1 A chemical heat analysis in accordance with Specification A 961/A 961M shall be made and conform to the chemical composition prescribed in Table 2.

7.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

7.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material is not permitted.

7.4 Steel grades covered in this specification shall not contain an unspecified element, other than nitrogen in stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation or Grade designation and identification symbol in Table 2.

7.5 *Product Analysis*—The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961/A 961M.

8. Mechanical Properties

8.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

8.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except for ferritic grades when the post-weld heat treatment is conducted at least 50 °F [30 °C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the maximum cross section of the forgings they represent.

8.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position where *T* is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the mid-length of the test specimen shall be at least *T* from any second heat-treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

8.3.1 With prior purchase approval, the test specimen for ferritic steel forgings may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance (2 t) from any second surface. However, the test depth shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where ¼ $T \times T$ testing (see 8.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

8.3.2 *Metal Buffers*—The required distances from heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½-in. [13-mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

8.4 For annealed low alloy steels, ferritic stainless steels, and martensitic stainless steels, and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

8.5 *Tension Tests*:

8.5.1 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—One tension test shall be made for each heat in each heat treatment charge.

8.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each heat of each forging type (see Note 1) and section size is required, instead of one test from each heat in each heat-treatment charge.

NOTE 1—"Type" in this case is used to describe the forging shape such as a flange, ell, tee, and the like.

8.5.2 *Austenitic and Ferritic-Austenitic Stainless Steel Grades*—One tension test shall be made for each heat.

8.5.2.1 When heat treated in accordance with 6.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

8.5.2.2 When the alternative method in 6.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forgings they represent.

8.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

8.6 *Hardness Tests*:

8.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 8.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

8.6.2 When the reduced number of tension tests permitted by 8.5.1.1 is applied, additional hardness tests shall be made on forgings or samples, as defined in 8.2, scattered throughout the load (see Note 2). At least eight samples shall be checked from each batch load, and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheat treated and the requirements of 8.5.1 shall apply.

NOTE 2—The tension test required in 8.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 8.6.2 are required when 8.5.1.1 is applied to ensure the prescribed heat-treating cycle and uniformity throughout the load.

8.7 *Notch Toughness Requirements*—Grades F 3V, F 3VCb, and F 22V.

8.7.1 Impact test specimens shall be Charpy V-notch Type, as shown in Fig. 11a of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

TABLE 2 Chemical Requirements[A]

Identification Symbol	UNS Designation	Grade	Composition, % Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
						Low Alloy Steels							
F 1	K12822	carbon-molybdenum	0.28	0.60–0.90	0.045	0.045	0.15–0.35			0.44–0.65			
F 2[B]	K12122	0.5 % chromium, 0.5 % molybdenum	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60		0.50–0.81	0.44–0.65			
F 5[C]	K41545	4 to 6 % chromium	0.15	0.30–0.60	0.030	0.030	0.50	0.50	4.0–6.0	0.44–0.65			
F 5a[C]	K42544	4 to 6 % chromium	0.25	0.60	0.040	0.030	0.50	0.50	4.0–6.0	0.44–0.65			
F 9	K90941	9 % chromium	0.15	0.30–0.60	0.030	0.030	0.50–1.00		8.0–10.0	0.90–1.10			
F 10	S33100	20 nickel, 8 chromium	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0				
F 91	K90901	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.06–0.10		N 0.03–0.07 Al 0.02[D] V 0.18–0.25 Ti 0.01[D] Zr 0.01[D]
F 92	K92460	9 % chromium, 1.8 % tungsten, 0.2 % vanadium plus columbium	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.50–9.50	0.30–0.60	0.04–0.09		V 0.15–0.25 N 0.030–0.070 Al 0.02[D] W 1.50–2.00 B 0.001–0.006 Ti 0.01[D] Zr 0.01[D]
F 122	K91271	11 % chromium, 2 % tungsten, 0.2 % vanadium, plus molybdenum, columbium, copper, nickel, nitrogen, and boron	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.00–11.50	0.25–0.60	0.04–0.10		V 0.15–0.30 B 0.005 N 0.040–0.100 Al 0.02[D] Cu 0.30–1.70 W 1.50–2.50 Ti 0.01[D] Zr 0.01[D]
F 911	K91061	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.060–0.10		W 0.90–1.10 Al 0.02[D] N 0.04–0.09 V 0.18–0.25 B 0.0003–0.006 Ti 0.01[D] Zr 0.01[D]
F 11 Class 1	K11597	1.25 % chromium, 0.5 % molybdenum	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00		1.00–1.50	0.44–0.65			
F 11 Class 2	K11572	1.25 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00		1.00–1.50	0.44–0.65			
F 11 Class 3	K11572	1.25 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00		1.00–1.50	0.44–0.65			
F 12 Class 1	K11562	1 % chromium, 0.5 % molybdenum	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max		0.80–1.25	0.44–0.65			
F 12 Class 2	K11564	1 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60		0.80–1.25	0.44–0.65			
F 21	K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max		2.7–3.3	0.80–1.06			

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 3V	K31830	3 % chromium, 1 % molybdenum, 0.25 % vanadium plus boron and titanium	0.05–0.18	0.30–0.60	0.020	0.020	0.10		2.8–3.2	0.90–1.10		0.015–0.035	V 0.20–0.30 B 0.001–0.003
F 3VCb	K31390	3 % chromium, 1 % molybdenum, 0.25 % vanadium plus boron, columbium, and titanium	0.10–0.15	0.30–0.60	0.020	0.010	0.10	0.25	2.7–3.3	0.90–1.10	0.015–0.070	0.015	V 0.20–0.30 Cu 0.25 Ca 0.0005–0.0150
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50		2.00–2.50	0.87–1.13			
F 22 Class 3	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50		2.00–2.50	0.87–1.13			
F 22V	K31835	2.25 % chromium, 1 % molybdenum, 0.25 % vanadium	0.11–0.15	0.30–0.60	0.015	0.010	0.10	0.25	2.00–2.50	0.90–1.10	0.07	0.030	Cu 0.20 V 0.25–0.35 B 0.002 Ca 0.015[E]
F 23	K41650	2.25 % chromium, 1.6 % tungsten, 0.25 % vanadium, plus molybdenum, columbium, and boron	0.04–0.10	0.10–0.60	0.030	0.010	0.50		1.90-2.60	0.05-0.30	0.02–0.08		V 0.20–0.30 B 0.0005–0.006 N 0.030 Al 0.030 W 1.45–1.75
F 24	K30736	2.25 % chromium, 1 % molybdenum, 0.25 % vanadium plus titanium and boron	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45		2.20–2.60	0.90–1.10		0.06-0.10	V 0.20–0.30 N 0.12 Al 0.020 B 0.0015–0.0070
FR	K22035	2 % nickel, 1 % copper	0.20	0.40–1.06	0.045	0.050		1.60–2.24					Cu 0.75–1.25
F 36	K21001	1.15 % nickel, 0.65 % copper, molybdenum, and columbium	0.10–0.17	0.80–1.20	0.030	0.025	0.25–0.50	1.00–1.30	0.30	0.25–0.50	0.015–0.045		N 0.020 Al 0.050 Cu 0.50–0.80 V 0.02
						Martensitic Stainless Steels							
F 6a	S41000	13 % chromium 410[F]	0.15	1.00	0.040	0.030	1.00	0.50	11.5–13.5				
F 6b	S41026	13 % chromium, 0.5 % molybdenum	0.15	1.00	0.020	0.020	1.00	1.00–2.00	11.5–13.5	0.40–0.60			Cu 0.50
F 6NM	S41500	13 % chromium, 4 % nickel	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00			
						Ferritic Stainless Steels							
F XM-27Cb[G]	S44627	27 chromium, 1 molybdenum XM-27[F]	0.010	0.40	0.020	0.020	0.40	0.50	25.0–27.5	0.75–1.50	0.05–0.20		N 0.015 Cu 0.20
F 429	S42900	15 chromium 429[F]	0.12	1.00	0.040	0.030	0.75	0.50	14.0–16.0				
F 430	S43000	17 chromium 430[F]	0.12	1.00	0.040	0.030	0.75	0.50	16.0–18.0				
						Austenitic Stainless Steels							
F 304[H]	S30400	18 chromium, 8 nickel 304[F]	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0				

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 304H	S30409	18 chromium, 8 nickel 304H[F]	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0				
F 304L[H]	S30403	18 chromium, 8 nickel, low carbon 304L[F]	0.030	2.00	0.045	0.030	1.00	8.0–13.0	18.0–20.0				
F 304N[I]	S30451	18 chromium, 8 nickel, modified with nitrogen 304N[F]	0.08	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0				
F 304LN[I]	S30453	18 chromium, 8 nickel, modified with nitrogen 304LN[F]	0.030	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0				
F 309H	S30909	23 chromium, 13.5 nickel 309H[F]	0.04–0.10	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0				
F 310	S31000	25 chromium, 20 nickel 310[F]	0.25	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0				
F 310H	S31009	25 chromium, 20 nickel 310H[F]	0.04–0.10	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0				
F 310MoLN	S31050	25 chromium, 22 nickel, modified with molybdenum and nitrogen, low carbon 310MoLN[F]	0.030	2.00	0.030	0.015	0.40	21.0–23.0	24.0–26.0	2.00–3.00			N 0.10–0.16
F 316[H]	S31600	18 chromium, 8 nickel, modified with molybdenum 316[F]	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00			
F 316H	S31609	18 chromium, 8 nickel, modified with molybdenum 316H[F]	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00			
F 316L[H]	S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon 316L[F]	0.030	2.00	0.045	0.030	1.00	10.0–15.0	16.0–18.0	2.00–3.00			
F 316N[I]	S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316N[F]	0.08	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00			
F 316LN[I]	S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316LN[F]	0.030	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00			
F 316Ti	S31635	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316Ti	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00		[J]	N 0.10 max
F 317	S31700	19 chromium, 13 nickel, 3.5 molybdenum 317[F]	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0			

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 317L	S31703	19 chromium, 13 nickel, 3.5 molybdenum 317L[F]	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0			
F 321	S32100	18 chromium, 8 nickel modified with titanium 321[F]	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0			[K]	
F 321H	S32109	18 chromium, 8 nickel, modified with titanium 321H[F]	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0			[L]	
F 347	S34700	18 chromium, 8 nickel modified with columbium 347[F]	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[M]		
F 347H	S34709	18 chromium, 8 nickel, modified with columbium 347H[F]	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[N]		
F 348	S34800	18 chromium, 8 nickel modified with columbium 348[F]	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[M]		Co 0.20 Ta 0.10
F 348H	S34809	18 chromium, 8 nickel, modified with columbium 348H[F]	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[N]		Co 0.20 Ta 0.10
F XM-11	S21904	20 chromium, 6 nickel, 9 manganese XM-11[F]	0.040	8.0–10.0	0.060	0.030	1.00	5.5–7.5	19.0–21.5				N 0.15–0.40
F XM-19	S20910	22 chromium, 13 nickel, 5 manganese XM-19[F]	0.06	4.0–6.0	0.040	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	0.10–0.30		N 0.20–0.40 V 0.10–0.30
F 20	N08020	35 nickel, 20 chromium, 3.5 copper, 2.5 molybdenum	.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	8xCmin –1.00		Cu 3.0–4.0
F 44	S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5			Cu 0.50–1.00 N 0.18–0.22
F 45	S30815	21 chromium, 11 nickel modified with nitrogen and cerium	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0				N 0.14–0.20 Ce 0.03–0.08
F 46	S30600	18 chromium, 15 nickel, 4 silicon	0.018	2.00	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20			Cu 0.50
F 47	S31725	19 chromium, 15 nickel, 4 molybdenum 317LM[F]	0.030	2.00	0.045	0.030	0.75	13.0–17.5	18.0–20.0	4.0–5.0			N 0.10
F 48	S31726	19 chromium, 15 nickel, 4 molybdenum 317LMN[F]	0.030	2.00	0.045	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0			N 0.10–0.20
F 49	S34565	24 chromium, 17 nickel, 6 manganese, 5 molybdenum	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	0.10		N 0.40–0.60
F 56	S33228	32 nickel, 27 chromium with columbium	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0		0.6–1.0		Ce 0.05–0.10 Al 0.025

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 58	S31266	24 chromium, 20 nickel, 6 molybdenum, 2 tungsten with nitrogen	0.030	2.0–4.0	0.035	0.020	1.00	21.0–24.0	23.0–25.0	5.2–6.2			N 0.35–0.60 Cu 1.00–2.50 W 1.50–2.50
F 62	N08367	21 chromium, 25 nickel, 6.5 molybdenum	0.030	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.0–7.0			N 0.18–0.25 Cu 0.75
F 63	S32615	18 chromium, 20 nickel, 5.5 silicon	0.07	2.00	0.045	0.030	4.8-6.0	19.0-22.0	16.5-19.5	0.30-1.50			Cu 1.50-2.50
F 64	S30601	17.5 chromium, 17.5 nickel, 5.3 silicon	0.015	0.50-0.80	0.030	0.013	5.0-5.6	17.0-18.0	17.0-18.0	0.20			Cu 0.35, N 0.05
F 904L	N08904	21 chromium, 26 nickel, 4.5 molybdenum 904L[F]	0.020	2.0	0.040	0.030	1.00	23.0–28.0	19.0–23.0	4.0–5.0			Cu 1.00–2.00 N 0.10
						Ferritic-Austenitic Stainless Steels							
F 50	S31200	25 chromium, 6 nickel, modified with nitrogen	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00			N 0.14–0.20
F 51	S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5			N 0.08–0.20
F 52	S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50			N 0.15–0.35
F 53	S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen 2507[F]	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0			N 0.24–0.32 Cu 0.50
F 54	S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5			N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50
F 55	S32760	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0			N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00[G]
F 57	S39277	26 chromium, 7 nickel, 3.7 molybdenum	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0			Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33
F 59	S32520	25 chromium, 6.5 nickel, 4 molybdenum with nitrogen	0.030	1.50	0.035	0.020	0.80	5.5–8.0	24.0–26.0	3.0–5.0			N 0.20–0.35 Cu 0.50–3.00
F 60	S32205	22 chromium, 5.5 nickel, 3 molybdenum, modified with nitrogen 2205[F]	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5			N 0.14–0.20

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 61	S32550	26 chromium, 6 nickel, 3.5 molybdenum with nitrogen and copper 255[F]	0.040	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9			Cu 1.50–2.50 N 0.10–0.25
F 65	S32906	29 chromium, 6.5 nickel, 2 molybdenum with nitrogen	0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.5–2.6			Cu 0.80 N 0.30–0.40
F 66	S32202	22 chromium, 2.0 nickel, 0.25 molybdenum with nitrogen	0.030	2.00	0.040	0.010	1.00	1.00–2.80	21.5–24.0	0.45			N 0.18–0.26

[A] All values are maximum unless otherwise stated.
[B] Grade F 2 was formerly assigned to the 1 % chromium, 0.5 % molybdenum grade which is now Grade F 12.
[C] The present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, and the like.
[D] Applies to both heat and product analyses.
[E] For Grade F22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.
[F] Naming system developed and applied by ASTM.
[G] Grade F XM-27Cb shall have a nickel plus copper content of 0.50 max %. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002 %.
[H] Grades F 304, F 304L, F 316, and F 316L shall have a maximum nitrogen content of 0.10 %.
[I] Grades F 304N, F 316N, F 304LN, and F 316LN shall have a nitrogen content of 0.10 to 0.16 %.
[J] Grade F 316Ti shall have a titanium content not less than five times the carbon plus nitrogen content and not more than 0.70 %.
[K] Grade F 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70 %.
[L] Grade F 321H shall have a titanium content of not less than four times the carbon content and not more than 0.70 %.
[M] Grades F 347 and F 348 shall have a columbium content of not less than ten times the carbon content and not more than 1.10 %.
[N] Grades F 347H and F 348H shall have a columbium content of not less than eight times the carbon content and not more than 1.10 %.
[O] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

TABLE 3 Tensile and Hardness Requirements

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
		Low Alloy Steels			
F 1	70 [485]	40 [275]	20	30	143–192
F 2	70 [485]	40 [275]	20	30	143–192
F 5	70 [485]	40 [275]	20	35	143–217
F 5a	90 [620]	65 [450]	22	50	187–248
F 9	85 [585]	55 [380]	20	40	179–217
F 10	80 [550]	30 [205]	30	50	. . .
F 91	85 [585]	60 [415]	20	40	248 max
F 92	90 [620]	64 [440]	20	45	269 max
F 122	90 [620]	58 [400]	20	40	250 max
F 911	90 [620]	64 [440]	18	40	187–248
F 11 Class 1	60 [415]	30 [205]	20	45	121–174
F 11 Class 2	70 [485]	40 [275]	20	30	143–207
F 11 Class 3	75 [515]	45 [310]	20	30	156–207
F 12 Class 1	60 [415]	32 [220]	20	45	121–174
F 12 Class 2	70 [485]	40 [275]	20	30	143–207
F 21	75 [515]	45 [310]	20	30	156–207
F 3V, and F 3VCb	85–110 [585–760]	60 [415]	18	45	174–237
F 22 Class 1	60 [415]	30 [205]	20	35	170 max
F 22 Class 3	75 [515]	45 [310]	20	30	156–207
F 22V	85–110 [585–780]	60 [415]	18	45	174–237
F 23	74 [510]	58 [400]	20	40	220 max
F 24	85 [585]	60 [415]	20	40	248 max
FR	63 [435]	46 [315]	25	38	197 max
F 36, Class 1	90 [620]	64 [440]	15	. . .	252 max
F 36, Class 2	95.5 [660]	66.5 [460]	15	. . .	252 max
		Martensitic Stainless Steels			
F 6a Class 1	70 [485]	40 [275]	18	35	143–207
F 6a Class 2	85 [585]	55 [380]	18	35	167–229
F 6a Class 3	110 [760]	85 [585]	15	35	235–302
F 6a Class 4	130 [895]	110 [760]	12	35	263–321
F 6b	110–135 [760–930]	90 [620]	16	45	235–285
F 6NM	115 [790]	90 [620]	15	45	295 max
		Ferritic Stainless Steels			
F XM-27Cb	60 [415]	35 [240]	20	45	190 max
F 429	60 [415]	35 [240]	20	45	190 max
F 430	60 [415]	35 [240]	20	45	190 max
		Austenitic Stainless Steels			
F 304	75 [515][B]	30 [205]	30	50	. . .
F 304H	75 [515][B]	30 [205]	30	50	. . .
F 304L	70 [485][C]	25 [170]	30	50	. . .
F 304N	80 [550]	35 [240]	30[D]	50[E]	. . .
F 304LN	75 [515][B]	30 [205]	30	50	. . .
F 309H	75 [515][B]	30 [205]	30	50	. . .
F 310	75 [515][B]	30 [205]	30	50	. . .
F 310 MoLN	78 [540]	37 [255]	25	40	. . .
F 310H	75 [515][B]	30 [205]	30	50	. . .
F 316	75 [515][B]	30 [205]	30	50	. . .
F 316H	75 [515][B]	30 [205]	30	50	. . .
F 316L	70 [485][C]	25 [170]	30	50	. . .
F 316N	80 [550]	35 [240]	30[D]	50[E]	. . .
F 316LN	75 [515][B]	30 [205]	30	50	. . .
F 316Ti	75 [515]	30 [205]	30	40	. . .
F 317	75 [515][B]	30 [205]	30	50	. . .
F 317L	70 [485][C]	25 [170]	30	50	. . .
F 347	75 [515][B]	30 [205]	30	50	. . .
F 347H	75 [515][B]	30 [205]	30	50	. . .
F 348	75 [515][B]	30 [205]	30	50	. . .
F 348H	75 [515][B]	30 [205]	30	50	. . .
F 321	75 [515][B]	30 [205]	30	50	. . .
F 321H	75 [515][B]	30 [205]	30	50	. . .
F XM-11	90 [620]	50 [345]	45	60	. . .
F XM-19	100 [690]	55 [380]	35	55	. . .
F 20	80 [550]	35 [240]	30	50	. . .
F 44	94 [650]	44 [300]	35	50	. . .

TABLE 3 *Continued*

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
F 45	87 [600]	45 [310]	40	50	. . .
F 46	78 [540]	35 [240]	40	50	. . .
F 47	75 [525]	30 [205]	40	50	. . .
F 48	80 [550]	35 [240]	40	50	. . .
F 49	115 [795]	60 [415]	35	40	. . .
F 56	73 [500]	27 [185]	30	35	. . .
F 58	109 [750]	61 [420]	35	50	. . .
F 62	95 [655]	45 [310]	30	50	. . .
F 63	80 [550]	32 [220]	25	. . .	192 max
F 64	90 [620]	40 [275]	35	50	217 max
F 904L	71 [490]	31 [215]	35	. . .	. . .
		Ferritic-Austenitic Stainless Steels			
F 50	100–130 [690–900]	65 [450]	25	50	. . .
F 51	90 [620]	65 [450]	25	45	. . .
F 52	100 [690]	70 [485]	15	. . .	. . .
F 53	116 [800][F]	80 [550][F]	15	. . .	310 max
F 54	116 [800]	80 [550]	15	30	310 max
F 55	109–130 [750–895]	80 [550]	25	45	. . .
F 57	118 [820]	85 [585]	25	50	. . .
F 59	112 [770]	80 [550]	25	40	. . .
F 60	95 [655]	65 [450]	25	45	. . .
F 61	109 [750]	80 [550]	25	50	. . .
F 65	109 [750]	80 [550]	25	. . .	. . .
F 66	94 [650]	65 [450]	30	. . .	290 max

[A] Determined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method may also be used.
[B] For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].
[C] For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].
[D] Longitudinal. The transverse elongation shall be 25 % in 2 in. or 50 mm, min.
[E] Longitudinal. The transverse reduction of area shall be 45 % min.
[F] For sections over 2 in. [50 mm] in thickness, the minimum tensile strength shall be 106 ksi [730 MPa]; the minimum yield strength shall be 75 ksi [515 MPa].

8.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.2, 8.3 and 8.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.7.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat-treated surface of the forging.

8.7.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J], and it shall meet a minimum value of 35 ft-lbf [48 J].

8.7.5 The impact test temperature shall be 0 °F [−18 °C].

9. Grain Size for Austenitic Grades

9.1 All H grades and grade F 63 shall be tested for average grain size by Test Methods E 112.

9.1.1 Grades F 304H, F 309H, F 310H, and F 316H shall have a grain size of ASTM No. 6 or coarser.

9.1.2 Grades F 321H, F 347H, and F 348H shall have a grain size of ASTM No. 7 or coarser.

9.1.3 Grade F 63 shall have a grain size of ASTM No. 3 or finer.

10. Corrosion Testing for Austenitic Grades

10.1 Corrosion testing is not required by this specification.

10.2 Austenitic grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S4.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 8.

12. Workmanship, Finish, and Appearance

12.1 Forgings shall conform to the requirements of Specification A 961/A 961M.

12.2 The forgings shall be free of scale, machining burrs which might hinder fit-up, and other injurious imperfections as defined herein. The forgings shall have a workmanlike finish, and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S9 of Specification A 961/A 961M) at the discretion of the manufacturer with the following limitations and requirements:

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 4 except as otherwise provided in Supplementary Requirement S5. The electrodes shall be purchased in accordance with ASME Specifications SFA-5.4, SFA-5.5, SFA-5.9, or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc process, the gas tungsten-arc process, and gas shielded processes using flux-core consumables, may be used.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic-particle inspection in accordance with Test Method A 275/A 275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid-penetrant inspection in accordance with Test Method E 165 for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 4 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 4, provided purchaser approval is obtained prior to repair.

13.1.6 Repair by welding shall not exceed 10 % of the surface area of the forging nor 33⅓ % of the wall thickness of the finished forging or ⅜ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

13.1.7 When approval of the purchaser is obtained, the limitations set forth in 13.1.6 may be exceeded, but all other requirements of Section 13 shall apply.

13.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

13.1.9 Post-weld heat treatment times for F 36 are: for Class 1, up to 2 in. [50 mm] in thickness, 1 h per in. [25 mm], 15 minutes minimum, and over 2 in. [50 mm], 15 minutes for each additional in. of thickness or fraction thereof; for Class 2, 1 h per in. [25 mm], ½ h minimum.

TABLE 4 Repair Welding Requirements

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post Weld Heat-Treatment Temperature, Minimum or Range, °F [°C]
		Low Alloy Steels	
F 1	E 7018-A 1	200–400 [95–205]	1150 [620]
F 2	E 8018-B 1	300–600 [150–315]	1150 [620]
F 5	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 5a	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 9	E 505-15 or 16	400–700 [205–370]	1250 [675]
F 10[B]	...	...	...
F 91	9 % Cr, 1 % Mo, VCbN	400–700 [205–370]	1350–1470 [730–800]
F 92	9 % Cr, 0.5 % Mo, 1.5 % W, VCbNiN	400–700 [205–370]	1350–1470 [730–800]
F 122	11 % Cr, 2 % W, MoVCbCuN	400–700 [205–370]	1350–1470 [730–800]
F 911	9 % Cr, 1 % Mo, 1 % W, VCbN	400–700 [205–370]	1365–1435 [740–780]
F 11, Class 1, 2, and 3	E 8018-B 2	300–600 [150–315]	1150 [620]
F 12, Class 1 and 2	E 8018-B 2	300–600 [150–315]	1150 [620]
F 21	E 9018-B 3	300–600 [150–315]	1250 [675]
F 3V, and F 3VCb	3 % Cr, 1 % Mo, ¼ % V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22V	2.25 % Cr, 1 % Mo, 0.25 % V-Cb	300–600 [150–315]	1250 [675]
F 23	2.25 % Cr, 1.6 % W, 0.25 % V-Mo-Cb-B	300-600 [150–315]	1350–1470 [730–800]
F 24	2.25 % Cr, 1 % Mo, 0.25 % V	200–400 [95–205][C]	1350–1470 [730–800][C]
F 36, Class 1	1.15 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1100–1200 [595–650]
F 36, Class 2	1.15 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1000–1150 [540–620]
		Martensitic Stainless Steels	
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13 % Cr, 1½ % Ni, ½ % Mo	400–700 [205–370]	1150 [620]
F 6NM	13 % Cr, 4 % Ni	300–700 [150–370]	1050 [565]
		Ferritic Stainless Steels	
F XM-27Cb	26 % Cr, 1 % Mo	NR[D]	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
		Austenitic Stainless Steels	
F 304	E 308-15 or 16	NR	1900 [1040] + WQ[E]
F 304L	E 308L-15 or 16	NR	1900 [1040] + WQ
F 304H	E 308-15 or 16	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ

TABLE 4 *Continued*

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post Weld Heat-Treatment Temperature, Minimum or Range, °F [°C]
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 309H	E 309-15 or 16[F]	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 310H	E 310-15 or 16	NR	1900 [1040] + WQ
F 310MoLN	E 310Mo-15 or 16	NR	1920–2010 [1050–1100] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316Ti	E 316-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 321[B]	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H[B]	E 347-15 or 16	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16	NR	1925 [1050] + WQ
F 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 20	E/ER-320, 320LR	NR	1700–1850 [925–1010] + WQ
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45[B]	...	...	...
F 46	...	...	...
F 47	...[G]	...	2100 [1150] + WQ
F 48	...[G]	...	2100 [1150] + WQ
F 49	...[G]	...	2100 [1150] + WQ
F 58	E NiCrMo-10	...	2100 [1150] + WQ
F 62	E NiCrMo-3	NR	2025 [1105] + WQ
F 904L	E NiCrMo-3	NR	1920–2100 [1050–1150] + WQ
	Ferritic-Austenitic Stainless Steels		
F 50	25 % Cr, 6 % Ni, 1.7 % Mo	NR	NR
F 51	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 52	26 % Cr, 8 % Ni, 2 % Mo	NR	NR
F 53	25 % Cr, 7 % Ni, 4 % Mo	NR	NR
F 54	25 % Cr, 7 % Ni, 3 % Mo, W	NR	NR
F 55	25 % Cr, 7 % Ni, 3.5 % Mo	NR	NR
F 57	25 % Cr, 7 % Ni, 3 % Mo, 1.5 % Cu, 1 % W	NR	NR
F 59	E Ni CrMo-10	NR	NR
F 60	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 61	26 % Cr, 9 % Ni, 3.5 % Mo	NR	NR
F 65	29 % Cr, 6.5 % Ni, 2 % Mo	NR	NR
F 66	22 % Cr, 2 % Ni, 0.25 % Mo	NR	NR

[A] Electrodes shall comply with ASME SFA 5.4, SFA 5.5, and corresponding ER grades of SFA-5.9 or SFA-5.11.
[B] Purchaser approval required.
[C] Not required for not below 0.500 in. [12.7 mm].
[D] NR = not required.
[E] WQ = water quench.
[F] Filler metal shall additionally have 0.04 % minimum carbon.
[G] Match filler metal is available. Fabricators have also used AWS A 5.14, Class ER, NiCrMo-3 and AWS A 5.11, Class E, NiCrMo-3 filler metals.

14. Inspection

14.1 Inspection provisions of Specification A 961/A 961M apply.

15. Rejection and Rehearing

15.1 The purchaser shall comply with the provisions of Specification A 961/A 961M.

16. Certification

16.1 In addition to the certification requirements of Specification A 961/A 961M, test reports shall be furnished to the purchaser or his representative.

16.2 Test reports shall include certification that all requirements of this specification have been met. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

16.2.1 Type heat treatment, Section 6,

16.2.2 Product analysis results, Section 8 of Specification A 961/A 961M,

16.2.3 Tensile property results, Section 8 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

16.2.4 Chemical analysis results, Section 7 (Table 2), 16.2.5 Hardness results, Section 8 (Table 3),

16.2.6 Grain size results, Section 9, and

16.2.7 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 In addition to the marking requirements of Specification A 961/A 961M, the manufacturer's name (see Note 3) or symbol shall be permanently marked on each forging.

NOTE 3—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification, and the results have been determined to meet the requirements of this specification.

17.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters QT following the specification designation.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 4, the letters "WNS" shall be marked following the specification designation.

17.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply).

17.1.4 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, and the like.

17.2 *Bar Coding*—In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirements; pipe fittings; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service applications, high; wrought material

SUPPLEMENTARY REQUIREMENTS

In addition to any of the supplementary requirements of Specification A 961/A 961M, the following supplementary requirements shall apply only when specified by the purchaser in the order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Heat Treatment Details

S2.1 The manufacturer shall furnish a detailed test report containing the information required in 16.2 and shall include all pertinent details of the heat-treating cycle given the forgings.

S3. Material for Optimum Resistance to Stress-Corrosion Cracking

S3.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A 484/A 484M.

S4. Corrosion Tests

S4.1 All austenitic stainless steels shall pass intergranular corrosion tests performed in accordance with Practice E of Practices A 262.

S4.2 Intergranular corrosion tests shall be performed on specimens of ferritic stainless steels as described in Practices A 763.

S4.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S5. Special Filler Metal

S5.1 In repair-welded F 316, F 316L, F 316H, and F 316N forgings, the deposited weld metal shall conform to E 308 composition wire. Forgings repair welded with E 308 weld metal shall be marked F __ W 308.

S6. Hardness Test

S6.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S7. Alternate Heat Treatment (Grade F 91 and F 92)

S7.1 Grade F 91 shall be normalized in accordance with Section 6 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper at 1350 °F [730 °C] minimum to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 6. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7"shall be included with the required marking of the forging.

S8. Heat Treatment of Austenitic Forgings

S8.1 The purchaser shall specify the heat-treatment method (in 6.1 or in 6.3.1) that shall be employed.

S8.2 The manufacturer shall provide a test report containing the information required in 16.2 and shall include a statement of the heat-treatment method employed.

S9. Grain Size for Austenitic Grades

S9.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S10. Stabilization Treatment

S10.1 Subsequent to the solution anneal for Grades F 321, F 321H, F 347, F 347H, F 348, and F 348H, these grades shall be given a stabilization heat treatment at 1500 to 1600 °F [815 to 870 °C] for a minimum of 2 h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 17, the grade designation symbol shall be followed by the symbol "S10."

S11. Grain Size Requirements for Non-H-Grade Austenitic Steels Used Above 1000 °F [540 °C]

S11.1 Non-H grades of austenitic stainless steels shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be on a certified test report.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 08, that may impact the use of this specification. (Approved May 1, 2008)

(*1*) Added new grade S32202 to Tables 1-4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 07a, that may impact the use of this specification. (Approved March 1, 2008)

(*1*) Revised 1.2, 5.4, and 6.5 to remove the size limit for solution-annealed austenitic stainless steel parts machined from bar.

(*2*) Revised the heat treat range and added table footnote D for Grade F 65 in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 07, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Revised the Yield Strength for Grade F 60 in Table 3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 06, that may impact the use of this specification. (Approved May 1, 2007)

(*1*) Added Grade F 316Ti, S31635, to Tables 1-4

(*2*) Revised chemistry of Grades F 91, F 92, F 911, and F 122 in Table 2.

(*3*) Added grades to direct quench exclusion in 6.3.1.

Designation: A 193/A 193M – 07

Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications[1]

This standard is issued under the fixed designation A 193/A 193M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. The term *bolting material* as used in this specification covers bars, bolts, screws, studs, stud bolts, and wire. Bars and wire shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high temperature characteristics.

NOTE 1—The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting material suitable for use at the lower range of high temperature applications, reference should be made to Specification A 354.

NOTE 3—For grades of alloy-steel bolting material suitable for use in low temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 14.

1.4 Supplementary Requirements S1 through S10 are provided for use when additional tests or inspection are desired. These shall apply only when specified in the purchase order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable *M* specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 788/A 788M Specification for Steel Forgings, General Requirements

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

B 696 Specification for Coatings of Cadmium Mechanically Deposited

B 766 Specification for Electrodeposited Coatings of Cadmium

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1936. Last previous edition approved in 2006 as A 193/A 193M-06a.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-193 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E 112 Test Methods for Determining Average Grain Size
E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E 150 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times[4]
E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates[4]
E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328 Test Methods for Stress Relaxation for Materials and Structures
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Examination
E 606 Practice for Strain-Controlled Fatigue Testing
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 *ANSI Standards:*[5]
B1.1 Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.3.1M Metric Hex Cap Screws
B18.3 Hexagon Socket and Spline Socket Screws
B18.3.1M Metric Socket Head Cap Screws

2.3 *AIAG Standard:*[6]
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 The inquiry and orders shall include the following, as required, to describe the desired material adequately:

3.1.1 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

3.1.2 Description of items required (that is, bars, bolts, screws, or studs),

3.1.3 Nuts, if required by purchaser, in accordance with 14.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 7.3, 7.5.1, 11.2, 15.1, and 16.1.

3.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (See Supplementary Requirement S13). When coated fasteners are ordered the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

5. Manufacture (Process)

5.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

5.2 *Quality*—See Specification A 962/A 962M for requirements.

6. Discard

6.1 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

7. Heat Treatment

7.1 Ferritic steels shall be properly heat treated as best suits the high temperature characteristics of each grade. Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the cooling transformation range. The materials which are to be furnished in the liquid-quenched condition shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*) and quenched in a liquid medium under substantially uniform conditions for each quenching charge. Use of water quenching is prohibited for any ferritic grade when heat treatment is part of the fastener manufacturing process. This prohibition does not apply to heat treated bar or to fasteners machined therefrom. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2 and Table 3.

[4] Withdrawn.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from Automotive Industry Action Group, 26200 Lahser, Suite 200, Southfield, MI 48034.

TABLE 1 Chemical Requirements (Composition, percent)[A]

Type	Ferritic Steels			
Grade	B5		B6 and B6X	
Description	5% Chromium		12 % Chromium	
UNS Designation			S41000 (410)	
	Range	Product Variation, Over or Under[B]	Range	Product Variation Over or Under[B]
Carbon	0.10 min	0.01 under	0.08–0.15	0.01 over
Manganese, max	1.00	0.03 over	1.00	0.03 over
Phosphorus, max	0.040	0.005 over	0.040	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	1.00 max	0.05 over
Chromium	4.0–6.0	0.10	11.5–13.5	0.15
Molybdenum	0.40–0.65	0.05	. . .	. . .

Type	Ferritic Steels			
Grade	B7, B7M		B16	
Description	Chromium-Molybdenum[C]		Chromium-Molybdenum-Vanadium	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon	0.37–0.49[D]	0.02	0.36–0.47	0.02
Manganese	0.65–1.10	0.04	0.45–0.70	0.03
Phosphorus, max	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02
Chromium	0.75–1.20	0.05	0.80–1.15	0.05
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03
Vanadium	. . .	. . .	0.25–0.35	0.03
Aluminum, max %[E]	. . .	. . .	0.015	. . .

Type	Austenitic Steels,[F] Classes 1, 1A, 1D, and 2							
Grade	B8, B8A		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA	
UNS Designation	S30400 (304)		S34700 (347)		S31600 (316)		S30500	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.12	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20
Nickel	8.0–11.0	0.15	9.0–12.0	0.15	10.0–14.0	0.15	11.0–13.0	0.15
Molybdenum	. . .	. . .	. . .	. . .	2.00–3.00	0.10	. . .	. . .
Columbium + tantalum	. . .	. . .	10 x carbon content, min; 1.10 max	0.05 under	. . .	. . .	. . .	. . .

Type	Austenitic Steels,[F] Classes 1A, 1B, 1D, and 2					
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA	
UNS Designation	S30451 (304N)		S31651 (316N)		S31254	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00	0.03 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010	0.002 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10	6.0–6.5	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02
Copper	. . .	. . .	. . .	. . .	0.50–1.00	. . .

TABLE 1 *Continued*

Type	Austenitic Steels[F], Classes 1, 1A, and 2	
Grade	B8T, B8TA	
UNS Designation	S32100 (321)	
	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over
Manganese, max	2.00	0.04 over
Phosphorus, max	0.045	0.010 over
Sulfur, max	0.030	0.005 over
Silicon, max	1.00	0.05 over
Chromium	17.0–19.0	0.20
Nickel	9.0–12.0	0.15
Titanium	5 x (C + N) min, 0.70 max[G]	0.05 under

Type	Austenitic Steels[F], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
UNS Designation	S20910		S21800	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.06	0.01 over	0.10	0.01 over
Manganese	4.0–6.0	0.05	7.0–9.0	0.06
Phosphorus, max	0.045	0.005 over	0.060	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	3.5–4.5	0.15
Chromium	20.5–23.5	0.25	16.0–18.0	0.20
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50–3.00	0.10	. . .	. . .
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10–0.30	0.05	. . .	. . .
Vanadium	0.10–0.30	0.02	. . .	. . .

Type	Austenitic Steels[F], Classes 1, 1A and 1D			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
UNS Designation	S30453		S31653	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.
[B] Product analysis—Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.
[C] Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.
[D] For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 %, max. For the B7M grade, a minimum carbon content of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.
[E] Total of soluble and insoluble.
[F] Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.
[G] Nitrogen content is to be reported for this grade.

TABLE 2 Mechanical Requirements — Inch Products

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Ferritic Steels				
B5 4 to 6 % chromium	up to 4, incl	1100	100	80	16	50	. . .
B6 13 % chromium	up to 4, incl	1100	110	85	15	50	. . .
B6X 13 % chromium	up to 4, incl	1100	90	70	16	50	26 HRC
B7 Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HB or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HB or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HB or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HB or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HB or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HB or 35 HRC

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
			Austenitic Steels			
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HB or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HB or 35 HRC
over 1 to 1¼ , incl		105	65	20	35	321 HB or 35 HRC
over 1¼ to 1½ , incl		100	50	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN[D] ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
over ¾ to 1 incl		100	80	20	45	321 HB or 35 HRC
Over 1 to 1¼ , incl		95	65	25	45	321 HB or 35 HRC
over 1¼ to 1½ , incl		90	50	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2[D] 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC

TABLE 2 *Continued*

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
over 2 to 2½ incl		90	65	30	40	321 HB or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HB or 35 HRC
Class 2C: B8M3[D] 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HB or 35 HRC
over 2		85	60	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.
[C] For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
[D] For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3 Mechanical Requirements —Metric Products

Class	Diameter, [mm]	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Ferritic Steels				
B5 4 to 6 % chromium	up to M100, incl	593	690	550	16	50	. . .
B6 13 % chromium	up to M100, incl	593	760	585	15	50	. . .
B6X 13 % chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7 Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HB or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HB or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HB or 99 HRB
	over M100 to M180	620	690	515	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HB or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HB or 35 HRC
	over M100 to M180	650	690	585	16	45	321 HB or 35 HRC

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	515	205	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	550	240	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	690	380	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	655	345	35	55	271 HB or 28 HRC

TABLE 3 *Continued*

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	655	345	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D] M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HB or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HB or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HB or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN,[D] M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HB or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HB or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HB or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2,[D] M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HB or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HB or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HB or 35 HRC
Class 2C: B8M3,[D] M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HB or 35 HRC
over M48		585	415	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).

[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over M20 mm in diameter

[C] For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

[D] For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

7.1.1 Quenched and tempered or normalized and tempered ferritic material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

7.2 Both B6 and B6X materials shall be held, at the tempering temperature for a minimum time of 1 h. Identification Symbol B 6X material may be furnished in the as-rolled-and-tempered condition. Cold working is permitted with the hardness limitation (26 HRC maximum) of Table 2 for the B 6X grade.

7.3 All austenitic stainless steels shall receive a carbide solution treatment (see 7.3.1-7.3.4 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

7.3.1 *Classes 1 and 1B, and Class 1C Grades B8R and B8S*—After rolling of the bar, forging, or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.2 *Class 1D*—Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8N, B8MN, B8R, and B8S bar shall be cooled rapidly immediately following hot working while the temperature is above 1750 °F [955 °C] so that grain boundary carbides are in solution. Class 1D shall be restricted to applications at temperatures less than 850 °F [455 °C].

7.3.3 *Class 1A and Class 1C Grades B8RA and B8SA*—Finished fasteners shall be carbide solution treated after all rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.4 *Classes 2, 2B, and 2C*—Material shall be carbide solution treated by heating from ambient temperature and holding a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling at a rate sufficient to prevent the precipitation of the carbide. Following this treatment the material shall then be strain hardened to achieve the required properties.

NOTE 4—Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

7.4 If scale-free bright finish is required, this shall be specified in the purchase order.

7.5 B7 and B7M bolting material shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after all machining and forming operations, including thread rolling and any type of cutting. Surface preparation for hardness testing, nondestructive evaluation, or ultrasonic bolt tensioning is permitted.

7.5.1 Unless otherwise specified, material for Grade B7 may be heat treated by the Furnace, the Induction or the Electrical Resistance method.

NOTE 5—It should be taken into consideration that stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat treating method to another. The purchaser may specify Supplementary Requirement S8, if stress-relaxation testing is desired.

7.6 Material Grade B16 shall be heated to a temperature range from 1700 to 1750 °F [925 to 955 °C] and oil quenched. The minimum tempering temperature shall be as specified in Table 2.

8. Chemical Composition

8.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 8. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 8. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A 788.

10. Mechanical Properties

10.1 *Tensile Properties*:

10.1.1 *Requirements*—The material as represented by the tension specimens shall conform to the requirements prescribed in Table 2 at room temperature after heat treatment. Alternatively, stainless strain hardened headed fasteners (Class 2, 2B, and 2C) shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 2. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

10.1.2 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 13.1.3, headed fasteners shall be wedge tested full size and shall conform to the tensile strength shown in Table 2. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$Ts = UTS \times As \tag{1}$$

where:

Ts = wedge tensile strength,
UTS = tensile strength specified in Table 2, and
As = stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$As = 0.785\,(D - (0.974/n))^2 \tag{2}$$

where:

D = nominal thread size, and
n = the number of threads per inch.

10.2 *Hardness Requirements*:

10.2.1 The hardness shall conform to the requirements prescribed in Table 2. Hardness testing shall be performed in accordance with either Specification A 962/A 962M or with Test Methods F 606.

10.2.2 *Grade B7M*—The maximum hardness of the grade shall be 235 HB or 99 HRB. The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E 566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 13.1.1) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100 % by indentation hardness methods. Product that has been 100 % tested and found acceptable shall have a line under the grade symbol.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Workmanship, Finish, and Appearance

11.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

11.2 Bolt heads shall be in accordance with the dimensions of ANSI B18.2.1 or ANSI B18.2.3.1M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head fillet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ANSI B18.2.1 or ANSI B18.2.3.1M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ANSI B18.3 or ANSI B18.3.1M.

12. Retests

12.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Test Specimens

13.1 *Number of Tests*—For heat-treated bars, one tension test shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

13.1.1 For studs, bolts, screws, and so forth, one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1⅛ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1⅛ [30] to 1¾ [42], incl	4500 lb [2000 kg] or fraction thereof
Over 1¾ [42] to 2½ [64], incl	6000 lb [2700 kg] or fraction thereof
Over 2½ [64]	100 pieces or fraction thereof

13.1.2 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1, provided they are not given a subsequent heat treatment.

13.1.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1½ in. in body diameter and smaller, with body length three times the diameter or longer, and that are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 10.1.2. This testing shall be in addition to tensile testing as specified in 10.1.1. The lot size shall be as shown in 13.1.1. Failure shall occur in the body or threaded section with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A 194/A 194M.

15. Rejection and Rehearing

15.1 Unless otherwise specified in the basis of purchase, any rejection based on product analysis shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

15.2 Material that shows defects subsequent to its acceptance at the place of manufacture shall be rejected, and the manufacturer shall be notified.

15.3 *Product Analysis*—Samples that represent rejected material shall be preserved for two weeks from the date of the test report. In the case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The producer of the raw material or finished fasteners shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

16.2 Certification shall also include at least the following:

16.2.1 A statement that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

16.2.2 The specification number, year date, and identification symbol.

17. Product Marking

17.1 The marking symbol and manufacturer's identification symbol shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts ¼ in. [6 mm] in diameter and larger. (If the available area is inadequate, the marking symbol may be placed on one end with the manufacturer's identification symbol placed on the other end.) The marking symbol shall be as shown in Table 4 and Table 5. Grade B7M, which has been 100 % evaluated in conformance with the specification, shall have a line under the marking symbol to distinguish it from B7M produced to previous specification revisions not requiring 100 % hardness testing.

17.2 For bolting materials, including threaded bars, furnished bundled and tagged or boxed, the tags and boxes shall carry the marking symbol for the material identification and the manufacturer's identification symbol or name.

17.3 For purposes of product marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

17.4 *Bar Coding*—In addition to the requirements in 17.1, 17.2, and 17.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 hardness; heat treatment

TABLE 4 Marking of Ferritic Steels

Grade	Marking Symbol
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M[A]	B7M $\underline{\text{B7M}}$
B16	B16
B16 + Supplement S12	B16R

[A] For explanations, see 10.2.2 and 17.1.

TABLE 5 Marking of Austenitic Steels

Class	Grade	Marking Symbol
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
Class 1A	B8A	B8A
	B8CA	B8B or B8CA
	B8MA	B8D or B8MA
	B8PA	B8H or B8PA
	B8TA	B8J or B8TA
	B8LNA	B8L or B8LNA
	B8MLNA	B8K or B8MLNA
	B8NA	B8V or B8MA
	B8MNA	B8W or B8MNA
	B8MLCuNA	B9K or B8MLCuNA
Class 1B	B8N	B8N
	B8MN	B8Y or B8MN
	B8MLCuN	B9J or B8MLCuN
Class 1C	B8R	B9A or B8R
	B8RA	B9B or B8RA
	B8S	B9D or B8S
	B8SA	B9F or B8SA
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
	B8S	B102
Class 2	B8	B8SH
	B8C	B8CSH
	B8P	B8PSH
	B8T	B8TSH
	B8N	B8NSH
	B8M	B8MSH
	B8MN	B8YSH
	B8MLCuN	B0JSH
Class 2B	B8M2	B9G or B8M2
	B8	B9
Class 2C	B8M3	B9H or B8M3

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Test Methods E 21, E 139, and E 292, and Practices E 150 and E 151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A 320/A 320M, Sections 6 and 7, shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A 320/A 320M, bolting should be ordered to that specification in preference to this specification.

S3. 100 % Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Table 2.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs 2½ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253–319 HB or 25–34 HRC.

S5. Product Marking

S5.1 Marking and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the marking symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than ¼ in. [6 mm] in diameter and studs smaller than ⅜ in. [10 mm] in diameter and for ¼ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E 709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3 % of the diameter into the bar.

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Test Methods E 328. The test shall be performed at 850 °F [454 °C] for a period of 100 h. The initial stress shall be 50 M psi [345 MPa]. The residual stress at 100 h shall be 17 M psi [117 MPa] minimum.

S9. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S9.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S10. Hardness Testing of Class 2 Bolting Materials for ASME Applications

S10.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads, and no more material than necessary shall be removed to prepare the flat areas. Hardness determinations shall be made at the same frequency as tensile tests.

S11. Thread Forming

S11.1 Threads shall be formed after heat treatment. Application of this supplemental requirement to grade B7M or the grades listed in 7.3.3 is prohibited.

S12. Stress Rupture Testing of Grade B16

S12.1 One test shall be made for each heat treat lot. Testing shall be conducted using a combination test bar in accordance with Test Methods E 292. Rupture shall occur in the smooth section of each test specimen. The test shall be conducted at 1100 °F [595 °C] and 20 ksi [140 MPa]. The test shall be continued until the sample ruptures. Rupture life shall be 25 h minimum. Testing is not required on material less than ½ in. [12 mm] thick.

S12.2 When a purchase order for fasteners invokes S12, the product marking supplied shall be "B16R."

S13. Coatings on Bolting Materials

S13.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S13.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S13.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, or F 1941, Test Method F 1940, or other standards.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium-coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 06a, that may impact the use of this specification. (Approved March 1, 2007).

(*1*) Deleted the space between the S and the numbers in the UNS designations in Table 1.

(*2*) Added permissible product variations for B8MLCuN and B8MLCuNA in Table 1.

(*3*) Added the requirement to report nitrogen for S32100 and changed the order of the elements in Table 1 for this grade to be consistent with the other stainless grades.

(*4*) Corrected the metric yield strength for B16 M100 to M180 in Table 3.

(*5*) Corrected the metric conversion in S12.

(*6*) Added reference to Test Method F 1940 and Specification F 1941, and dropped reference to Specification B 633, in S13.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 06, that may impact the use of this specification. (Approved March 1, 2006).

(*1*) Revised Section 3 and inserted new Section 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 05, that may impact the use of this specification. (Approved January 15, 2006).

(*1*) Revised title and scope to agree with that of Specification A 194/A 194M.

Designation: A 194/A 194M – 08b

Endorsed by
Manufacturers Standardization Society
of the Valve and Fittings Industry
Used in USNRC-RDT Standards

Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both[1]

This standard is issued under the fixed designation A 194/A 194M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range ¼ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range ¼ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service, or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirement S1, the purchaser should take special care to ensure that 8.2.2, Supplementary Requirement S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements (S1 through S8) of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable" M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Within the text, the SI units are shown in brackets.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 276 Specification for Stainless Steel Bars and Shapes
A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium
E 112 Test Methods for Determining Average Grain Size
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))
F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 *American National Standards:*[4]

B 1.1 Unified Screw Threads
B 1.2 Gages and Gaging for Unified Inch Screw Threads

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-194 in Section II of that code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

***A Summary of Changes section appears at the end of this standard.**

B 1.13M Metric Screw Threads
B 18.2.2 Square and Hex Nuts
B 18.2.4.6M Metric Heavy Hex Nuts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Austenitic Grades*—All grades with a prefix of "8" or "9".

3.1.2 *Ferritic Grades*—Grades 1, 2, 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16.

3.1.3 *Lot*—Unless otherwise specified (see Discussion below), a lot is the quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.3.1 *Discussion*—When Supplementary Requirement S5 is invoked on the purchase order, the following definitions of a lot shall apply:

3.1.3.2 *For Grade 8 Nuts*—The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

3.1.3.3 *For All Other Grade Nuts*— (see 8.2 and 8.1.2.1)—All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.4 *Type*

3.1.4.1 *For Grade 8 Nuts*—Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.4.2 *For Grade 6 Nuts*—Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.5 *Series*—The dimensional relationship and geometry of the nuts as described in ANSI B 18.2.2 or B 18.2.4.6M.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation, year date, and grade, issue date and revision letter,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 9),

4.1.4 Options in accordance with 8.2.2.1, 9.1, 9.2, 10.3, and 12, and

4.1.5 Supplementary Requirements, if any.

4.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (see Supplementary Requirements S7 and S8). When coated nuts are ordered, the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4.3 See Supplementary Requirement S3 for nuts to be used in low temperature applications (Specification A 320/A 320M).

4.4 *Proof Load Testing*—See Supplementary Requirement S9 for proof load testing of nuts manufactured to dimensions and configurations other than those covered in Tables 3 and 4.

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Manufacture (Process)

6.1 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

6.1.1 Electric-furnace (with separate degassing and refining optional),

6.1.2 Vacuum induction furnace, or

6.1.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

6.2 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

6.3 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

6.3.1 All Grade 1 and 2 nuts made by cold forging or by machining from cold-drawn bars shall be stress-relief annealed at a temperature of at least 1000 °F [538 °C].

6.3.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

6.4 Grades 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. These grades shall be reheated above the critical range of the steel, quenched in a suitable medium, and then tempered at a temperature not less than the following:

Grade	Minimum Tempering Temperature, °F [°C]
2H	850 [455]
2HM	1150 [620]
3	1050 [565]
4	1100 [595]
6 and 6F	1100 [595]
7	1100 [595]
7M	1150 [620]
16	1200 [650]

Nuts machined from bar heat treated in accordance with this specification need not be reheat-treated. For Grade 2HM and 7M nuts, a final stress relief shall be done at or above the minimum tempering temperature after all forming, machining, and tapping operations. This final stress relief may be the tempering operation.

6.4.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

6.5 Grades 8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, 8MLCuN, and 9C nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

TABLE 1 Chemical Requirements[A,B,C,D]

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur,[E] %	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
1	carbon		0.15 min	1.00	0.040	0.050	0.40	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2, 2HM, and 2H	carbon		0.40 min	1.00	0.040	0.050	0.40	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	carbon, molybdenum		0.40–0.50	0.70–0.90	0.035	0.040	0.15–0.35	. . .	. . .	0.20–0.30	. . .	. . .	. . .	. . .
3	Type 501		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	. . .	0.40–0.65	. . .	. . .	. . .	. . .
6	Type 410	S41000	0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .	. . .	. . .
6F	Type 416	S41600	0.15	1.25	0.060	0.15 min	1.00	12.0–14.0	. . .	. . .	. . .	. . .	. . .	. . .
6F	Type 416Se	S41623	0.15	1.25	0.060	0.060	1.00	12.0–14.0	. . .	. . .	. . .	. . .		Selenium, 0.15 min
7, 7M	Type 4140/ 4142/ 4145, 4140H, 4142H, 4145H		0.37–0.49	0.65–1.10	0.035	0.04	0.15–0.35	0.75–1.20	. . .	0.15–0.25	. . .	. . .	. . .	. . .
8, 8A	Type 304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .
8C, 8CA	Type 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	10 x carbon content, min	. . .	. . .
8M, 8MA	Type 316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	. . .	. . .
8T, 8TA	Type 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	5 x (C+N) min - 0.70 max	. . .	0.10	. . .
8F, 8FA	Type 303	S30300	0.15	2.00	0.20	0.15 min	1.00	17.0–19.0	8.0–10.0	. . .	. . .	. . .	. . .	. . .
8F, 8FA	Type 303Se	S30323	0.15	2.00	0.20	0.06	1.00	17.0–19.0	8.0–10.0	. . .	. . .	. . .		Selenium, 0.15 min
8P, 8PA	Type 305 with restricted carbon	S30500	0.08	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	. . .	. . .	. . .	. . .	. . .
8N, 8NA	Type 304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	0.10–0.16	
8LN, 8LNA	Type 304LN	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	0.10–0.16	
8MN, 8MNA	Type 316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	0.10–0.16	
8MLN, 8MLNA	Type 316LN	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	0.10–0.16	
8R, 8RA[F]	XM19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	. . .	0.10–0.30	0.20–0.40	Vanadium, 0.10–0.30
8S, 8SA		S21800	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	. . .	. . .	. . .	0.08–0.18	
8MLCuN, 8MLCuNA	S31254	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	. . .	. . .	0.18–0.22	Copper, 0.50–1.00
9C, 9CA	N08367	N08367	0.030	2.00	0.040	0.030	1.00	20.0-22.0	23.5- 25.5	6.0-7.0			0.18-0.25	Copper 0.75
16	Chromium Molybdenum Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	. . .	0.50–0.65	. . .	. . .	. . .	Vanadium, 0.25–0.35 Aluminum[B] 0.015

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.
[B] Total aluminum, soluble and insoluble.
[C] Maximum, unless minimum or range is indicated.
[D] Where ellipses (…) appear in this table there is no requirement.
[E] Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060 % max is not technologically appropriate.
[F] As described in Specification A 276.

TABLE 2 Hardness Requirements[A]

Grade and Type	Completed Nuts			Sample Nut after Treatment as in 8.1.5	
	Brinell Hardness	Rockwell Hardness		Brinell Hardness, min	Rockwell Hardness B Scale, min
		C Scale	B Scale		
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H to 1½ in. or M36, incl	248 to 327	24 to 35	...	179	89
2H over 1½ in. or M36	212 to 327	35 max	95 min	147	79
2HM and 7M	159 to 235	...	84 to 99	159	84
3, 4, 7, and 16	248 to 327	24 to 35	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8LN, 8MLN, 8MLCuN, and 9C	126 to 300	32 max	60 min	...	...
8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8LNA, 8MLNA, 8MLCuNA, and 9CA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	25 max	88 min	...	...

[A] Where ellipses (…) appear in this table there is no requirement.

6.6 Grades 8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, and 9CA nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8. Mechanical Requirements

8.1 *Hardness Test*:

8.1.1 *Requirements*:

8.1.1.1 All nuts shall meet the hardness requirements specified in Table 2.

8.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M, and 16 which have been given the treatment described in 8.1.5 shall meet the minimum hardness specified in Table 2.

8.1.2 *Number of Tests*— (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

8.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

8.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 8.1.5 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

8.1.3 *Number of Tests, Grades 2HM and 7M*:

8.1.3.1 Each nut shall be tested by Brinell or Rockwell methods to ensure product conformance.[5]

8.1.3.2 In addition, 8.1.2.2 shall be met.

8.1.4 *Number of Tests, All Types of Grade 8*—Tests on the number of sample nuts in accordance with 8.1.2.1 shall be performed by the manufacturer.

8.1.5 *Test 2*—In addition to the testing required by 8.1.2.1 the manufacturer shall also perform hardness tests on sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

[5] An underline as a marking requirement for grades 2HM and 7M has been removed but is permitted.

TABLE 3 Proof Load Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per Inch	Stress Area in.[2]	Proof Load, lbf[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
¼	20	0.0316	4 130	3 820	4 770	4 300	5 570	4 770
5⁄16	18	0.0524	6 810	6 290	7 860	7 070	9 170	7 860
3⁄8	16	0.0774	10 080	9 300	11 620	10 460	13 560	11 620
7⁄16	14	0.1063	13 820	12 760	15 940	14 350	18 600	15 940
½	13	0.1419	18 450	17 030	21 280	19 160	24 830	21 280
9⁄16	12	0.182	23 660	21 840	27 300	24 570	31 850	27 300
5⁄8	11	0.226	29 380	27 120	33 900	30 510	39 550	33 900
¾	10	0.334	43 420	40 080	50 100	45 090	58 450	50 100
7⁄8	9	0.462	60 060	55 440	69 300	62 370	80 850	69 300
1	8	0.606	78 780	72 720	90 900	81 810	106 000	90 900
1⅛	8	0.790	102 700	94 800	118 500	106 700	138 200	118 500
1¼	8	1.000	130 000	120 000	150 000	135 000	175 000	150 000
1⅜	8	1.233	160 200	148 000	185 000	166 500	215 800	185 000
1½	8	1.492	194 000	170 040	223 800	201 400	261 100	223 800

			All Types of Grade 8, Grades 9C and 9CA	
			Heavy Hex[H]	Hex[I]
¼	20	0.0316	2 540	2 380
5⁄16	18	0.0524	4 190	3 930
3⁄8	16	0.0774	6 200	5 810
7⁄16	14	0.1063	8 500	7 970
½	13	0.1419	11 350	10 640
9⁄16	12	0.182	14 560	13 650
5⁄8	11	0.226	18 080	16 950
¾	10	0.334	26 720	25 050
7⁄8	9	0.462	36 960	34 650
1	8	0.606	48 480	45 450
1⅛	8	0.790	63 200	59 250
1¼	8	1.000	80 000	75 000
1⅜	8	1.233	98 640	92 450
1½	8	1.492	119 360	111 900

[A] See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 130 000 psi.
[C] Based on proof stress of 120 000 psi.
[D] Based on proof stress of 150 000 psi.
[E] Based on proof stress of 135 000 psi.
[F] Based on proof stress of 175 000 psi.
[G] Based on proof stress of 150 000 psi.
[H] Based on proof stress of 80 000 psi.
[I] Based on proof stress of 75 000 psi.

Grade[A]	Temperature, °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

[A]Nuts intended to be coated with zinc or cadmium (marked in accordance with the requirements of Supplementary Requirement S8) are not subjected to the requirements of 8.1.5 (See Appendix X2).

8.1.5.1 *Special Requirement, Grades 2HM and 7M*—Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to (*1*) protect legibility of markings; (*2*) minimize exterior dimensional changes; and (*3*) maintain thread fit.

8.2 *Proof Load Test*:

8.2.1 *Requirements*—The nuts listed in Tables 3 and 4 shall be capable of withstanding the proof loads specifin therein. Proof load testing of nuts manufactured to dimensions and configurations other than those covered in Table 3 or Table 4 is only required when S9 is specified in the order or inquiry.

8.2.2 *Number of Tests*:

8.2.2.1 The manufacturer shall test the number of nuts specified in 8.1.2.1 following all production heat treatments. Nuts that would require a proof load in excess of 160 000 lb/f or 705 kN may be furnished on the basis of minimum hardness requirements. Testing of nuts requiring a proof load in excess of 160 000 lb/f or 705 kN is covered in Supplementary Requirements S1 amd S4.

8.2.3 *Test Method*—The test shall be run using a threaded mandrel or a test bolt in accordance with Specification A 962/A 962M.

8.3 *Cone Proof Load Test:*

TABLE 4 Proof Load Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Threads Pitch	Stress Area mm²	Proof Load, kN[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
M6	1.0	20.1	18.0	16.6	20.8	18.7	29.2	20.8
M8	1.25	36.6	32.8	30.2	37.9	34.0	44.1	37.9
M10	1.50	58.0	51.9	47.9	60.0	53.9	69.9	60.0
M12	1.75	84.3	75.5	69.5	87.3	78.4	101.6	87.3
M14	2.0	115.0	102.9	94.9	119.0	107.0	138.6	119.0
M16	2.0	157.0	140.5	129.5	162.5	146.0	189.2	162.5
M20	2.5	245.0	219.3	202.1	253.6	227.8	295.2	253.6
M22	2.5	303.0	271.2	249.9	313.6	281.8	365.1	313.6
M24	3.0	353.0	315.9	291.2	365.4	328.3	425.4	365.4
M27	3.0	459.0	411.0	378.7	475.1	426.9	553.4	475.1
M30	3.5	561.0	502.1	462.8	580.6	521.7	676.0	580.6
M36	4.0	817.0	731.2	674.0	845.6	759.8	984.5	845.6

Nominal Size, mm	Thread Pitch	All Types of Grade 8, and Grades 9C and 9CA		Hex[I]
		Stress Area, mm²	Heavy Hex[H]	
M6	1.0	20.1	11.1	10.4
M8	1.25	36.6	20.1	18.8
M10	1.50	58.0	31.9	29.9
M12	1.75	84.3	46.4	43.4
M14	2.0	115.0	63.3	59.2
M16	2.0	157.0	86.4	80.9
M20	2.5	245.0	134.8	126.2
M22	2.5	303.0	166.7	156.0
M24	3.0	353.0	194.2	181.8
M27	3.0	459.0	252.5	236.4
M30	3.5	561.0	308.6	288.9
M36	4.0	817.0	449.4	420.8

[A] See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 895 MPa.
[C] Based on proof stress of 825 MPa.
[D] Based on proof stress of 1035 MPa.
[E] Based on proof stress of 930 MPa.
[F] Based on proof stress of 1205 MPa.
[G] Based on proof stress of 1035 MPa.
[H] Based on proof stress of 550 MPa.
[I] Based on proof stress of 515 MPa.

8.3.1 *Requirements*—This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. Nuts in the size range ¼ to 1½ in. inclusive and M6 to M36 inclusive shall be proof load tested. Nuts not in this size range and all types of Grade 8 nuts are not subject to this test. Also, nuts manufactured to dimensions and configurations other than those covered by Specification A 962/A 962M, ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and ANSI B 18.2.4.6M are not subject to the cone proof load test. The cone proof load applied shall be determined in accordance with the Cone Proof Load requirements in Specification A 962/A 962M (tables or formulae or both) based upon the proof stresses shown in Table 5 and Table 6 of Specification A 194/A 194M.

8.3.2 *Number of Tests*—The manufacturer shall sample and test the number of nuts specified in 8.1.2.1. The lot shall be considered acceptable if the sample nut(s) withstand(s) application of the cone proof load without failure.

9. Dimensions

9.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ANSI B 18.2.2 and ANSI B 18.2.4.6M. Unless otherwise specified, the American National Standard Heavy

TABLE 5 Proof Stress Using 120° Hardened Steel Cone — Inch

Type	Proof Stress – psi, Minimum		
	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	120 000	135 000	150 000
Heavy Hex	130 000	150 000	175 000

TABLE 6 Proof Stress Using 120° Hardened Steel Cone — Metric

Type	Proof Stress – MPa, Minimum		
	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	825	930	1035
Heavy Hex	895	1035	1205

Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ANSI B 18.2.2 and ANSI B 18.2.4.6M.

9.2 Unless otherwise specified, threads shall be in accordance with ANSI B 1.1 or ANSI B 1.13M, and shall be gaged in accordance with ANSI B 1.2 and ANSI B 1.13M as described in 9.2.1 and 9.2.2.

9.2.1 Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Metric nuts up to and including M24 nominal size shall be coarse thread series tolerance 6H.

9.2.2 Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished. Metric nuts over M24 nominal size shall be coarse thread series tolerance 6H.

10. Workmanship, Finish, and Appearance

10.1 Nuts shall be free of defects and shall be good commercial finish.

10.2 If visible surface imperfections in size ¼ through 1½ in. and M6 through M36 and in any grade other than Grade 8 become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 8.3 shall be employed.

10.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

11. Retests

11.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S2.

12. Certification

12.1 The producer of nuts shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), mechanical tests, and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M.

12.2 Certification shall also include at least the following:

12.2.1 A statement that the fasteners were manufactured, sampled, tested and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

12.2.2 The specification number, year date, and identification symbol.

13. Product Marking

13.1 All nuts shall bear the manufacturer's identification mark.

13.2 Nuts shall be legibly marked on one face to indicate the grade and process of the manufacturer, as presented in Table 7. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser.

13.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

14. Keywords

14.1 bolting; chemical analysis; coated; marking on fasteners; plated

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirement shall be proof load tested in accordance with 8.2.2.1 and shall withstand the proof load specified in Table 8 and Table 9. Testing nuts requiring proof loads over 160 000 lbf or 705 kN is only required when Supplementary Requirement S4 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts

TABLE 7 Marking of Nuts[A]

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6
1	1	1B	...
2	2	2B	...
2H[B]	2H	2HB	...
2HM[B]	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L[C]	4L	4BL	. . .
6	6	6B	. . .
6F	6F	6FB	...
7	7	7B	...
7L[C]	7L	7BL	...
7M[B]	7M	7MB	...
8	8	8B	8A
8C	8C	8CB	8CA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
9C	9C	9CB	9CA
16	16	16B	

[A] Where ellipses (…) appear in this table there is no requirement.
[B] The letters H and M indicate heat-treated nuts (see Section 6).
[C] See Supplementary Requirement S3.

made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Retests by Purchaser's Representative

S2.1 The purchaser's representative may select two nuts per keg (200-lb unit [90-kg]) for sizes ⅝ in. and M16 and smaller, one nut per keg for sizes over ⅝ in. and M16 up to and including 1½ in. and M36, and one nut per every two kegs for sizes larger than 1½ in. and M36, which shall be subjected to the tests specified in Section 8.

S3. Low-Temperature Requirements for Grade 4, Grade 7 or Grade 7M Nuts

S3.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7 shall apply. When low-temperature requirements are specified for Grade 7M nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7M shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Impact testing is not required when the bar stock or nut is smaller than ⅝ in. [16 mm] in diameter.

S3.2 An" L" shall be added to the marking, as shown in Table 7, for nuts so tested.

S4. Proof Load Tests of Large Nuts

S4.1 Proof load testing of nuts requiring proof loads of over 160 000 lbf or 705 kN is required. Testing shall be performed in accordance with 8.2 to the loads required in Table 10 and Table 11. The maximum load will be based entirely on the equipment available.

S5. Control of Product by Heat Number

S5.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

S6. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S6.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S7. Coating on Nuts

S7.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S7.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

NOTE S7.1—Modification of thread dimensions may result in loss of load carrying ability.

S7.1.2 Reference to Specifications A 153/A 153M, B 633, B 695, B 696, B 766, F 1941, F 2329, or Test Method F 1940, or other standards.

S8. Marking Coated Nuts

S8.1 Nuts coated with zinc shall have an asterisk (*) marked after the grade symbol. Nuts coated with cadmium shall have a plus sign (+) marked after the grade symbol.

S9. Proof Load Testing

S9.1 Proof load tests of nuts made to dimensions, thread pitch, and configurations other than those covered in Table 3 or Table 4 shall be made using loads agreed upon between the manufacturer and the purchaser.

TABLE 8 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

			Proof Load, lbf[A]			
Nominal Size, in.	Threads per in.	Stress Area, in.^{2}	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
¼	20	0.0316	3 480	3 160	3 950	3 480
5⁄16	18	0.0523	5 760	5 240	6 550	5 760
⅜	16	0.0774	8 510	7 740	9 675	8 510
7⁄16	14	0.1063	11 690	10 630	13 290	11 690
½	13	0.1419	15 610	14 190	17 740	15 610
9⁄16	12	0.182	20 020	18 200	22 750	20 020
⅝	11	0.226	24 860	22 600	28 250	24 860
¾	10	0.334	36 740	33 400	41 750	36 740
⅞	9	0.462	46 200	41 580	53 130	46 200
1	8	0.606	60 600	54 540	69 690	60 600
1⅛	8	0.790	75 050	67 150	82 950	75 050
1¼	8	1.000	95 000	85 000	105 000	95 000
1⅜	8	1.233	110 970	98 640	123 300	110 970
1½	8	1.492	134 280	119 360	149 200	134 280

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 110 000 psi up to ¾ in.; 100 000 psi ⅞ to 1 in.; 95 000 psi 1⅛ to 1¼ in.; 90 000 psi 1⅜ to 1½ in.
[C] Based on proof stress of 100 000 psi up to ¾ in.; 90 000 psi ⅞ to 1 in.; 85 000 psi 1⅛ to 1¼ in.; 80 000 psi 1⅜ to 1½ in.
[D] Based on proof stress of 125 000 psi up to ¾ in.; 115 000 psi ⅞ to 1 in.; 105 000 psi 1⅛ to 1¼ in.; 100 000 psi 1⅜ to 1½ in.

TABLE 9 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

			Proof Load, kN[A]			
Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
M6	1.0	20.1	15.3	13.9	17.3	15.3
M8	1.25	36.6	27.8	25.3	31.3	27.8
M10	1.50	58.0	44.1	40.0	49.9	44.1
M12	1.75	84.3	64.1	58.2	72.5	64.1
M14	2.0	115.0	87.4	79.4	98.9	87.4
M16	2.0	157.0	119.3	108.3	135.0	119.3
M20	2.5	245.0	186.2	169.0	210.9	186.2
M22	2.5	303.0	209.0	187.9	240.9	209.0
M24	3.0	353.0	243.5	218.9	280.6	243.5
M27	3.0	459.0	300.6	268.5	332.7	300.6
M30	3.5	561.0	367.5	328.2	406.7	367.5
M36	4.0	817.0	506.5	449.4	563.7	506.5

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 760 MPa up to M20 mm; 690 MPa M22 to M24 mm; 655 MPa M27 to M30; and 620 MPa for M36.
[C] Based on proof stress of 690 MPa up to M20 mm; 620 MPa M22 to M24 mm; 585 MPa M27 to M30; and 550 MPa for M36.
[D] Based on proof stress of 860 MPa up to M20 mm; 795 MPa M22 to M24 mm; 725 MPa M27 to M30 mm; and 690 MPa for M36.

TABLE 10 Proof Load for Large Heavy Hex Nuts — Inch[A]

Nominal Size, in.	Threads per in.	Stress Area, in.^{2}	Proof Load, lbf[B]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1⅝	8	1.78	231 400	267 000	311 500
1¾	8	2.08	270 400	312 000	364 000
1⅞	8	2.41	313 300	361 500	421 800
2	8	2.77	360 100	415 500	484 800
2¼	8	3.56	462 800	534 000	623 000
2½	8	4.44	577 200	666 000	777 000
2¾	8	5.43	705 900	814 500	950 250

[A] ANSI B 18.2.2 in the size range over 1½ in. provides dimensions only for heavy hex nuts. Refer to 8.3.1.
[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table 8. The proof load for jam nuts shall be 46 % of the tabulated load.

TABLE 11 Proof Load for Large Heavy Hex Nuts — Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Proof Load, kN[B]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
M42	4.5	1120	1002.4	1159.2	1349.6
M48	5	1470	1315.7	1521.4	1771.4
M56	5.5	2030	1816.9	2101.0	2446.2
M64	6	2680	2398.6	2773.8	3229.4
M72	6	3460	3096.7	3581.1	4169.3

[A] ANSI B 18.2.4.6M in the size range over M36 provides dimensions only for heavy hex nuts. Refer to 7.3.1.
[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 4 or Table 9. The proof load for jam nuts shall be 46 % of the tabulated load.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 08a, that may impact the use of this specification. (Approved August 1, 2008)

(*1*) Added reference to Specifications B 633 and F 2329 in S7.1.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 08, that may impact the use of this specification. (Approved May 1, 2008)

(*1*) Added new 4.4 and Supplementary Requirement S9 and revised 8.2.1 for proof load testing for nuts not covered in Tables 3 and 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07b, that may impact the use of this specification. (Approved April 1, 2008)

(*1*) Added Nitrogen for Grades 8T and 8TA in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07a, that may impact the use of this specification. (Approved December 1, 2007)

(*1*) Added Note S7.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added reference to Test Method F 1940 in S7.1.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 06a, that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Revised cone proof load test requirements to reference recent changes to Specification A 962/A 962M and Test Methods and Definitions A 370.

SPECIFICATION FOR STEEL CASTINGS, CARBON, SUITABLE FOR FUSION WELDING FOR HIGH-TEMPERATURE SERVICE

SA-216/SA-216M

(Identical with ASTM Specification A 216/A 216M-93 except for the addition of 2.3 and editorial differences in 2.1 and 10.1.) 98

1. Scope

1.1 This specification covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

1.2 Three grades, WCA, WCB, and WCC, are covered in this specification. Selection will depend upon design and service conditions, mechanical properties, and the high temperature characteristics.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Applicable Documents

98 **2.1** *ASTM Standards:*

A 703 Specification for Steel Castings, General Requirements for Pressure-Containing Parts
E 165 Practice for Liquid Penetrant Examination
E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

SP 55 Steel Castings for Valve, Flanges, and Fittings, and Other Components (Visual Method)

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the applicable requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail. 98

4. Ordering Information 98

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing, dimensional tolerances shall be included on the casting drawing,

4.1.2 Grade of steel,

4.1.3 Options in the specification,

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the annealed, or normalized, or normalized and tempered condition unless Supplementary Requirement S15 is specified.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometer.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Tensile Requirements

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under ASME Section IX.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

10.3 Castings containing any repair weld that exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.^{2} [65 cm^2] in area, or that was made to correct hydrostatic test defects, shall be stress relieved or heat-treated after welding. This mandatory stress relief or heat-treatment shall be in accordance with the procedure qualification used.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade WCA	Grade WCB	Grade WCC
Carbon, max	0.25[A]	0.30[B]	0.25[C]
Manganese, max	0.70[A]	1.00[B]	1.20[C]
Phosphorus, max	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045
Silicon, max	0.60	0.60	0.60
Specified residual elements:			
Copper, max	0.30	0.30	0.30
Nickel, max	0.50	0.50	0.50
Chromium, max	0.50	0.50	0.50
Molybdenum, max	0.20	0.20	0.20
Vanadium, max	0.03	0.03	0.03
Total of these specified residual elements, max[D]	1.00	1.00	1.00

[A] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10%.
[B] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% Mn above the specified maximum will be permitted up to a maximum of 1.28%.
[C] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.40%.
[D] Not applicable when Supplementary Requirement S11 is specified.

TABLE 2
TENSILE REQUIREMENTS

	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]	40 [275]
Elongation in 2 in. [50 mm], min, %[B]	24	22	22
Reduction of area, min, %	35	35	35

[A] Determine by either 0.2% offset method or 0.5% extension-under-load method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumberated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S3. Bend Test

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation.

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S11. Carbon Equivalent

S11.1 When specified on the order, the maximum carbon equivalent shall be:

Grade	Carbon, Equivalent, max
WCA	0.50
WCB	0.50
WCC	0.55

S11.2 Carbon equivalent (CE) shall be determined as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S15. Quench and Temper Heat-Treatment

Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications[1]

This standard is issued under the fixed designation A 240/A 240M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ϵ[1] NOTE—Table 2 was corrected editorially in July 2007.

1. Scope*

1.1 This specification[2] covers chromium, chromium-nickel, and chromium-manganese-nickel stainless steel plate, sheet, and strip for pressure vessels and for general applications.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 This specification is expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

E 112 Test Methods for Determining Average Grain Size

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*[4]

J 1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M.

3.1.1 Definitions;
3.1.2 General requirements for delivery;
3.1.3 Ordering information;
3.1.4 Process;
3.1.5 Special tests;
3.1.6 Heat treatment;
3.1.7 Dimensions and permissible variations;
3.1.8 Workmanship, finish and appearance;
3.1.9 Number of tests/test methods;
3.1.10 Specimen preparation;
3.1.11 Retreatment;
3.1.12 Inspection;
3.1.13 Rejection and rehearing;
3.1.14 Material test report;
3.1.15 Certification; and
3.1.16 Packaging, marking, and loading.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1 and shall conform to applicable requirements specified in Specification A 480/A 480M.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.17 on Flat-Rolled and Wrought Stainless Steel.

Current edition approved April 1, 2007. Published April 2007. Originally approved in 1940. Last previous edition approved in 2006 as A 240/A 240M – 06c.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-240 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

***A Summary of Changes section appears at the end of this standard.**

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Table 2.

5.2 When specified by the purchaser, Charpy impact tests shall be performed in accordance with Supplementary Requirement S1.

6. Materials for High-Temperature Service

6.1 The austenitic *H* Types shall conform to an average grain size of ASTM No. 7 or coarser as measured by Test Methods E 112.

6.2 Supplementary Requirement S2 shall be invoked when non-H grade austenitic stainless steels are ordered for ASME Code applications for service above 1000°F [540°C].

6.3 Grade S31060, unless otherwise specified in the purchase order, shall conform to an average grain size of ASTM No. 7 or coarser, as measured by Test Methods E 112.

7. Keywords

7.1 chromium; chromium-nickel stainless steel; chromium-manganese-nickel stainless steel; pressure vessels

TABLE 1 Chemical Composition Requirements, %[A]

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E,F]
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)												
N08020	. . .	0.07	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	2.00–3.00	. . .	3.0–4.0	Cb 8×C min, 1.00 max
N08367	. . .	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	. . .
N08700	. . .	0.04	2.00	0.040	0.030	1.00	19.0–23.0	24.0–26.0	4.3–5.0	. . .	0.50	Cb 8×C min 0.40 max
N08800	800[G]	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	0.75	Fe[H] 39.5 min Al 0.15–0.60 Ti 0.15–0.60
N08810	800H[G]	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	0.75	Fe[H] 39.5 min Al 0.15–0.60 Ti 0.15–0.60
N08811	. . .	0.06–0.10	1.50	0.040	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	0.75	Fe[H] 39.5 min Ti[I] 0.15–0.60 Al[I] 0.15–0.60
N08904	904L[G]	0.020	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	1.0–2.0	. . .
N08926	. . .	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	0.5–1.5	. . .
S20100	201	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	. . .	0.25	. . .	. . .
S20103	. . .	0.03	5.5–7.5	0.045	0.030	0.75	16.0–18.0	3.5–5.5	. . .	0.25	. . .	. . .
S20153	. . .	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	. . .	0.10–0.25	1.00	. . .
S20161	. . .	0.15	4.0–6.0	0.040	0.040	3.0–4.0	15.0–18.0	4.0–6.0	. . .	0.08–0.20	. . .	. . .
S20200	202	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	. . .	0.25	. . .	. . .
S20400	. . .	0.030	7.0–9.0	0.040	0.030	1.00	15.0–17.0	1.50–3.00	. . .	0.15–0.30	. . .	. . .
S20910	XM-19[J]	0.06	4.0–6.0	0.040	0.030	0.75	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	. . .	Cb 0.10–0.30 V 0.10–0.30
S21400	XM-31[J]	0.12	14.0–16.0	0.045	0.030	0.30–1.00	17.0–18.5	1.00	. . .	0.35 min	. . .	. . .
S21600	XM-17[J]	0.08	7.5–9.0	0.045	0.030	0.75	17.5–22.0	5.0–7.0	2.00–3.00	0.25–0.50	. . .	. . .
S21603	XM-18[J]	0.03	7.5–9.0	0.045	0.030	0.75	17.5–22.0	5.0–7.0	2.00–3.00	0.25–0.50	. . .	. . .
S21800	. . .	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	. . .	0.08–0.18	. . .	. . .
S24000	XM-29[J]	0.08	11.5–14.5	0.060	0.030	0.75	17.0–19.0	2.3–3.7	. . .	0.20–0.40	. . .	. . .
S30100	301	0.15	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	. . .	0.10	. . .	. . .
S30103	301L[G]	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	. . .	0.20	. . .	. . .
S30153	301LN[G]	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	. . .	0.07–0.20	. . .	. . .
S30200	302	0.15	2.00	0.045	0.030	0.75	17.0–19.0	8.0–10.0	. . .	0.10	. . .	. . .
S30400	304	0.07	2.00	0.045	0.030	0.75	17.5–19.5	8.0–10.5	. . .	0.10	. . .	. . .
S30403	304L	0.030	2.00	0.045	0.030	0.75	17.5–19.5	8.0–12.0	. . .	0.10	. . .	. . .
S30409	304H	0.04–0.10	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	. . .	. . .	. . .	. . .
S30415	. . .	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	. . .	0.12–0.18	. . .	Ce 0.03–0.08
S30451	304N	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	. . .	0.10–0.16	. . .	. . .
S30452	XM-21[J]	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	. . .	0.16–0.30	. . .	. . .
S30453	304LN	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–12.0	. . .	0.10–0.16	. . .	. . .
S30500	305	0.12	2.00	0.045	0.030	0.75	17.0–19.0	10.5–13.0	. . .	. . .	. . .	. . .
S30600	. . .	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	0.20	. . .	0.50	. . .
S30601	. . .	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	0.05	0.35	. . .
S30615	. . .	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	. . .	. . .	. . .	Al 0.80–1.50
S30815	. . .	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	. . .	0.14–0.20	. . .	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	. . .	. . .	. . .	. . .
S30909	309H[G]	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	. . .	. . .	. . .	. . .
S30940	309Cb[G]	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	. . .	. . .	. . .	Cb 10×C min, 1.10 max
S30941	309HCb[G]	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	. . .	. . .	. . .	Cb 10×C min, 1.10 max
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	. . .	. . .	. . .	. . .
S31009	310H[G]	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phos-phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E,F]
S31040	310Cb[G]	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	. . .	. . .	. . .	Cb 10×C min, 1.10 max
S31041	310HCb[G]	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	. . .	. . .	. . .	Cb 10×C min, 1.10 max
S31050	310 MoLN[G]	0.020	2.00	0.030	0.010	0.50	24.0–26.0	20.5–23.5	1.60–2.60	0.09–0.15	. . .	. . .
S31060	. . .	0.05–0.10	1.00	0.040	0.030	0.50	22.0–24.0	10.0–12.5	. . .	0.18–0.25	. . .	Ce + La 0.025–0.070 B 0.001–0.010
S31254	. . .	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.22	0.50–1.00	. . .
S31266	. . .	0.030	2.0–4.0	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	0.35–0.60	1.00–2.50	W 1.50–2.50
S31277	. . .	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50	. . .
S31600	316	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	. . .
S31603	316L	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	. . .
S31609	316H	0.04–0.10	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	. . .
S31635	316Ti[G]	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	Ti 5 × (C + N) min, 0.70 max
S31640	316Cb[G]	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	Cb 10 × C min, 1.10 max
S31651	316N	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	. . .	. . .
S31653	316LN	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	. . .	. . .
S31700	317	0.08	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	. . .	. . .
S31703	317L	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	. . .	. . .
S31725	317LM[G]	0.030	2.00	0.045	0.030	0.75	18.0–20.0	13.5–17.5	4.0–5.0	0.20	. . .	. . .
S31726	317LMN[G]	0.030	2.00	0.045	0.030	0.75	17.0–20.0	13.5–17.5	4.0–5.0	0.10–0.20	. . .	. . .
S31727	. . .	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	0.15–0.21	2.8–4.0	. . .
S31753	317LN[G]	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10–0.22	. . .	. . .
S32050	. . .	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	0.40	. . .
S32053	. . .	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	0.17–0.22	. . .	. . .
S32100	321	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–12.0	. . .	0.10	. . .	Ti 5 × (C + N) min, 0.70 max
S32109	321H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–12.0	. . .	. . .	. . .	Ti 4 × (C + N) min, 0.70 max
S32615	. . .	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	. . .	1.50–2.50	. . .
S32654	. . .	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	. . .
S33228	. . .	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	. . .	. . .	. . .	Ce 0.05–0.10 Cb 0.6–1.0 Al 0.025
S33400	334[G]	0.08	1.00	0.030	0.015	1.00	18.0–20.0	19.0–21.0	. . .	. . .	. . .	Al 0.15–0.60 Ti 0.15–0.60
S34565	. . .	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	. . .	Cb 0.10
S34700	347	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	. . .	. . .	. . .	Cb 10 × C min, 1.00 max
S34709	347H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	. . .	. . .	. . .	Cb 8 × C min, 1.00 max
S34800	348	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	. . .	. . .	. . .	(Cb + Ta) 10×C min, 1.00 max Ta 0.10 Co 0.20
S34809	348H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	. . .	. . .	. . .	(Cb + Ta) 8×C min, 1.00 max Ta 0.10 Co 0.20
S35045	. . .	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	. . .	. . .	0.75	Al 0.15–0.60 Ti 0.15–0.60
S35125	. . .	0.10	1.00–1.50	0.045	0.015	0.50	20.0–23.0	31.0–35.0	2.00–3.00	. . .	. . .	Cb 0.25–0.60
S35135	. . .	0.08	1.00	0.045	0.015	0.60–1.00	20.0–25.0	30.0–38.0	4.0–4.8	. . .	0.75	Ti 0.40–1.00

TABLE 1 *Continued*

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phos-phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E,F]
S35315	. . .	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	. . .	0.12–0.18	. . .	Ce 0.03–0.10
S38100	XM-15[J]	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	. . .	. . .	. . .	. . .
S38815	. . .	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	13.0–17.0	0.75–1.50	. . .	0.75–1.50	Al 0.30
Duplex (Austenitic-Ferritic)												
S31200	. . .	0.030	2.00	0.045	0.030	1.00	24.0–26.0	5.5–6.5	1.20–2.00	0.14–0.20	. . .	. . .
S31260	. . .	0.03	1.00	0.030	0.030	0.75	24.0–26.0	5.5–7.5	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31803	. . .	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20	. . .	. . .
S32001	. . .	0.030	4.0–6.0	0.040	0.030	1.00	19.5–21.5	1.00–3.00	0.60	0.05–0.17	1.00	. . .
S32003	. . .	0.030	2.00	0.030	0.020	1.00	19.5–22.5	3.0–4.0	1.50–2.00	0.14–0.20	. . .	. . .
S32101	. . .	0.040	4.0–6.0	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.10–0.80	0.20–0.25	0.10–0.80	. . .
S32205	2205[G]	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20	. . .	. . .
S32304	2304[G]	0.030	2.50	0.040	0.030	1.00	21.5–24.5	3.0–5.5	0.05–0.60	0.05–0.20	0.05–0.60	
S32506	. . .	0.030	1.00	0.040	0.015	0.90	24.0–26.0	5.5–7.2	3.0–3.5	0.08–0.20	. . .	W 0.05–0.30
S32520	. . .	0.030	1.50	0.035	0.020	0.80	24.0–26.0	5.5–8.0	3.0–4.0	0.20–0.35	0.50–2.00	. . .
S32550	255[G]	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32750	2507[G]	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.0–8.0	3.0–5.0	0.24–0.32	0.50	. . .
S32760[K]	. . .	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S32900	329	0.08	1.00	0.040	0.030	0.75	23.0–28.0	2.0–5.00	1.00–2.00	. . .	. . .	. . .
S32906	. . .	0.030	0.80–1.50	0.030	0.030	0.80	28.0–30.0	5.8–7.5	1.50–2.60	0.30–0.40	0.80	. . .
S32950	. . .	0.030	2.00	0.035	0.010	0.60	26.0–29.0	3.5–5.2	1.00–2.50	0.15–0.35	. . .	. . .
S39274†	. . .	0.030	1.00	0.030	0.020	0.80	24.0–26.0	6.0–8.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
Ferritic or Martensitic (Chromium)												
S32803	. . .	0.015	0.50	0.020	0.0035	0.55	28.0–29.0	3.0–4.0	1.80–2.50	0.020 (C+N) 0.030	. . .	Cb 12×(C+N) min, 0.15–0.50
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5–14.5	0.60	. . .	. . .	. . .	Al 0.10–0.30
S40900[L]	409[L]											
S40910	. . .	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	. . .	0.030	. . .	Ti 6×(C+N) min, 0.50 max; Cb 0.17
S40920	. . .	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	. . .	0.030	. . .	Ti 8×(C+N) min, Ti 0.15–0.50; Cb 0.10
S40930	. . .	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	. . .	0.030	. . .	(Ti+Cb) [0.08+8 ×(C+N)] min, 0.75 max; Ti 0.05 min
S40945	. . .	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.50	. . .	0.030	. . .	Cb 0.18–0.40 Ti 0.05–0.20
S40975	. . .	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.50–1.00	. . .	0.030	. . .	Ti 6×(C+N) min, 0.75 max
S40977	. . .	0.030	1.50	0.040	0.015	1.00	10.5–12.5	0.30–1.00	. . .	0.030	. . .	. . .
S41000	410	0.08–0.15	1.00	0.040	0.030	1.00	11.5–13.5	0.75	. . .	. . .	. . .	. . .
S41003	. . .	0.030	1.50	0.040	0.030	1.00	10.5–12.5	1.50	. . .	0.030	. . .	. . .
S41008	410S	0.08	1.00	0.040	0.030	1.00	11.5–13.5	0.60	. . .	. . .	. . .	. . .
S41045	. . .	0.030	1.00	0.040	0.030	1.00	12.0–13.0	0.50	. . .	0.030	. . .	Cb 9×(C+N) min, 0.60 max
S41050	. . .	0.04	1.00	0.045	0.030	1.00	10.5–12.5	0.60–1.10	. . .	0.10	. . .	. . .
S41500[M]	. . .	0.05	0.50–1.00	0.030	0.030	0.60	11.5–14.0	3.5–5.5	0.50–1.00	. . .	. . .	. . .
S42035	. . .	0.08	1.00	0.045	0.030	1.00	13.5–15.5	1.0–2.5	0.2–1.2	. . .	. . .	Ti 0.30–0.50
S42900	429[G]	0.12	1.00	0.040	0.030	1.00	14.0–16.0	. . .	. . .	. . .	. . .	. . .
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	0.75	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E,F]
S43035	439	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	. . .	0.030	. . .	Ti [0.20+4(C+N)] min, 1.10 max; Al 0.15
S43400	434	0.12	1.00	0.040	0.030	1.00	16.0–18.0	. . .	0.75–1.25	. . .	. . .	. . .
S43600	436	0.12	1.00	0.040	0.030	1.00	16.0–18.0	. . .	0.75–1.25	. . .	. . .	Cb 5×C min, 0.80 max
S43932	. . .	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	. . .	0.030	. . .	(Ti+Cb) [0.20+4(C+N)] min, 0.75 max; Al 0.15
S43940	. . .	0.030	1.00	0.040	0.015	1.00	17.5–18.5	. . .	. . .	. . .	. . .	Ti 0.10–0.60 Cb [0.30+(3×C)] min
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	. . .	(Ti+Cb)[0.20+4(C+N)] min, 0.80 max
S44500	. . .	0.020	1.00	0.040	0.012	1.00	19.0–21.0	0.60	. . .	0.03	0.30–0.60	Cb 10×(C+N) min, 0.80 max
S44626	XM-33[J]	0.06	0.75	0.040	0.020	0.75	25.0–27.0	0.50	0.75–1.50	0.04	0.20	Ti 0.20–1.00; Ti 7(C+N) min
S44627	XM-27[J]	0.010[N]	0.40	0.020	0.020	0.40	25.0–27.5	0.50	0.75–1.50	0.015[N]	0.20	Cb 0.05–0.20 (Ni + Cu) 0.50
S44635	. . .	0.025	1.00	0.040	0.030	0.75	24.5–26.0	3.5–4.5	3.5–4.5	0.035	. . .	(Ti+Cb) [0.20+4 (C+N)] min, 0.80 max
S44660	. . .	0.030	1.00	0.040	0.030	1.00	25.0–28.0	1.0–3.5	3.0–4.0	0.040	. . .	(Ti+Cb) 0.20 – 1.00, Ti + Cb 6×(C+N) min
S44700	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	3.5–4.2	0.020	0.15	(C+N) 0.025
S44735	. . .	0.030	1.00	0.040	0.030	1.00	28.0–30.0	1.00	3.6–4.2	0.045	. . .	(Ti+Cb) 0.20–1.00, (Ti+Cb) 6× (C+N) min
S44800	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.00–2.50	3.5–4.2	0.020	0.15	(C+N) 0.025
S46800	. . .	0.030	1.00	0.040	0.030	1.00	18.0–20.0	0.50	. . .	0.030	. . .	Ti 0.07–0.30 Cb 0.10–0.60 (Ti+Cb) [0.20+4 (C+N)] min, 0.80 max
S44535	. . .	0.030	0.30–0.80	0.050	0.020	0.50	20.0–24.0	. . .	. . .	. . .	0.50	La 0.04–0.20 Ti 0.03–0.20 Al 0.50

[A] Maximum, unless range or minimum is indicated.

[B] Designation established in accordance with Practice E 527 and SAE J 1086.

[C] Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

[D] Carbon analysis shall be reported to nearest 0.01 % except for the low-carbon types, which shall be reported to nearest 0.001 %.

[E] The terms Columbium (Cb) and Niobium (Nb) both relate to the same element.

[F] When two minimums or two maximums are listed for a single type, as in the case of both a value from a formula and an absolute value, the higher minimum or lower maximum shall apply.

[G] Common name, not a trademark, widely used, not associated with any one producer.

[H] Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

[I] (Al + Ti) 0.85–1.20.

[J] Naming system developed and applied by ASTM.

[K] Cr + 3.3 Mo + 16 N = 40 min.

[L] S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.

[M] Plate version of CA-6NM.

[N] Product (check or verification) analysis tolerance over the maximum limit for C and N in XM-27 shall be 0.002 %.

† UNS number was editorially corrected.

TABLE 2 Mechanical Test Requirements

UNS Designation	Type[A]	Tensile Strength, min		Yield Strength,[B] min		Elongation in 2 in. or 50 mm, min, %	Hardness, max[C]		Cold Bend°[D]
		ksi	MPa	ksi	MPa		Brinell	Rockwell B	
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)									
N08020	. . .	80	550	35	240	30[E]	217	95	not required
N08367									
Sheet and Strip		100	690	45	310	30	. . .	100	not required
Plate		95	655	45	310	30	241	. . .	not required
N08700	. . .	80	550	35	240	30	192	90	not required
N08800	800[F]	75	520	30[G]	205[G]	30[H]	. . .	. . .	not required
N08810	800H[F]	65	450	25[G]	170[G]	30	. . .	. . .	not required
N08811	. . .	65	450	25	170	30	. . .	. . .	not required
N08904	904L[F]	71	490	31	220	35	. . .	90	not required
N08926	. . .	94	650	43	295	35	. . .	. . .	not required
S20100	201-1[I]	75	515	38	260	40	217	95	. . .
S20100	201-2[I]	95	655	45	310	40	241	100	. . .
S20103	201L[F]	95	655	38	260	40	217	95	not required
S20153	201LN[F]	95	655	45	310	45	241	100	not required
S20161	. . .	125	860	50	345	40	255	25[J]	not required
S20200	202	90	620	38	260	40	241	. . .	. . .
S20400	. . .	95	655	48	330	35	241	100	not required
S20910	XM-19[K]								
Sheet and Strip		105	725	60	415	30	241	100	not required
Plate		100	690	55	380	35	241	100	not required
S21600	XM-17[J]								
Sheet and Strip		100	690	60	415	40	241	100	not required
Plate		90	620	50	345	40	241	100	not required
S21603	XM-18[K]								
Sheet and Strip		100	690	60	415	40	241	100	not required
Plate		90	620	50	345	40	241	100	not required
S21800	. . .	95	655	50	345	35	241	100	not required
S24000	XM-29[K]								
Sheet and Strip		100	690	60	415	40	241	100	not required
Plate		100	690	55	380	40	241	100	not required
S30100	301	75	515	30	205	40	217	95	not required
S30103	301L[F]	80	550	32	220	45	241	100	not required
S30153	301LN[F]	80	550	35	240	45	241	100	not required
S30200	302	75	515	30	205	40	201	92	not required
S30400	304	75	515	30	205	40	201	92	not required
S30403	304L	70	485	25	170	40	201	92	not required
S30409	304H	75	515	30	205	40	201	92	not required
S30415	. . .	87	600	42	290	40	217	95	not required
S30451	304N	80	550	35	240	30	217	95	not required
S30452	XM-21[K]								
Sheet and Strip		90	620	50	345	30	241	100	not required
Plate		85	585	40	275	30	241	100	not required
S30453	304LN	75	515	30	205	40	217	95	not required
S30500	305	70	485	25	170	40	183	88	not required
S30600	. . .	78	540	35	240	40	. . .	. . .	. . .
S30601	. . .	78	540	37	255	30	. . .	. . .	not required
S30615	. . .	90	620	40	275	35	217	95	not required
S30815	. . .	87	600	45	310	40	217	95	. . .
S30908	309S	75	515	30	205	40	217	95	not required
S30909	309H[F]	75	515	30	205	40	217	95	not required
S30940	309Cb[F]	75	515	30	205	40	217	95	not required

TABLE 2 *Continued*

UNS Designation	Type[A]	Tensile Strength, min		Yield Strength,[B] min		Elongation in 2 in. or 50 mm, min, %	Hardness, max[C]		Cold Bend°[D]
		ksi	MPa	ksi	MPa		Brinell	Rockwell B	
S30941	309HCb[F]	75	515	30	205	40	217	95	not required
S31008	310S	75	515	30	205	40	217	95	not required
S31009	310H[F]	75	515	30	205	40	217	95	not required
S31040	310Cb[F]	75	515	30	205	40	217	95	not required
S31041	310HCb[F]	75	515	30	205	40	217	95	not required
S31050	310 MoLN[F]								
	t ≤ 0.25 in.	84	580	39	270	25	217	95	not required
	t > 0.25 in.	78	540	37	255	25	217	95	not required
S31060	. . .	87	600	41	280	40	217	95	not required
S31254									
Sheet and Strip		100	690	45	310	35	223	96	not required
Plate		95	655	45	310	35	223	96	not required
S31266	. . .	109	750	61	420	35	. . .	. . .	not required
S31277	. . .	112	770	52	360	40	. . .	. . .	not required
S31600	316	75	515	30	205	40	217	95	not required
S31603	316L	70	485	25	170	40	217	95	not required
S31609	316H	75	515	30	205	40	217	95	not required
S31635	316Ti[F]	75	515	30	205	40	217	95	not required
S31640	316Cb[F]	75	515	30	205	30	217	95	not required
S31651	316N	80	550	35	240	35	217	95	not required
S31653	316LN	75	515	30	205	40	217	95	not required
S31700	317	75	515	30	205	35	217	95	not required
S31703	317L	75	515	30	205	40	217	95	not required
S31725	317LM[F]	75	515	30	205	40	217	95	not required
S31726	317LMN[F]	80	550	35	240	40	223	96	not required
S31727	. . .	80	550	36	245	35	217	96	not required
S31753	317LN	80	550	35	240	40	217	95	not required
S32050	. . .	98	675	48	330	40	250	. . .	not required
S32053	. . .	93	640	43	295	40	217	96	not required
S32100	321	75	515	30	205	40	217	95	not required
S32109	321H	75	515	30	205	40	217	95	not required
S32615[L]	. . .	80	550	32	220	25	. . .	. . .	not required
S32654	. . .	109	750	62	430	40	250	. . .	not required
S33228	. . .	73	500	27	185	30	217	95	not required
S33400	334[F]	70	485	25	170	30	. . .	92	not required
S34565	. . .	115	795	60	415	35	241	100	not required
S34700	347	75	515	30	205	40	201	92	not required
S34709	347H	75	515	30	205	40	201	92	not required
S34800	348	75	515	30	205	40	201	92	not required
S34809	348H	75	515	30	205	40	201	92	not required
S35045	. . .	70	485	25	170	35	. . .	. . .	not required
S35125	. . .	70	485	30	205	35	. . .	. . .	not required
S35135									
Sheet and Strip	. . .	80	550	30	205	30	. . .	. . .	not required
Plate	. . .	75	515	30	205	30	. . .	. . .	not required
S35315	. . .	94	650	39	270	40	217	95	not required
S38100	XM-15[K]	75	515	30	205	40	217	95	not required
S38815	. . .	78	540	37	255	30	. . .	. . .	not required
Duplex (Austenitic-Ferritic)									
S31200	. . .	100	690	65	450	25	293	31[J]	not required
S31260	. . .	100	690	70	485	20	290	. . .	. . .
S31803	. . .	90	620	65	450	25	293	31[J]	not required
S32001	. . .	90	620	65	450	25	. . .	25[J]	not required

TABLE 2 *Continued*

UNS Designation	Type[A]	Tensile Strength, min		Yield Strength,[B] min		Elongation in 2 in. or 50 mm, min, %	Hardness, max[C]		Cold Bend°[D]
		ksi	MPa	ksi	MPa		Brinell	Rockwell B	
S32003	. . .								
	t ≤ 0.187 in. [5.00 mm]	100	690	70	485	25	293	31[J]	not required
	t ≥ 0.187 in. [5.00 mm]	95	655	65	450	25	293	31[J]	not required
S32101	. . .								
	t ≤ 0.187 in. [5.00 mm]	101	700	77	530	30	290	. . .	not required
	t > 0.187 in. [5.00 mm]	94	650	65	450	30	290	. . .	not required
S32205	2205[F]	95	655	65	450	25	293	31[J]	not required
S32304	2304[F]	87	600	58	400	25	290	32[J]	not required
S32506	. . .	90	620	65	450	18	302	32[J]	not required
S32520	. . .	112	770	80	550	25	310	. . .	not required
S32550	255[F]	110	760	80	550	15	302	32[J]	not required
S32750	2507[F]	116	795	80	550	15	310	32[J]	not required
S32760	. . .	108	750	80	550	25	270	. . .	not required
S32900	329	90	620	70	485	15	269	28[J]	not required
S32906	. . .								
	t < 0.4 in. [10.0 mm]	116	800	94	650	25.0	310	32[J]	not required
	t ≥ 0.4 in. [10.0 mm]	109	750	80	550	25.0	310	32[J]	not required
S32950[M]	. . .	100	690	70	485	15	293	32[J]	not required
S39274†	. . .	116	800	80	550	15	310	32[J]	not required
Ferritic or Martensitic (Chromium)									
S32803	. . .	87	600	72	500	16	241	100	not required
S40500	405	60	415	25	170	20	179	88	180
S40900[N]	409[N]								
S40910	. . .	55	380	25	170	20	179	88	180
S40920	. . .	55	380	25	170	20	179	88	180
S40930	. . .	55	380	25	170	20	179	88	180
S40945	. . .	55	380	30	205	22	. . .	80	180
S40975	. . .	60	415	40	275	20	197	92	180
S40977	. . .	65	450	41	280	18	180	88	not required
S41000	410	65	450	30	205	20	217	96	180
S41003	. . .	66	455	40	275	18	223	20[J]	not required
S41008	410S	60	415	30	205	22[O]	183	89	180
S41045	. . .	55	380	30	205	22	. . .	80	180
S41050	. . .	60	415	30	205	22	183	89	180
S41500	. . .	115	795	90	620	15	302	32[J]	not required
S42035	. . .	80	550	55	380	16	180	88	not required
S42900	429[F]	65	450	30	205	22[O]	183	89	180
S43000	430	65	450	30	205	22[O]	183	89	180
S43035	439	60	415	30	205	22	183	89	180
S43400	434	65	450	35	240	22	. . .	89	180
S43600	436	65	450	35	240	22	. . .	89	180
S43932	. . .	60	415	30	205	22	183	89	180
S43940	. . .	62	430	36	250	18	180	88	not required

TABLE 2 *Continued*

UNS Designation	Type[A]	Tensile Strength, min		Yield Strength,[B] min		Elongation in 2 in. or 50 mm, min, %	Hardness, max[C]		Cold Bend°[D]
		ksi	MPa	ksi	MPa		Brinell	Rockwell B	
S44400	. . .	60	415	40	275	20	217	96	180
S44500	. . .	62	427	30	205	22	. . .	83	180
S44626	XM-33[K]	68	470	45	310	20	217	96	180
S44627	XM-27[K]	65	450	40	275	22	187	90	180
S44635	. . .	90	620	75	515	20	269	28[J]	180
S44660	. . .	85	585	65	450	18	241	100	180
S44700	. . .	80	550	60	415	20	223	20[J]	180
S44735	. . .	80	550	60	415	18	255	25[J]	180
S44800	. . .	80	550	60	415	20	223	20[J]	180
S46800	. . .	60	415	30	205	22	. . .	90	180
S44535	. . .	58	400	36	250	25[E]	. . .	50–90[P]	not required

[A] Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[B] Yield strength shall be determined by the offset method at 0.2 % in accordance with Test Methods and Definitions A 370. Unless otherwise specified (see Specification A 480/A 480M, paragraph 4.1.11, Ordering Information), an alternative method of determining yield strength may be based on total extension under load of 0.5 %.
[C] Either Brinell or Rockwell B Hardness is permissible.
[D] Bend tests are not required for chromium steels (ferritic or martensitic) thicker than 1 in. [25 mm] or for any austenitic or duplex (austenitic-ferritic) stainless steels regardless of thickness.
[E] Elongation for thickness, less than 0.015 in. (0.38 mm) shall be 20 % minimum, in 1 in. (25.4 mm).
† UNS number was editorially corrected.
[F] Common name, not a trademark, widely used, not associated with any one producer.
[G] Yield strength requirements shall not apply to material under 0.020 in [0.50 mm] in thickness.
[H] Not applicable for thicknesses under 0.010 in. [0.25 mm].
[I] Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.
[J] Rockwell C scale.
[K] Naming system developed and applied by ASTM.
[L] For S32615, the grain size as determined in accordance with the Test Methods E 112, Comparison Method, Plate II, shall be No. 3 or finer.
[M] Prior to Specification A 240 – 89b, the tensile value for S32950 was 90 ksi.
[N] S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.
[O] Material 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20 %.
[P] Hardness is required to be provided for information only, but is not required to meet a particular requirement.

SUPPLEMENTARY REQUIREMENTS

A supplementary requirement shall apply only when specified in the purchase order.

S1. Charpy Impact Testing of Plate

S1.1 Charpy impact tests shall be conducted in accordance with Test Methods and Definitions A 370.

S1.2 *Number of Tests*—One impact test (3 specimens) shall be made from one plate per heat treatment lot in the final heat treated condition.

S1.3 *Orientation of Test Specimens*—Unless specified as transverse specimens (long axis of the specimen transverse to the final rolling direction, root of the notch perpendicular to the rolling face) on the purchase order, the orientation of the specimens shall be longitudinal (long axis of the specimen parallel to the final rolling direction, root of the notch perpendicular to the rolling face). The manufacturer is permitted to test transverse specimens provided that such tests meet the acceptance criteria applicable to longitudinal specimens. Unless otherwise specified on the purchase order, the specimens shall be taken so as to include the mid-thickness of the product.

S1.4 *Test Temperature*—The purchaser shall specify the test temperature. The manufacturer is permitted to test specimens at a temperature lower than that specified by the purchaser, provided that such tests shall meet the acceptance criteria applicable to specimens tested at the specified temperature (see Note).

NOTE —Test Methods A 923, Method B, applicable to some duplex (austenitic-ferritic) stainless steels as listed in Test Methods A 923, uses a Charpy impact test for the purpose of determining the absence of detrimental intermetallic phases. Method B specifies a test temperature and acceptance criterion, expressed as impact energy, for each type of steel covered. It may be economical for the Charpy impact tests performed on duplex stainless steels covered in both Specification A 240 and Test Methods A 923 to be performed at the lower of the temperatures specified by this supplementary requirement and Test Methods A 923 Method B, with measurement of both lateral expansion and impact energy.

S1.5 *Acceptance Limit* —Unless otherwise specified on the purchase order, each of the three specimens tested shall show a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

S1.6 *Records*—The recorded results shall include the specimen orientation, specimen size, test temperature, absorbed energy values (if required), and lateral expansion opposite the notch.

S2. Materials for High-Temperature Service

S2.1 Unless an H grade has been ordered, this supplementary requirement shall be specified for ASME Code applications for service above 1000°F [540°C].

S2.2 The user is permitted to use an austenitic stainless steel as the corresponding H grade when the material meets all requirements of the H grade including chemistry, annealing temperature, and grain size (see Section 6).

S2.3 The user is permitted to use an L grade austenitic stainless steel for service above 1000°F [540°C], subject to the applicable allowable stress table of the ASME Code, when the material meets all requirements of this specification and the grain size is ASTM No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size shall be reported on a Certified Test Report.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A 240/A 240M – 06c, that may impact the use of this standard. (Approved April 1, 2007.)

(*1*) Revised the Cr in the composition of S30400 and S30403, and C in S30400 in Table 1.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 240/A 240M – 06b, that may impact the use of this standard. (Approved November 1, 2006.)

(*1*) Revised Si content in Table 1 for UNS S32906 from 0.50 % to 0.80 %.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 240/A 240M – 06a, that may impact the use of this standard. (Approved July 1, 2006.)

(*1*) S35125 added to Tables 1 and 2.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 240/A 240M – 06, that may impact the use of this standard. (Approved June 15, 2006.)

(*1*) New grade S44535 added to Tables 1 and 2.

(*2*) Footnote P added to Table 2.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 240/A 240M – 05a, that may impact the use of this standard. (Approved March 1, 2006.)

(*1*) Revised S32003 strength in Table 2.

Designation: A 276 – 06

Standard Specification for Stainless Steel Bars and Shapes[1]

This standard is issued under the fixed designation A 276; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers hot-finished or cold-finished bars except bars for reforging (Note 1). It includes rounds, squares, and hexagons, and hot-rolled or extruded shapes, such as angles, tees, and channels in the more commonly used types of stainless steels. The free-machining types (Note 2) for general corrosion resistance and high-temperature service are covered in a separate specification.

NOTE 1—For bars for reforging, see Specification A 314.

NOTE 2—For free-machining stainless bars designed especially for optimum machinability, see Specification A 582/A 582M.

NOTE 3—There are standards covering high nickel, chromium, austenitic corrosion, and heat resisting alloy materials. These standards are under the jurisdiction of ASTM Subcommittee B02.07 and may be found in *Annual Book of ASTM Standards*, Vol. 02.04.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 314 Specification for Stainless Steel Billets and Bars for Forging

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A 582/A 582M Specification for Free-Machining Stainless Steel Bars

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Document:*[3]

SAE J 1086 Recommended Practice for Numbering Metals and Alloys

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include but are not limited to the following:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material: stainless steel,

3.1.3 Form (bars, angles, etc.),

3.1.4 Condition (Section 4.1),

3.1.5 Finish (Section 8 of Specification A 484/A 484M),

3.1.6 Surface preparation of shapes (Section 8 of Specification A 484/A 484M),

3.1.7 Applicable dimensions including size, thickness, width, and length,

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3.1.8 Cross section (round, square, etc.),

3.1.9 Type or UNS designation (Table 1),

3.1.10 ASTM designation and date of issue, and

3.1.11 Whether bars are to be rolled as bars or cut from strip or plate.

3.1.12 Test for magnetic permeability when specified by customer purchase order when ordering Types 201 and 205.

3.1.13 Special requirements.

NOTE 4—A typical ordering description is as follows: 5000 lb (2268 kg) Stainless Steel Bars, Annealed and Centerless Ground, 1½ in. (38.10 mm) Round, 10 to 12 ft (3.05 to 3.66 m) in length, Type 304, ASTM Specification A 276 dated ______. End use: machined valve parts.

4. Manufacture

4.1 *Condition*:

4.1.1 Bars shall be furnished in one of the following conditions listed in the Mechanical Requirements table:

4.1.1.1 *Condition A*—Annealed

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.17 on Flat-Rolled and Wrought Stainless Steel.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

***A Summary of Changes section appears at the end of this standard.**

TABLE 1 Chemical Requirements[A]

UNS Designation[B]	Type	Composition, %									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
						Austenitic Grades					
N08367	. . .	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	Cu 0.75
N08700	. . .	0.04	2.00	0.040	0.030	1.00	19.0–23.0	24.0–26.0	4.3–5.0	. . .	Cu 0.50 Cb 8 × C min 0.40 max
S20100	201	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	. . .	0.25	. . .
S20161	. . .	0.15	4.0–6.0	0.045	0.030	3.0–4.0	15.0–18.0	4.0–6.0	. . .	0.08–0.20	. . .
S20162	. . .	0.15	4.0–8.0	0.040	0.040	2.5–4.5	16.5–21.0	6.0–10.0	0.50–2.50	0.05–0.25	. . .
S20200	202	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	. . .	0.25	. . .
S20500	205	0.12–0.25	14.0–15.5	0.060	0.030	1.00	16.5–18.0	1.0–1.7	. . .	0.32–0.40	. . .
S20910	XM-19	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	Cb 0.10–0.30, V 0.10–0.30
S21800	. . .	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	. . .	0.08–0.18	. . .
S21900	XM-10	0.08	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	. . .	0.15–0.40	. . .
S21904	XM-11	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	. . .	0.15–0.40	. . .
S24000	XM-29	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	. . .	0.20–0.40	. . .
S24100	XM-28	0.15	11.0–14.0	0.045	0.030	1.00	16.5–19.0	0.50–2.50	. . .	0.20–0.45	. . .
S28200	. . .	0.15	17.0–19.0	0.045	0.030	1.00	17.0–19.0	. . .	0.75–1.25	0.40–0.60	Cu 0.75–1.25
S30200	302	0.15	2.00	0.045	0.030	1.00	17.0–19.0	8.0–10.0	. . .	0.10	. . .
S30215	302B	0.15	2.00	0.045	0.030	2.00–3.00	17.0–19.0	8.0–10.0	. . .	0.10	. . .
S30400	304	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .
S30403	304L[C]	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	. . .	. . .	. . .
S30451	304N	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	0.10–0.16	. . .
S30452	XM-21	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–10.0	. . .	0.16–0.30	. . .
S30453	304LN	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	0.10–0.16	. . .
S30454	. . .	0.03	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	0.16–0.30	. . .
S30500	305	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	. . .	. . .	. . .
S30800	308	0.08	2.00	0.045	0.030	1.00	19.0–21.0	10.0–12.0	. . .	. . .	. . .
S30815	. . .	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	. . .	0.14–0.20	Ce 0.03–0.08
S30900	309	0.20	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .
S30908	309S	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .
S30940	309Cb	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	. . .	. . .	Cb 10×C-1.10
S31000	310	0.25	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	. . .	. . .	. . .
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	. . .	. . .	. . .
S31040	310Cb	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	. . .	. . .	Cb 10×C-1.10
S31254	. . .	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.22	Cu 0.50–1.00
S31400	314	0.25	2.00	0.045	0.030	1.50–3.00	23.0–26.0	19.0–22.0	. . .	. . .	. . .
S31600	316	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .
S31603	316L[C]	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .
S31635	316Ti	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	0.10	Ti 5×(C+N)-0.70
S31640	316Cb	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	0.10	Cb 10×C-1.10
S31651	316N	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	. . .
S31653	316LN	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	. . .
S31654	. . .	0.03	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.16–0.30	. . .
S31700	317	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	0.10	. . .
S31725	. . .	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	. . .
S31726	. . .	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	0.10–0.20	. . .
S31727	. . .	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	0.15–0.21	Cu 2.8–4.0
S32053	. . .	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	0.17–0.22	. . .
S32100	321	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Ti 5×(C+N)-0.70[D]
S32654	. . .	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	Cu 0.30–0.60
S34565	. . .	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	Cb 0.10
S34700	347	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Cb 10×C–1.10
S34800	348	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Cb 10×C–1.10, Ta 0.10 Co 0.20
						Austenitic-Ferritic Grades					
S31100	XM-26	0.06	1.00	0.045	0.030	1.00	25.0–27.0	6.0–7.0	. . .	. . .	Ti 0.25
S31803	. . .	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20	. . .
S32101	. . .	0.040	4.0–6.0	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.10–0.80	0.20–0.25	Cu 0.10–0.80
S32205	. . .	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20	. . .
S32304	. . .	0.030	2.50	0.040	0.030	1.00	21.5–24.5	3.0–5.5	0.05–0.60	0.05–0.20	Cu 0.05–0.60
S32506	. . .	0.030	1.00	0.040	0.015	0.90	24.0–26.0	5.5–7.2	3.0–3.5	0.08–0.20	W 0.05–0.30
S32550	. . .	0.04	1.50	0.040	0.030	1.0	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	Cu 1.50–2.50
S32760[E]	. . .	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	3.0–4.0	0.20–0.30	Cu 0.50–1.00 W 0.50–1.00
						Ferritic Grades					
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5–14.5	0.50	. . .	. . .	Al 0.10–0.30

TABLE 1 *Continued*

UNS Designation[B]	Type	Composition, %									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
S40976	. . .	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.75–1.00	. . .	0.040	Cb 10×(C+N)-0.80
S42900	429	0.12	1.00	0.040	0.030	1.00	14.0–16.0	. . .	. . .	. . .	. . .
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	. . .	. . .	. . .	. . .
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	Ti+Cb 0.20+4 × (C+N)-0.80
S44600	446	0.20	1.50	0.040	0.030	1.00	23.0–27.0	0.75	. . .	0.25	. . .
S44627	XM-27[F]	0.010[G]	0.40	0.020	0.020	0.40	25.0–27.5	0.50	0.75–1.50	0.015[G]	Cu 0.20 Cb 0.05–0.20
S44700	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	3.5–4.2	0.020	C+N 0.025 Cu 0.15
S44800	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.00–2.50	3.5–4.2	0.020	C+N 0.025 Cu 0.15
Martensitic Grades											
S40300	403	0.15	1.00	0.040	0.030	0.50	11.5–13.0	. . .	. . .	. . .	. . .
S41000	410	0.08–0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .
S41040	XM-30	0.18	1.00	0.040	0.030	1.00	11.0–13.0	. . .	. . .	. . .	Cb 0.05–0.30
S41400	414	0.15	1.00	0.040	0.030	1.00	11.5–13.5	1.25–2.50	. . .	. . .	. . .
S41425	. . .	0.05	0.50–1.00	0.020	0.005	0.50	12.0–15.0	4.0–7.0	1.50–2.00	0.06–0.12	Cu 0.30
S41500	[H]	0.05	0.50–1.00	0.030	0.030	0.60	11.5–14.0	3.5–5.5	0.50–1.00	. . .	. . .
S42000	420	0.15 min	1.00	0.040	0.030	1.00	12.0–14.0	. . .	. . .	. . .	. . .
S42010	. . .	0.15–0.30	1.00	0.040	0.030	1.00	13.5–15.0	0.35–0.85	0.40–0.85	. . .	. . .
S43100	431	0.20	1.00	0.040	0.030	1.00	15.0–17.0	1.25–2.50	. . .	. . .	. . .
S44002	440A	0.60–0.75	1.00	0.040	0.030	1.00	16.0–18.0	. . .	0.75	. . .	. . .
S44003	440B	0.75–0.95	1.00	0.040	0.030	1.00	16.0–18.0	. . .	0.75	. . .	. . .
S44004	440C	0.95–1.20	1.00	0.040	0.030	1.00	16.0–18.0	. . .	0.75	. . .	. . .

[A] Maximum, unless range or minimum is indicated.
[B] Designations established in accordance with Practice E 527 and SAE J 1086.
[C] For some applications, the substitution of Type 304L for Type 304, or Type 316L for Type 316 may be undesirable because of design, fabrication, or service requirements. In such cases, the purchaser should so indicate on the order.
[D] Nitrogen content is to be reported for this grade.
[E] % Cr + 3.3 × % Mo + 16 × % N ≥ 40.
[F] Nickel plus copper shall be 0.50 % max.
[G] Product analysis tolerance over the maximum limit for carbon and nitrogen shall be 0.002 %.
[H] Wrought version of CA 6NM.

4.1.1.2 *Condition H*—Hardened and tempered at a relatively low temperature

4.1.1.3 *Condition T*—Hardened and tempered at a relatively high temperature

4.1.1.4 *Condition S—Strain Hardened*—Relatively light cold work

4.1.1.5 *Condition B*—Relatively severe cold work

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition specified in Table 1.

5.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties Requirements

6.1 The material shall conform to the mechanical test requirements specified in Table 2.

6.2 The martensitic grades shall be capable of meeting the hardness requirements after heat treating as specified in Table 3.

6.3 Hardness measurements, when required, shall be made at a location midway between the surface and the center of the cross section.

7. Magnetic Permeability

7.1 When required by the purchase order, the magnetic permeability of Types 201 and 205 in the annealed condition shall not exceed 1.2 as tested by a Severn-type indicator.

8. General Requirements

8.1 In addition to the requirements of this specification, all requirements of the current edition of Specification A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance to this specification.

9. Certification

9.1 Upon request of the purchaser in the contract or order, the producer's certification that the material was manufactured and tested in accordance with this specification, together with a certified report of the test results shall be furnished at the time of the shipment.

10. Keywords

10.1 austenitic stainless steel; austenitic-ferritic duplex stainless steel; ferritic stainless steel; martensitic stainless steel; stainless steel bars; stainless steel shapes

TABLE 2 Mechanical Requirements

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, min ksi	Tensile Strength, min MPa	Yield Strength,[A] min ksi	Yield Strength,[A] min MPa	Elongation in 2 in. (50 mm)[B] or 4D min %	Reduction of Area,[C,D] min, %	Brinell Hardness,[E] max
			Austenitic Grades							
N08367	A	hot-finished or cold-finished	all	95	655	45	310	30	50	. . .
N08700	A	hot-finished or cold-finished	all	80	550	35	240	30	50	. . .
201, 202	A	hot-finished or cold-finished	all	75	515	40	275	40	45	. . .
S20161	A	hot-finished	all	125	860	50	345	40	40	255
		cold-finished	all	125	860	50	345	40	40	311
S20162	A	hot-finished or cold finished	all	100	690	50	345	50	60	. . .
205	A	hot-finished or cold-finished	all	100	690	60	414	40	50	. . .
XM-19	A	hot-finished or cold-finished	all	100	690	55	380	35	55	. . .
	As hot-rolled	hot-finished or cold-finished	up to 2 (50.8), incl	135	930	105	725	20	50	. . .
			over 2 to 3 (50.8 to 76.2), incl	115	795	75	515	25	50	. . .
			over 3 to 8 (76.2 to 203.2), incl	100	690	60	415	30	50	. . .
S21800	A	hot-finished or cold-finished	all	95	655	50	345	35	55	241
XM-10, XM-11	A	hot-finished or cold-finished	all	90	620	50	345	45	60	. . .
XM-29	A	hot-finished or cold-finished	all	100	690	55	380	30	50	. . .
XM-28	A	hot-finished or cold-finished	all	100	690	55	380	30	50	. . .
S24565	A	hot-finished or cold-finished	all	115	795	60	415	35	40	. . .
S28200	A	hot-finished or cold finished	all	110	760	60	410	35	55	. . .
302, 302B, 304, 304LN, 305, 308, 309, 309S, 309Cb, 310, 310S, 310Cb, 314, 316, 316LN, 316Cb, 316TI, 317, 321, 347, 348	A	hot-finished	all	75[F]	515	30[F]	205	40[G]	50	. . .
		cold-finished	up to ½ (12.70) incl	90	620	45	310	30	40	. . .
			over ½ (12.70)	75[F]	515	30[F]	205	30	40	. . .
304L, 316L	A	hot-finished	all	70	485	25	170	40[G]	50	. . .
		cold-finished	up to ½ (12.70) incl.	90	620	45	310	30	40	. . .
			over ½ (12.70)	70	485	25	170	30	40	. . .
304N, 316N	A	hot-finished or cold-finished	all	80	550	35	240	30	. . .	. . .
202, 302, 304, 304N, 316, 316N	B	cold-finished	up to ¾ (19.05) incl	125	860	100	690	12	35	. . .
304L, 316L			over ¾ (19.05) to 1 (25.40)	115	795	80	550	15	35	. . .
			over 1 (25.40) to 1¼ (31.75)	105	725	65	450	20	35	. . .
			over 1¼ (31.75) to 1½ (38.10)	100	690	50	345	24	45	. . .
			over 1½ (38.10) to 1¾ (44.45)	95	655	45	310	28	45	. . .
304, 304N, 316, 316N 304L, 316L	S	cold-finished	up to 2 (50.8) incl	95	650	75	515	25	40	. . .
			over 2 to 2½ (50.8 to 63.5) incl	90	620	65	450	30	40	. . .
			over 2½ to 3 (63.5 to 76.2) incl	80	550	55	380	30	40	. . .
XM-21, S30454, S31654	A	hot-finished or cold-finished	all	90	620	50	345	30	50	. . .
XM-21, S30454 S31654	B	cold-finished	up to 1 (25.40) incl	145	1000	125	860	15	45	. . .
			over 1 (25.40) to 1¼ (31.75)	135	930	115	795	16	45	. . .
			over 1¼ (31.75) to 1½ (38.10)	135	895	105	725	17	45	. . .

TABLE 2 *Continued*

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, min		Yield Strength,[A] min		Elongation in 2 in. (50 mm)[B] or 4D min %	Reduction of Area,[C,D] min, %	Brinell Hardness,[E] max
				ksi	MPa	ksi	MPa			
			over 1½ (38.10) to 1¾ (44.45)	125	860	100	690	18	45	. . .
S30815	A	hot-finished or	all	87	600	45	310	40	50	. . .
		cold-finished		87	600	45	310	40	50	. . .
S31254	A	hot-finished or cold-finished	all	95	650	44	300	35	50	. . .
S31725	A	hot-finished or cold-finished	all	75	515	30	205	40	. . .	. . .
S31726	A	hot-finished or cold-finished	all	80	550	35	240	40	. . .	. . .
S31727	A	hot-finished or cold-finished	all	80	550	36	245	35	. . .	217
S32053	A	hot-finished or cold-finished	all	93	640	43	295	40	. . .	217
S32654	A	hot-finished or cold-finished	all	109	750	62	430	40	40	250
			Austenitic-Ferritic Grades							
XM-26	A	hot-finished or cold-finished	all	90	620	65	450	20	55	. . .
S31803	A	hot-finished or cold-finished	all	90	620	65	448	25	. . .	290
S32056	A	hot-finished or cold-finished	all	90	620	65	450	18	. . .	302
S32101	A	hot-finished or cold-finished	all	94	650	65	450	30	. . .	290
S32205	A	hot-finished or cold-finished	all	95	655	65	450	25	. . .	290
S32304	A	hot-finished or cold-finished	all	87	600	58	400	25	. . .	290
S32550	A	hot-finished or cold-finished	all	109	750	80	550	25	. . .	290
S32550	S	cold-finished	all	125	860	105	720	16	. . .	335
S32760	A	hot-finished or cold-finished	all	109	750	80	550	25	. . .	290
S32760	S	cold-finished	all	125	860	105	720	16	. . .	335
			Ferritic Grades							
405[H]	A	hot-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	207
		cold-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	217
429	A	hot-finished	all	70	480	40	275	20	45	. . .
		cold-finished	all	70	480	40	275	16	45	. . .
430	A	hot-finished or cold-finished	all	60	415	30	207	20	45	. . .
S40976	A	hot-finished or cold-finished	all	60	415	20	140	20	45	244
S44400	A	hot-finished	all	60	415	45	310	20	45	217
		cold-finished	all	60	415	45	310	16	45	217
446, XM-27	A	hot-finished	all	65	450	40	275	20	45	219
		cold-finished	all	65	450	40	275	16	45	219
S44700	A	hot-finished	all	70	480	55	380	20	40	. . .
		cold-finished	all	75	520	60	415	15	30	. . .
S44800	A	hot-finished	all	70	480	55	380	20	40	. . .
		cold-finished	all	75	520	60	415	15	30	. . .
			Martensitic Grades							
403, 410	A	hot-finished	all	70	480	40	275	20	45	. . .
		cold-finished	all	70	480	40	275	16	45	. . .
403, 410	T	hot-finished	all	100	690	80	550	15	45	. . .
		cold-finished	all	100	690	80	550	12	40	. . .
XM-30	T	hot-finished	all	125	860	100	690	13	45	302
		cold-finished	all	125	860	100	690	12	35	. . .
403, 410	H	hot-finished	all	120	830	90	620	12	40	. . .
		cold-finished	all (rounds only)	120	830	90	620	12	40	. . .
XM-30	A	hot-finished	all	70	480	40	275	13	45	235
		cold-finished	all	70	480	40	275	12	35	. . .
414	A	hot-finished or cold-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	298
414	T	hot-finished or cold-finished	all	115	790	90	620	15	45	. . .

TABLE 2 *Continued*

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, min		Yield Strength,[A] min		Elongation in 2 in. (50 mm)[B] or 4D min %	Reduction of Area,[C,D] min, %	Brinell Hardness,[E] max
				ksi	MPa	ksi	MPa			
S41425	T	hot-finished	all	120	825	95	655	15	45	321
S41500	T	hot-finished or cold-finished	all	115	795	90	620	15	45	295
420	A	hot-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	241
		cold-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	255
S42010	A	hot-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	235
		cold-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	255
431	A	hot-finished or cold-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	285
440A, 440B, and 440C	A	hot-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	269
		cold-finished	all	. . .	. . .	. . .	. . .	. . .	. . .	285

[A] Yield strength shall be determined by the 0.2 % offset method in accordance with Test Methods and Definitions A 370. An alternative method of determining yield strength may be used based on a total extension under load of 0.5 %.
[B] For some specific products, it may not be practicable to use a 2-in. or 50-mm gage length. The use of sub-size test specimens, when necessary, is permissible in accordance with Test Methods and Definitions A 370.
[C] Reduction of area does not apply on flat bars 3⁄16 in. (4.76 mm) and under in thickness as this determination is not generally made in this product size.
[D] The material shall be capable of meeting the required reduction of area where listed, but actual measurement and reporting of the reduction of area are not required unless specified in the purchase order.
[E] Or equivalent Rockwell hardness.
[F] For extruded shapes of all Cr-Ni grades of Condition A, the yield strength shall be 25 ksi (170 MPa) min and tensile strength shall be 70 ksi (480 MPa) min.
[G] For shapes having section thickness of 1⁄2 in. (12.5 mm) or less, 30% min. elongation is acceptable.
[H] Material shall be capable of being heat treated to a maximum Brinell hardness of 250 when oil quenched from 1750°F (953°C).

TABLE 3 Response to Heat Treatment

Type[A]	Heat Treatment Temperature[B] °F (°C), min	Quenchant	Hardness HRC, min
403	1750 (955)	Air	35
410	1750 (955)	Air	35
414	1750 (955)	Oil	42
420	1825 (995)	Air	50
S42010	1850 (1010)	Oil	48
431	1875 (1020)	Oil	40
440A	1875 (1020)	Air	55
440B	1875 (1020)	Oil	56
440C	1875 (1020)	Air	58

[A] Samples for testing shall be in the form of a section not exceeding 3⁄8 in. (9.50 mm) in thickness.
[B] Temperature tolerance is ±25°F (14°C).

SUMMARY OF CHANGES

Committee A01.17 has identified the location of selected changes to this standard since the last issue, A 276 – 05a, that may impact the use of this standard. (Approved March 1, 2006.)

(*1*) Added 304L and 316L to Table 2 for condition B and condition S.

Committee A01.17 has identified the location of selected changes to this standard since the last issue, A 276 – 05, that may impact the use of this standard. (Approved Sept. 1, 2005.)

(*1*) Added UNS N08700 to Table 1 and Table 2.

Committee A01.17 has identified the location of selected changes to this standard since the last issue, A 276 – 04, that may impact the use of this standard. (Approved March 1, 2005.)

(*1*) Added S31727, S32053, and S32506 to Table 1 and Table 2.

SPECIFICATION FOR GRAY IRON CASTINGS FOR PRESSURE-CONTAINING PARTS FOR TEMPERATURES UP TO 650°F (350°C) A08

SA-278/SA-278M

(Identical with ASTM Specification A 278/A 278M-01(R06) except for an editorial change to 5.1.1 and a change to 16.1 making certification mandatory.)

1. Scope

1.1 This specification covers gray iron for castings suitable for pressure-containing parts for use at temperatures up to 650°F (350°C).

1.2 *Classes of Iron:*

1.2.1 Castings of all classes are suitable for use up to 450°F (230°C). For temperatures above 450°F and up to 650°F, only Class 40, 45, 50, 55, and 60 castings are suitable.

1.2.2 Castings of all classes are suitable for use up to 230°C. For temperatures above 230°C and up to 350°C, only Class 275, 300, 325, 350, 380, and 415 castings are suitable.

2. Referenced Documents

2.1 *ASTM Standards:*
A 644 Terminology Relating to Iron Castings
E 8 Test Methods for Tension Testing of Metallic Materials

3. Terminology

3.1 Definitions of many terms common to gray iron castings may be found in Terminology A 644.

4. Classification

4.1 Classification by tensile strength.

4.1.1 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in ksi, in English units. Class 25 has a minimum specified tensile strength of 25 ksi.

4.1.2 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in MPa, in Metric units. Class 150 has a minimum specified tensile strength of 150 MPa.

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 Specification designation and year date,

5.1.2 Class of iron required and service temperature,

5.1.3 Quantity,

5.1.4 *Heat Treatment:*

5.1.4.1 Whether or not heat treatment is required for Class 40, 45, 50, 55, and 60 castings to be used at temperatures at 450°F or less (see 6.2),

5.1.4.2 Whether or not heat treatment is required for Class 275, 300, 325, 350, 380, and 415 castings to be used at temperatures at 230°C or less (see 6.2),

5.1.5 The size of separately cast test bar to be poured (see Section 9 and Table 1),

5.1.6 The size of test specimen to be machined from test bars C or S, and

5.1.7 Special requirements.

6. Materials and Manufacture

6.1 Castings intended for use above 450°F (230°C) shall be stress-relieved by placing them in a suitable furnace at a temperature not exceeding 400°F (200°C) and heating them uniformly to the temperatures and for the times specified in Table 2. The heating and cooling rates shall be uniform and shall not be more than 400°F/h (250°C/h) for castings of 1 in. (25 mm) maximum section.

For heavier sections the maximum heating and cooling rates in degrees Fahrenheit per hour shall be 400 divided by the maximum section thickness.

6.2 *Heat Treatment and Cooling Rate:*

6.2.1 Castings of Class Nos. 45, 50, 55, and 60, which are to be used at temperatures below 450°F, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 500°F at an average rate of not more than 100°F/h for castings up to 1 in. in section. For heavier sections the maximum cooling rate in degrees Fahrenheit per hour shall be 100 divided by the maximum section thickness.

6.2.2 Castings of Class Nos. 275, 300, 325, 350, 380, and 415, which are to be used at temperatures below 230°C, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 250°C at an average rate of not more than 50°C/h for castings up to 25 mm in section. For heavier sections the maximum cooling rate in degrees Celsius per hour shall be 1250 divided by the maximum section thickness.

7. Chemical Composition

7.1 *Carbon Equivalent:*

7.1.1 Class 40, 45, 50, 55, and 60 castings intended for service above 450°F (230°C) shall have a maximum carbon equivalent of 3.8% as calculated from the equation CE = %C + 0.3 (%Si + %P). The maximum phosphorus and sulfur contents shall be 0.25% and 0.12%, respectively.

7.1.2 Class 275, 300, 325, 350, 380, and 415 castings intended for service above 230°C shall have a maximum carbon equivalent of 3.8% as calculated from the equation CE = %C + 0.3 (%Si + %P). The maximum phosphorus and sulfur contents shall be 0.25% and 0.12%, respectively.

7.2 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately $\frac{1}{32}$ in. thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

8. Tensile Requirements

8.1 Iron used in supplying castings to this specification shall conform to the tensile requirements prescribed in Table 3 and Table 4.

9. Test Bars

9.1 Separately cast test bars having the dimensions shown in Table 1 shall be poured from the same lot as the castings represented. The size of the test bar to be poured shall be selected by the purchaser using Table 5. In the event no choice is made, the selection will be made by the manufacturer.

9.2 Separately cast test bars shall be heat treated in the same furnace together with the castings represented.

9.3 At the option of the manufacturer, test coupons may be removed from the casting at a location agreed upon between the manufacturer and purchaser.

9.4 Castings weighing in excess of 2000 lb may be represented either by separately cast test bars (9.1) or by integrally cast test bars having a cooling rate closely approximating that of the controlling section of the casting.

9.5 For castings weighing in excess of 10 000 lb or having a controlling section greater than 2 in., test bars may be removed from the casting or integral projections having a cross section no less than the controlling section. The minimum tensile strength requirement for tension tests performed on either of these test bars shall be 80% of the specified class.

10. Molding and Pouring Test Bars

10.1 The test bars shall be cast in dried siliceous sand molds maintained at approximately room temperature. A suitable design for a mold is shown in Fig. 1.

11. Workmanship, Finish, and Appearance

11.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. If the pattern is supplied by the purchaser without drawings, the dimensions of the casting shall be as predicted by the pattern.

11.2 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order.

12. Sampling

12.1 A lot shall consist of one of the following:

12.1.1 All the metal poured from a single heating in a batch type melting furnace,

12.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or

12.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

12.1.3.1 The purchaser may agree to extend the 4 h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

13. Tension Test Specimens

13.1 Tension test specimens A and B in Fig. 2 shall be machined from test bars A and B in Table 1, respectively.

13.2 The purchaser shall specify whether test specimen B or C is to be machined from test bar C. If no choice is made, the manufacturer shall make the selection.

13.3 The size of the test specimen to be machined from test bar S shall be as agreed upon between the manufacturer and purchaser.

14. Number of Tests and Retests

14.1 One tension test shall be performed on each lot in accordance with Test Method E 8 and conform to the tensile requirements specified.

14.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected.

14.3 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

15. Repair

15.1 Any repairs performed on castings produced to this specification shall be agreed upon between the manufacturer and purchaser.

16. Certification

16.1 The manufacturer shall furnish his certification stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification including the year date. The certification shall also include the results of all tests performed.

16.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Inspection

17.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

18. Rejection and Rehearing

18.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

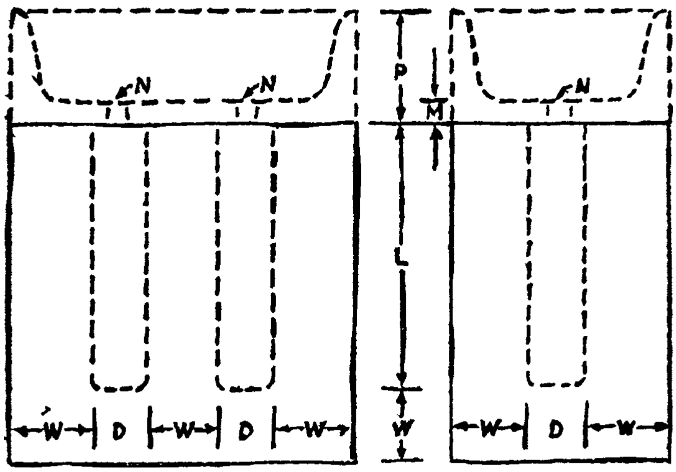
19. Product Marking

19.1 Castings shall have the name of the manufacturer, or his recognized trademark, and the class of iron to which it conforms, cast or indelibly stamped on a surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

20. Keywords

20.1 elevated temperature service; gray iron castings; pressure containing parts

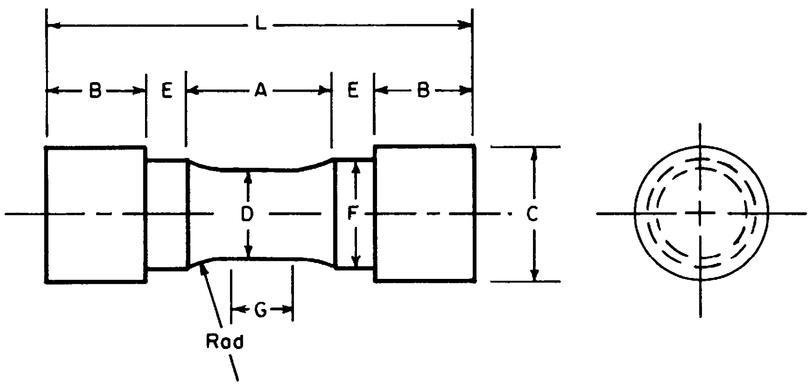
FIG. 1 SUITABLE DESIGN AND DIMENSIONS FOR MOLD FOR SEPARATELY CAST CYLINDRICAL TEST BARS FOR GRAY IRON



Number of test bars in a single mold-2 suggested.
L—see Table 1.
D—see Table 1.
W—not less than diameter, *D*.

P—2 in. (50-mm) suggested
N—5/16 in. (8-mm) in diameter, suggested
M—1.5 *N*, suggested

FIG. 2 TENSION-TEST SPECIMENS



Dimensions, in. (mm)	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50 (13)	0.75 (20)	1.25 (32)
D—Diameter	0.500 ± 0.010 (13 ± 0.25)	0.750 ± 0.015 (20 ± 0.4)	1.25 ± 0.025 (32 ± 0.5)
R—Radius of fillet, min	1 (25)	1 (25)	2 (50)
A—Length of reduced section, min	$1\frac{1}{4}$ (32)	$1\frac{1}{2}$ (38)	$2\frac{1}{4}$ (57)
L—Overall length, min	$3\frac{3}{4}$ (95)	4 (100)	$6\frac{3}{8}$ (160)
C—Diameter of end section, approximate	$\frac{7}{8}$ (22)	$1\frac{1}{4}$ (32)	$1\frac{7}{8}$ (47)
E—Length of shoulder, min	$\frac{1}{4}$ (6)	$\frac{1}{4}$ (6)	$\frac{5}{16}$ (8)
F—Diameter of shoulder	$\frac{5}{8} \pm \frac{1}{64}$ (16 ± 0.5)	$\frac{15}{16} \pm \frac{1}{64}$ (25 ± 0.5)	$1\frac{7}{16} \pm \frac{1}{64}$ (36 ± 0.5)
B—Length of end section	[A]	[A]	[A]

[A] Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

TABLE 1
DIAMETERS AND LENGTHS OF CAST TEST BARS

Test Bar	As-Cast Diameter, in. (mm) Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Length, in. (mm) Minimum (Specified)	Maximum (Recommended)
A	0.88 (23)	0.85 (22)	0.96 (25)	5.0 (125)	6.0 (150)
B	1.20 (33)	1.14 (32)	1.32 (36)	7.0 (175)	9.0 (150)
C	2.00 (54)	1.90 (53)	2.10 (58)	6.0 (150)	10.0 (255)
S[A]					

[A] All dimensions of Test Bar S shall be as agreed upon by the manufacturer and the purchaser.

TABLE 2
STRESS RELIEVING REQUIREMENTS

Class	Metal Temperature, °F (°C)	Holding Time, h[A] [B]	[B]
40, 45, 50, 55, 60 (275, 300, 325, 350, 380, 415)	1050 to 1200 (565 to 650)	2 (2 min)[B]	12 (12 max)[B]

[A] In no case shall the holding time be less than 1 h/in. of maximum metal section, or in excess of 12 h max, dependent upon which governs.
[B] In no case shall the holding time be less than 1 h/in. for every 25 mm metal section or in excess of 12 h max, depending upon which governs.

TABLE 3
TENSILE REQUIREMENTS

Class	Tensile Strength, min, ksi
No. 20	20
No. 25	25
No. 30	30
No. 35	35
No. 40	40
No. 45	45
No. 50	50
No. 55	55
No. 60	60

TABLE 4
TENSILE REQUIREMENTS (SI)

Class	Tensile Strength, min, MPa
No. 150	150
No. 175	175
No. 200	200
No. 225	225
No. 250	250
No. 275	275
No. 300	300
No. 325	325
No. 350	350
No. 380	380
No. 415	415

TABLE 5
SEPARATELY CAST TEST BARS FOR USE WHEN A SPECIFIC CORRELATION HAS NOT BEEN ESTABLISHED BETWEEN THE TEST BAR AND THE CASTING

Thickness of the Wall of the Controlling Section of the Casting, in. (mm)	Test Bar
Under 0.25 (6)	S
0.25 to 0.50 (6 to 12)	A
0.51 to 1.00 (13 to 25)	B
1.01 to 2 (25 to 50)	C
Over 2 (50)	S

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Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes[1]

This standard is issued under the fixed designation A312/A312M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers seamless, straight-seam welded, and heavily cold worked welded austenitic stainless steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades TP304, TP304L, and TP347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3, for service at temperatures as low as −425 °F [−250 °C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325 °F [−200 °C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50 °F [−45 °C].

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for service at temperatures where creep and stress rupture properties are important.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, it is permitted to specify in the order one or more of these supplementary requirements.

1.4 Table X1.1 lists the standardized dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. These dimensions are also applicable to heavily cold worked pipe. Pipe having other dimensions is permitted to be ordered and furnished provided such pipe complies with all other requirements of this specification.

1.5 Grades TP321 and TP321H have lower strength requirements for pipe manufactured by the seamless process in nominal wall thicknesses greater than ⅜ in. [9.5 mm].

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe
A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes
E112 Test Methods for Determining Average Grain Size
E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloysand is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-312 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standards:*[4]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code : Section VIII[5]

2.4 *AWS Standard:*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes[6]

2.5 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[7]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Specification A999/A999M and Terminology A941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification shall conform to the requirements of the current edition of Specification A999/A999M.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

5.2 *Heat Treatment:*

5.2.1 All pipe shall be furnished in the heat—treated condition in accordance with the requirements of Table 2. The heat—treatment procedure, except for "H" grades, S30815, S31035, S31272, S31254, S32654, N08367, N08904, N08925, and N08926 shall consist of heating the pipe to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

6. Materials and Manufacture

6.1 *Manufacture:*

6.1.1 The pipe shall be manufactured by one of the following processes:

6.1.2 *Seamless (SML) pipe* shall be made by a process that does not involve welding at any stage of production.

6.1.3 *Welded (WLD) pipe* shall be made using an automatic welding process with no addition of filler metal during the welding process.

6.1.4 *Heavily cold-worked (HCW) pipe* shall be made by applying cold working of not less than 35 % reduction in thickness of both wall and weld to a welded pipe prior to the final anneal. No filler shall be used in making the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW-51.

6.1.5 Welded pipe and HCW pipe of NPS 14 and smaller shall have a single longitudinal weld. Welded pipe and HCW pipe of a size larger than NPS 14 shall have a single longitudinal weld or shall be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections, or treatments shall be performed on each weld seam.

6.1.6 At the option of the manufacturer, pipe shall be either hot finished or cold finished.

6.1.7 The pipe shall be free of scale and contaminating exogenous iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.

6.2 *Heat Treatment*—All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2. Alternatively, for seamless pipe, immediately following hot forming while the temperature of the pipes is not less than the minimum solution treatment temperature specified in Table 2, pipes shall be individually quenched in water or rapidly cooled by other means (direct quenched).

6.3 *Grain Size:*

6.3.1 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E112, shall be No. 3 or finer.

6.3.2 The grain size of grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E112, shall be No. 6 or coarser.

6.3.3 The grain size of grades 304H, 316H, 321H, 347H, S31035, and 348H, as determined in accordance with Test Methods E112, shall be No. 7 or coarser.

6.3.4 The grain size of Grades N08810 and N08811, as determined in accordance with Test Methods E112, shall be No. 5 or coarser.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

[7] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

TABLE 1 Chemical Requirements

Grade	UNS Designation[A]	Composition, %[B]																	
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Boron	Aluminum	Other
. . .	S20400	0.030	7.0–9.0	0.045	0.030	1.00	15.0–17.0	1.50–3.00	. . .	. . .	. . .	. . .	0.15–0.30	. . .	. . .	. . .	. . .	. . .	
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .			
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .			
TPXM-11	S21904	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .			
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .			
TP201	S20100	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	. . .	. . .	. . .	. . .	0.25	. . .	. . .	. . .	. . .	. . .	
TP201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	. . .	. . .	. . .	. . .	0.10–0.25	. . .	1.00	. . .	. . .	. . .	
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .			
TP304L	S30403	0.035[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–13.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .			
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .			
. . .	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	. . .	. . .	. . .	. . .	0.12–0.18	. . .	. . .	0.03–0.08			
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–18.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .			
TP304LN	S30453	0.035	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .			
. . .	S30600	0.018	2.00	0.02	0.02	3.7–4.3	17.0–18.5	14.0–15.5	0.20	. . .	. . .	. . .	. . .	. . .	0.50 max	. . .			
. . .	S30615	0.16–0.24	2.00	0.030	0.03	3.2–4.0	17.0–19.5	13.5–16.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.80–1.50	
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08			
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	0.75	. . .	. . .	. . .	. . .	. . .		. . .			
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .				
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	. . .	10 × C min, 1.10 max	. . .	. . .	. . .		. . .			
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	. . .	10 × C min, 1.10 max	. . .	. . .	. . .					
	S31002	0.015	2.00	0.020	0.015	0.15	24.0–26.0	19.0–22.0	0.10	. . .	. . .	. . .	0.10	. . .					
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	. . .	. . .	. . .	. . .	. . .		. . .			
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .				
	S31035	0.04–0.10	0.60	0.030	0.015	0.40	21.5–23.5	23.5–26.5			0.30–0.60		0.15–0.30		2.0–3.5		0.002–0.008		W 2.0–4.0 Co 1.0–2.0

TABLE 1 *Continued*

Grade	UNS Designation[A]	Composition, %[B]																	
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Boron	Aluminum	Other
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	10 × C min, 1.10 max	...	...	...		...			
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	10 × C min, 1.10 max	...	...	...					
...	S31050	0.025	2.00	0.020	0.015	0.4	24.0–26.0	20.5–23.5	1.6–2.6	...	...	...	0.09–0.15	...	...	...			
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	...	...	...	0.18–0.22	...	0.50–1.00	...			
	S31272	0.08–012	1.5–2.00	0.030	0.015	0.25–0.75	14.0–16.0	14.0–16.0	1.00–1.40	0.30–0.60							0.004–0.008		
	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0				0.30–0.40		0.50–1.50				
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	...	...	...	...	...	...	...			
TP316L	S31603	0.035[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...	...	...	...			
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	...	...	...	...	...	...	...			
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	5× (C+N) –0.70	...	...	0.10	...	...	...	...	...	
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00				0.10–0.16	...	...	...			
TP316LN	S31653	0.035	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	...	...	...	0.10–0.16	...	...	...			
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–14.0	3.0–4.0	...	...	...	...	...	...	...			
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...	...	...	...			
...	S31725	0.03	2.00	0.040[F]	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	...	...	...	0.10	...	0.75	...			
...	S31726	0.03	2.00	0.040[F]	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	...	...	...	0.10–0.20	...	0.75	...			
...	S31727	0.03	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	...	...	...	0.15–0.21	...	2.8–4.0	...	...	...	
...	S32053	0.03	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	...	...	...	0.17–0.22	...	...	...	...	...	
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	[G]	...	...	0.10	...	...	...			
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	[H]	...	...	0.10	...	...	...			
...	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	...	...	...	...	...	1.50–2.50	...			
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	...	...	...	0.45–0.55	...	0.30–0.60	...			
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	0.60–1.00	...	...	...	...	0.05–0.10	...	0.025	
...	S34565	0.03	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	...	0.10		0.40–0.60	...	...	...	...		
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	[I]	...	...	...	...	...			
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	[J]	...	...	...	...	...			

TABLE 1 *Continued*

Grade	UNS Designation[A]	Composition, %[B]																
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Boron	Aluminum	Other
TP347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	0.20–0.50[K]	. . .	0.06–0.10	. . .	. . .	. . .	. . .	. . .	
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	[I]	0.10	. . .	. . .	. . .	. . .			
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	[J]	0.10	. . .	. . .	. . .	. . .			
. . .	S35045	0.06–0.10	1.50	. . .	0.015	1.00	25.0–29.0	32.0–37.0	. . .	0.15–0.60	. . .	. . .	. . .	. . .	0.75	. . .	. . .	0.15–0.60	
. . .	S35315	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	. . .	. . .	. . .	. . .	0.12–0.18	. . .	. . .	0.03–0.08	. . .	. . .	
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .			
. . .	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	. . .	. . .	. . .	. . .	. . .	0.75–1.50	. . .	. . .	0.30	
. . .	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	. . .	. . .	. . .	0.18–0.25	. . .	0.75	. . .	. . .	. . .	
800	N08800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	. . .	. . .	. . .	. . .	0.75	. . .	. . .	0.15–0.60	Fe[L] 39.5 min.
800H	N08810	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	0.15–0.60	. . .	. . .	. . .	. . .	0.75	. . .	. . .	0.15–0.60	Fe[L] 39.5 min.
	N08811	0.06–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	0.15–0.60[M]	. . .	. . .	. . .	. . .	0.75	. . .	. . .	0.15–0.60[M]	Fe[L] 39.5 min.
. . .	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	. . .	. . .	. . .	0.10	. . .	1.00–2.00	. . .	. . .	. . .	
. . .	N08925	0.020	1.00	0.045	0.030	0.50	19.0–21.0	24.0–26.0	6.0–7.0	. . .	. . .	. . .	0.10–0.20	. . .	0.80–1.50	. . .	. . .	. . .	
. . .	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	. . .	. . .	. . .	0.15–0.25	. . .	0.50–1.50	. . .	. . .	. . .	

[A] New designation established in accordance with Practice E527 and SAE J1086.
[B] Maximum, unless otherwise indicated. Where elipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.20 mm] in average wall thickness (0.044 in. [1.10 mm] in minimum wall thickness).
[E] For welded TP316, TP316N, TP316LN, and TP316H pipe, the nickel range shall be 10.0–14.0 %.
[F] For welded pipe, the phosphorus maximum shall be 0.045 %.
[G] Ti 5 × (C+N) min, 0.70 max.
[H] Ti 4 × (C+N) min, 0.60 max.
[I] The columbium content shall be not less than ten times the carbon content and not more than 1.00 %.
[J] The columbium content shall be not less than eight times the carbon content and not more than 1.0 %.
[K] Grade S34751 shall have a columbium (niobium) content of not less than 15 times the carbon content.
[L] Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.
[M] (Al + Ti) 0.85 – 1.20.

TABLE 2 Annealing Requirements

Grade or UNS Designation[A]	Heat Treating Temperature[B]	Cooling/Testing Requirements
All grades not individually listed below:	1900 °F [1040 °C]	C
TP321H, TP347H, TP348H		
Cold finished	2000 °F [1100 °C]	D
Hot finished	1925 °F [1050 °C]	D
TP304H, TP316H		
Cold finished	1900 °F [1040 °C]	D
Hot finished	1900 °F [1040 °C]	D
TP309H, TP309HCb, TP310H, TP310HCb	1900 °F [1040 °C]	D
S30600	2010–2140 °F [1100–1170 °C]	D
S30815, S31272	1920 °F [1050 °C]	D
S31035	2160–2280 °F [1180–1250 °C]	D
S31254, S32654	2100 °F [1150 °C]	D
S31277	2050 °F [1120 °C]	D
S31727, S32053	1975–2155 °F [1080–1180 °C]	D
S33228	2050–2160 °F [1120–1180 °C]	D
S34565	2050–2140 °F [1120–1170 °C]	D
S35315	2010 °F [1100 °C]	D
S38815	1950 °F [1065 °C]	D
N08367	2025 °F [1110 °C]	D
N08810	2050 °F [1120 °C]	D
N08811	2100 °F [1150 °C]	D
N08904	2000 °F [1100 °C]	D
N08925, N08926	2010–2100 °F [1100–1150 °C]	D

[A] New designation established in accordance with Practice E527 and SAE J1086.
[B] Minimum, unless otherwise stated.
[C] Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of pipes, heat treated by either separate solution annealing or by direct quenching, of passing Practices A262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.
[D] Quenched in water or rapidly cooled by other means.

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Permitted Variations in Wall Thickness

9.1 In addition to the implicit limitation of wall thickness for seamless pipe imposed by the limitation on weight in Specification A999/A999M, the wall thickness for seamless and welded pipe at any point shall be within the tolerances specified in Table 3, except that for welded pipe the weld area shall not be limited by the "Over" tolerance. The wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS and schedule number is shown in Table X1.1.

TABLE 3 Permitted Variations in Wall Thickness

	Tolerance, % from Nominal	
NPS Designator	Over	Under
⅛ to 2½ incl., all t/D ratios	20.0	12.5
3 to 18 incl., t/D up to 5 % incl.	22.5	12.5
3 to 18 incl., t/D > 5 %	15.0	12.5
20 and larger, welded, all t/D ratios	17.5	12.5
20 and larger, seamless, t/D up to 5 % incl.	22.5	12.5
20 and larger, seamless, t/D > 5 %	15.0	12.5

where:

t = Nominal Wall Thickness
D = Ordered Outside Diameter

10. Tensile Requirements

10.1 The tensile properties of the material shall conform to the requirements prescribed in Table 4.

11. Mechanical Tests, Grain Size Determinations, and Weld Decay Tests Required

11.1 *Mechanical Testing Lot Definition*— The term *lot* for mechanical tests shall be as follows:

11.1.1 Where the final heat treated condition is obtained, consistent with the requirements of 6.2, in a continuous furnace, by quenching after hot forming or in a batch-type furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, the term *lot* for mechanical tests shall apply to all pipes of the same specified outside diameter and specified wall thickness (or schedule) that are produced from the same heat of steel and subjected to the same finishing treatment within the same operating period.

11.1.2 Where the final heat treated condition is obtained, consistent with the requirements of 6.2, in a batch-type furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, the term *lot* shall apply to the larger of: (a) each 200 ft [60 m] or fraction thereof and (b) those pipes heat treated in the same furnace batch charge for pipes of the same specified outside diameter and specified wall thickness (or schedule) that are produced from the same heat of steel and are subjected to the same finishing temperature within the same operating period.

11.2 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

11.3 *Flattening Test*—For material heat treated in a continuous furnace, by quenching after hot forming or in a batch-type furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, flattening tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 lengths of pipe. For material heat treated in a batch-type furnace not equipped with recording pyrometers and automatically controlled within a 50

TABLE 4 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
. . .	S20400	95 [635]	48 [330]
TPXM-19	S20910	100 [690]	55 [380]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21904	90 [620]	50 [345]
TPXM-29	S24000	100 [690]	55 [380]
TP201	S20100	75 [515]	38 [260]
TP201LN	S20153	95 [655]	45 [310]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP304H	S30409	75 [515]	30 [205]
. . .	S30415	87 [600]	42 [290]
TP304N	S30451	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
. . .	S30600	78 [540]	35 [240]
. . .	S30615	90 [620]	40 [275]
. . .	S30815	87 [600]	45 [310]
TP309S	S30908	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
. . .	S31002	73 [500]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
	S31035	95 [655]	45 [310]
TP310Cb	S31040	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
. . .	S31050:		
t ≤ 0.25 in.		84 [580]	39 [270]
t > 0.25 in.		78 [540]	37 [255]
. . .	S31254:		
t ≤ 0.187 in. [5.00 mm]		98 [675]	45 [310]
t > 0.187 in. [5.00 mm]		95 [655]	45 [310]
. . .	S31272	65 [450]	29 [200]
. . .	S31277	112 [770]	52 [360]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP316H	S31609	75 [515]	30 [205]
. . .	S31635	75 [515]	30 [205]
TP316N	S31651	80 [550]	35 [240]
TP316LN	S31653	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
. . .	S31725	75 [515]	30 [205]
. . .	S31726	80 [550]	35 [240]
. . .	S31727	80 [550]	36 [245]
. . .	S32053	93 [640]	43 [295]
TP321	S32100:		
Welded		75 [515]	30 [205]
Seamless:			
≤ ⅜ in.		75 [515]	30 [205]
> ⅜ in.		70 [485]	25 [170]
TP321H	S32109:		
Welded		75 [515]	30 [205]
Seamless:			
≤ ⅜ in.		75 [515]	30 [205]
> ⅜ in.		70 [480]	25 [170]
. . .	S32615	80 [550]	32 [220]
. . .	S32654	109 [750]	62 [430]
. . .	S33228	73 [500]	27 [185]
. . .	S34565	115 [795]	60 [415]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP347LN	S34751	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
. . .	S35045	70 [485]	25 [170]
. . .	S35315		
Welded		94 [650]	39 [270]
Seamless		87 [600]	38 [260]
TPXM-15	S38100	75 [515]	30 [205]
. . .	S38815	78 [540]	37 [255]
. . .	N08367:		
t ≤ 0.187		100 [690]	45 [310]

TABLE 4 *Continued*

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
t > 0.187		95 [655]	45 [310]
800	N08800		
	cold-worked annealed	75 [515]	30 [205]
	hot finished annealed	65 [450]	25 [170]
800H	N08810	65 [450]	25 [170]
	N08811	65 [450]	25 [170]
. . .	N08904	71 [490]	31 [215]
. . .	N08925	87 [600]	43 [295]
. . .	N08926	94 [650]	43 [295]
Elongation in 2 in. or 50 mm (or 4*D*), min, %:		Longi-tudinal	Trans-verse
All Grades except S31050 and S32615		35	25
S32615, S31050		25	. . .
S31277, N08925		40	. . .
N08367 , N08800, N08810, N08811		30	. . .

°F [30 °C] or lesser range, flattening tests shall be made on 5 % of the pipe from each heat treated lot.

11.3.1 For welded pipe a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A370. For welded pipe with a specified wall thickness over ⅜ in., two side bend tests may be made instead of the face bend test. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

11.4 *Grain Size*—Grain size determinations on Grades TP309H, TP 309HCb, TP310H, TP310HCb, UNS S31035, UNS S32615, N08810, and N08811 shall be made on each heat treatment lot, as defined in 11.1, for the same number of pipes as prescribed for the flattening test in 11.3.

11.5 HCW pipe shall be capable of passing the weld decay tests listed in Supplementary S9 with a weld metal to base metal loss ratio of 0.90 to 1.1. The test is not required to be performed unless S9 is specified in the purchase order.

12. Hydrostatic or Nondestructive Electric Test

12.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

12.2 The hydrostatic test shall be in accordance with Specification A999/A999M, unless specifically exempted under the provisions of 12.3.

12.3 For pipe whose dimensions equal or exceed NPS10, the purchaser, with the agreement of the manufacturer, is permitted to waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH."

12.4 The nondestructive electric test shall be in accordance with Specification A999/A999M.

13. Lengths

13.1 Pipe lengths shall be in accordance with the following regular practice:

13.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft with the permitted range of 15 to 24 ft. Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

13.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and no pipe shall be more than ¼ in. [6 mm] over the specified length.

13.1.3 No jointers are permitted unless otherwise specified.

14. Workmanship, Finish, and Appearance

14.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Removal of imperfections by grinding is permitted, provided the wall thicknesses are not decreased to less than that permitted in Section 9 of Specification A999/A999M.

15. Repair by Welding

15.1 For welded pipe whose diameter equals or exceeds NPS 6, and whose nominal wall thickness equals or exceeds 0.200, it is permitted to make weld repairs to the weld seam with the addition of compatible filler metal using the same procedures specified for plate defects in the section on Repair by Welding of Specification A999/A999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filler rod qualified to the most current AWS Specification A5.9 as the grade of stainless steel pipe being repaired and as shown in Table 5. Alternatively, subject to approval by the purchaser, weld repairs shall be made only with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties.

15.4 Pipes that have had weld seam repairs with filler metal shall be uniquely identified and shall be so stated and identified on the certificate of tests. When filler metal other than that listed in Table 5 is used, the filler metal shall be identified on the certificate of tests.

16. Certification

16.1 In addition to the information required by Specification A999/A999M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall state which standard practice was followed and what reference discontinuities were used.

TABLE 5 Pipe and Filler Metal Specification

Pipe Grade	UNS Designation	Filler Metal AWS A5.9 Class	UNS Designation
TP201	S20100	. . .	. . . . . .
TP201LN	S20153	. . .	. . . . . .
TP304	S30400	ER308	S30800, W30840
TP304L	S30403	ER308L	S30883, W30843
TP304N	S30451	ER308	S30880, W30840
TP304LN	S30453	ER308L	S30883, W30843
TP304H	S30409	ER308	S30880, W30840
TP309Cb	S30940	. . .	. . . . . .
TP309S	S30908	. . .	. . . . . .
TP310Cb	S31040	. . .	. . . . . .
TP310S	S31008	. . .	. . . . . .
	S31272	. . .	. . . . . .
TP316	S31600	ER316	S31680, W31640
TP316L	S31603	ER316L	S31683, W31643
TP316N	S31651	ER316	S31680, W31640
TP316LN	S31653	ER316L	S31683, W31643
TP316H	S31609	ER316H	S31680, W31640
TP321	S32100	ER321	S32180, W32140
		ER347	S34780, W34740
TP347	S34700	ER347	S34780, W34740
TP348	S34800	ER347	S34780, W34740
TPXM-19	S22100	ER209	S20980, W32240
TPXM-29	S28300	ER240	S23980, W32440
. . .	N08367	. . .	N06625
. . .	S20400	ER209	S20980, W32240
800	N08800	ERNiCr-3[A]	N06082
800H	N08810	ERNiCr-3[A]	N06082
	N08811	ERNiCr-3[A]	N06082
. . .	N08925	. . .	N06625
. . .	N08926	. . .	N06625

[A] AWS A5.14 Class.

17. Marking

17.1 In addition to the marking specified in Specification A999/A999M, the marking shall include the NPS (nominal pipe size) or outside diameter and schedule number or average wall thickness, heat number, and NH when hydrotesting is not performed and ET when eddy-current testing is performed or UT when ultrasonic testing is performed. The marking shall also include the manufacturer's private identifying mark, the marking requirement of 12.3, if applicable, and whether seamless (SML), welded (WLD), or heavily cold-worked (HCW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

18. Government Procurement

18.1 *Scale Free Pipe for Government Procurement:*

18.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

18.1.2 The requirements of Specification A999/A999M for pipe and Specification A1016/A1016M for tubes shall be applicable when pipe or tube is ordered to this specification.

18.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
TP304	S30400
TP304L	S30403
TP304N	S30451
TP316	S31600
TP316L	S31603
TP316N	S31651
TP317	S31700
TP317L	S31703
TP321	S32100
TP347	S34700

18.1.4 *Part Number:*

Example: ASTM A312/A312MPipe 304 NPS 12 SCH 40S SMLS

Specification Number	ASTM A312
Pipe	P
Grade	304
NPS	12
Wall	0.375
SMLS OR WELDED	SML

18.1.4.1

Specification Number	ASTM A312
Tube	T
Grade	304
Outside Diameter	0.250
Wall	0.035
SMLS OR WELDED	WLD

18.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 4:

18.1.5.1 Pipe or tube,

18.1.5.2 Part number,

18.1.5.3 Ultrasonic inspection, if required,

18.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions,

18.1.5.5 Intergranular corrosion test, and

18.1.5.6 Level of preservation and packing required.

19. Keywords

19.1 austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This requirement is applicable only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 The entire length of weld in each double welded pipe shall be radiographically examined, using X-radiation, in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 13 each pipe shall be marked

"RT" after the specification and grade. Requirements of S5 shall be required in the certification.

S6. Stabilizing Heat Treatment

S6.1 Subsequent to the solution anneal required in 6.2, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be as agreed upon between the purchaser and vendor.

S7. Intergranular Corrosion Test

S7.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

S7.1.1 Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades. The applicability of this test and the preparation of the sample for testing for grades containing greater than 3 % molybdenum shall be as agreed by the purchaser and manufacturer.

NOTE S7.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S7.2 A stabilization heat treatment in accordance with Supplementary Requirement S6 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S8. Minimum Wall Pipe

S8.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 17, the pipe shall be marked S8.

S9. Weld Decay Test

S9.1 When specified in the purchase order, one sample from each lot of pipe shall be subject to testing in a boiling solution of 50 % reagent grade hydrochloric acid and 50 % water.

S9.2 The sample, of approximately 2–in. [50–mm] length, shall be prepared from a production length of pipe. Depending on the size of the pipe, it is permitted to section the sample longitudinally to allow it to fit in the Erlenmeyer flask. As a minimum, the tested sample shall include the entire weld and adjacent area and the full length of base metal 180° across from the weld. All burrs and sharp edges shall be removed by light grinding. Dust and grease shall be removed by cleaning with soap and water or other suitable solvents.

S9.3 The hydrochloric acid solution shall be prepared by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water.

Warning—Protect eyes and use rubber gloves when handling acid. Mixing and testing shall be performed in a protective enclosure.

S9.4 The test container shall be a 1–L Erlenmeyer flask equipped with ground-glass joints and an Ahline condenser. The volume of the solution shall be approximately 700 mL.

S9.5 The thickness of the weld and the base metal 180° from the weld shall be measured near both ends of the sample. These measurements shall be made with a micrometer with an anvil shape suitable for measuring the thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.6 The sample sections, both weld and base metal, shall be immersed in the flask containing the solution. Boiling chips shall be added and the solution brought to a boil. Boiling shall be maintained through the duration of the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base metal thickness (usually 2 h or less) If more than 60 % of the base metal thickness remains, it is permitted to terminate the test after 24 h.

S9.7 At the end of the test period, the samples shall be removed from the solution, rinsed with distilled water, and dried.

S9.8 The thickness measurements as in S9.5 shall be repeated. The anvil shape of the micrometer used shall be suitable for measuring the minimum remaining thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.9 The corrosion ratio, R, shall be calculated as follows:

$$R = (W_0 - W)/(B_0 - B)$$

where:

W_0 = average weld-metal thickness before the test,
W = average weld-metal thickness after the test,
B_0 = average base-metal thickness before the test, and
B = average base-metal thickness after the test,

S9.9.1 The corrosion ratio for HCW pipe shall be as specified in 11.5.

S9.9.2 The corrosion ratio shall be 1.25 or less, or as further restricted in the purchase order, when the weld decay test is specified for welded (WLD) pipe.

APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

X1.1 Table X1.1 is based on Table number 1 of the American National Standard for stainless steel pipe (ANSI B36.19).

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
	in.	mm	Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10–1979).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A312/A312M-12, that may impact the use of this specification. (Approved September 1, 2012)

(*1*) Revised formulas in footnotes G and H of Table 1 to include Nitrogen.

Committee A01 has identified the location of selected changes to this specification since the last issue, A312/A312M-11, that may impact the use of this specification. (Approved April 1, 2012)

(*1*) Revised wall thickness transition values for TP321H seamless pipe in Table 4 to ⅜ from 3⁄16 .

Committee A01 has identified the location of selected changes to this specification since the last issue, A312/A312M-09, that may impact the use of this specification. (Approved April 1, 2011)

(*1*) Added UNS N08800 to Table 1, Table 4, and Table 5. Added Footnote L to Table 1 and Footnote A to Table 5.
(*2*) Added UNS N08810 to new 6.3.4, 11.4, Table 1, Table 2, Table 4, and Table 5.
(*3*) Added UNS N08811 to new 6.3.4, 11.4, Table 1, Table 2, Table 4, and Table 5.
(*4*) Deleted Note F from Cb content for Grade TP347LN, S34751 in Table 1.
(*5*) Deleted reference to Ta from Footnote K of Table 1.
(*6*) Added optional side bend tests in lieu of face bend test for wall thickness over ⅜ in. in 11.3.1.

Designation: A351/A351M – 12b

Standard Specification for Castings, Austenitic, for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A351/A351M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers austenitic steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1).

NOTE 1—Carbon steel castings for pressure-containing parts are covered by Specification A216/A216M, low-alloy steel castings by Specification A217/A217M, and duplex stainless steel castings by Specification A995/A995M.

1.2 A number of grades of austenitic steel castings are included in this specification. Since these grades possess varying degrees of suitability for service at high temperatures or in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and high-temperature or corrosion-resistant characteristics, or both.

1.2.1 Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800°F [425°C].

1.3 Supplementary requirements of an optional nature are provided for use at the option of the purchaser. The Supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4.1 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable M specification designation (SI units), the inch-pound units shall apply. Within the text, the SI units are shown in brackets or parentheses.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A216/A216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
A217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
A985/A985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts
A995/A995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
E165 Practice for Liquid Penetrant Examination for General Industry
E709 Guide for Magnetic Particle Testing

2.2 *Manufacturers Standardization Society of the Valve and Fittings Industry Standard:*[4]

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Components (Visual Method)

3. General Conditions for Delivery

3.1 Other than investment castings – Material furnished to this specification shall conform to the requirements of Specification A703/A703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A703/A703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A703/A703M, this specification shall prevail.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Nov. 1, 2012. Published November 2012. Originally approved in 1952. Last previous edition approved in 2012 as A351/A351M – 12a. DOI: 10.1520/A0351_A0351M-12B.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-351/SA-351M in Section II of that code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

*A Summary of Changes section appears at the end of this standard

3.2 Investment Castings – Material furnished to this specification shall conform to the requirements of Specification A985/A985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A985/A985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A985/A985M, Specification A985/A985M shall prevail.

3.3 The post weld heat treatment requirements of Supplementary Requirement S11 may be specified when austenitic castings other than HK, HT, or CT15C are to be subjected to severe corrosive service.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 All castings shall receive a heat treatment at the temperature specified in Table 1, followed by a quench in water or rapid cool by other means except as noted.

NOTE 2—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature, and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

TABLE 1 Heat-Treatment Requirements

Grade	Temperature, min	
	°F	°C
HK30, HK40, HT30, CT15C	as-cast	as-cast
CF3, CF3A, CF8, CF8A, CF3M, CF3MA, CF8M, CF3MN, CG3M, CF10, CF10M, CG8M	1900	1040
CF10SMnN, CF8C, CF10MC	1950	1065
CN7M, CG6MMN	2050	1120
CK3MCuN, CN3MN, CH8, CH10, CH20, CK20	2100	1150
CE20N[A]	2225	1220

[A] Grade shall be quenched in water or the castings may be furnace cooled to 2050°F [1120°C] minimum, held for 15 min minimum and then quenched in water or rapidly cooled by other means.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

8. Tensile Properties

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A488/A488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S6 specified, weld repairs shall be inspected by liquid penetrant examination to the same standards that are used to inspect the castings.

NOTE 3—When austenitic steel castings are to be used in services where they will be subject to stress corrosion, the purchaser should so indicate in his order and such castings should be solution-heat treated following all weld repairs.

11. Keywords

11.1 austenitic stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 2 Chemical Requirements

Note 1—CE8MN, CD4MCu and CD3MWCuN have been deleted from this specification and added to Specification A995/A995M. They may now be supplied and purchased in compliance with Specification A995/A995M as grades 2A, 1B and 6A respectively.

Element, % (max, except where range is given)	CF3, CF3A J92700	CF8, CF8A J92600	CF3M, CF3MA J92800	CF8M J92900	CF3MN J92804	CF8C J92710	CF10 J92950	CF10M J92901	CH8 J93400	CH10 J93401	CH20 J93402	CK20 J94202	HK30 J94203	HK40 J94204
Carbon	0.03	0.08	0.03	0.08	0.03	0.08	0.04–0.10	0.04–0.10	0.08	0.04–0.10	0.04–0.20	0.04–0.20	0.25–0.35	0.35–0.45
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Silicon	2.00	2.00	1.50	1.50	1.50	2.00	2.00	1.50	1.50	2.00	2.00	1.75	1.75	1.75
Sulfur	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Phosphorus	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Chromium	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	18.0–21.0	18.0–21.0	22.0–26.0	22.0–26.0	22.0–26.0	23.0–27.0	23.0–27.0	23.0–27.0
Nickel	8.0–12.0	8.0–11.0	9.0–13.0	9.0–12.0	9.0–13.0	9.0–12.0	8.0–11.0	9.0–12.0	12.0–15.0	12.0–15.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0
Molybdenum	0.50	0.50	2.0–3.0	2.0–3.0	2.0–3.0	0.50	0.50	2.0–3.0	0.50	0.50	0.50	0.50	0.50	0.50
Columbium (niobium)	...	...	...	...	...	[A]	...	...	...	...	...	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nitrogen	...	...	...	...	0.10–0.20	...	...	...	...	...	...	...	...	...
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Element, % (max, except where range is given)	HT30 N08030	CF10MC	CN7M N08007	CN3MN J94651	CG-6MMN J93790	CG8M J93000	CF10S-MnN J92972	CT15C N08151	CK-3MCuN J93254	CE20N J92802	CG3M J92999
Carbon	0.25–0.35	0.10	0.07	0.03 max	0.06	0.08	0.10	0.05–0.15	0.025	0.20	0.03
Manganese	2.00	1.50	1.50	2.00 max	4.00–6.00	1.50	7.00–9.00	0.15–1.50	1.20	1.50	1.50
Silicon	2.50	1.50	1.50	1.00 max	1.00	1.50	3.50–4.50	0.50–1.50	1.00	1.50	1.50
Sulfur	0.040	0.040	0.040	0.010 max	0.030	0.04	0.030	0.03	0.010	0.040	0.04
Phosphorus	0.040	0.040	0.040	0.040 max	0.040	0.04	0.060	0.03	0.045	0.040	0.04
Chromium	13.0–17.0	15.0–18.0	19.0–22.0	20.0–22.0	20.50–23.50	18.0–21.0	16.0–18.0	19.0–21.0	19.5–20.5	23.0–26.0	18.0–21.0
Nickel	33.0–37.0	13.0–16.0	27.5–30.5	23.5–25.5	11.50–13.50	9.0–13.0	8.0–9.0	31.0–34.0	17.5–19.5	8.0–11.0	9.0–13.0
Molybdenum	0.50	1.75–2.25	2.0–3.0	6.0–7.0	1.50–3.00	3.0–4.0	...	...	6.0–7.0	0.50	3.0–4.0
Columbium (niobium)	...	[B]	...	...	0.10–0.30	...	...	0.50–1.50	...	...	...
Vanadium	...	...	...	...	0.10–0.30	...	...	...	...	...	...
Nitrogen	...	...	...	0.18–0.26	0.20–0.40	...	0.08–0.18	...	0.18–0.24	0.08–0.20	...
Copper	...	...	3.0–4.0	0.75 max	...	...	...	...	0.50–1.00	...	...

[A] Grade CF8C shall have a columbium content of not less than 8 times the carbon content but not over 1.00 %.
[B] Grade CF10MC shall have a columbium content of not less than 10 times the carbon content but not over 1.20 %.

TABLE 3 Tensile Requirements

	CF3 J92700	CF3A J92700	CF8 J92600	CF8A J92600	CF3M J92800	CF-3MA J92800	CF8M J92900	CF-3MN J92804	CF8C J92710	CF10 J92950	CF10M J92901	CH8 J93400	CH10 J93401	CH20 J93402	CK20 J94202	HK30 J94203	HK40 J94204
Tensile strength, min, ksi [MPa]	70 [485]	77 [530]	70 [485]	77 [530]	70 [485]	80 [550]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	70 [485]	65 [450]	65 [450]	62 [425]
Yield strength,[A] min, ksi [MPa]	30 [205]	35 [240]	30 [205]	35 [240]	30 [205]	37 [255]	30 [205]	37 [255]	30 [205]	30 [205]	30 [205]	28 [195]	30 [205]	30 [205]	28 [195]	35 [240]	35 [240]
Elongation in 2 in. or 50 mm,[B] min, %	35.0	35.0	35.0	35.0	30.0	30.0	30.0	35.0	30.0	35.0	30.0	30.0	30.0	30.0	30.0	10.0	10.0

	HT30 N08030	CF-10MC	CN7M N08007	CN-3MN J94651	CG 6MMN J93790	CG8M J93000	CF10S-MnN J92972	CT15C N08151	CK-3MCuN J93254	CE20N J92802	CG3M J92999
Tensile strength, min, ksi [MPa]	65 [450]	70 [485]	62 [425]	80 [550]	85 [585]	75 [515]	85 [585]	63 [435]	80 [550]	80 [550]	75 [515]
Yield strength,[A] min, ksi [MPa]	28 [195]	30 [205]	25 [170]	38 [260]	42.5 [295]	35 [240]	42.5 [295]	25 [170]	38 [260]	40 [275]	35 [240]
Elongation in 2 in. or 50 mm,[B] min, %	15.0	20.0	35.0	35	30.0	25.0	30.0	20.0	35	30.0	25

[A] Determine by the 0.2 % offset method.

[B] When ICI test bars are used in tensile testing as provided for in Specification A985/A985M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specifications A703/A703M and A985/A985M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specifications A703/A703M and A985/A985M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Destruction Tests

S5. Radiographic Inspection

S6. Liquid Penetrant Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E165 or Practice E709.

S11. Post Weld Heat Treatment

S11.1 All austenitic castings, except Grades HK, HT, and CT15C, which have been subjected to weld repairs, shall be given a post-weld solution heat treatment.

S33. Stabilization Heat Treatment of CF8C

S33.1 CF8C shall be stabilized at 1600-1650°F (870-900°C) for a minimum time of 1 h/in. (25 mm) of thickness and water quenched or rapidly cooled by other means. The grade designation symbol shall be followed by the symbol "S33."

S34. Stabilization Heat Treatment of CF10MC

S34.1 CF10MC shall be stabilized at 1600-1650°F (870-900°C) for a minimum time of 1 h/in. (25 mm) of thickness and water quenched or rapidly cooled by other means. The grade designation symbol shall be followed by the symbol "S34."

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A351/A351M – 12a) that may impact the use of this standard. (Approved Nov. 1, 2012.)

(1) Deleted former paragraph 1.2.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A351/A351M – 12) that may impact the use of this standard. (Approved Sept. 1, 2012.)

(1) Removed grade CE8MN from Table 1, Table 2 and Table 3.

Committee A01 has identified the location of selected changes to this standard since the last issue (A351/A351M – 10) that may impact the use of this standard. (Approved March 1, 2012.)

(1) New supplementary requirement S34 for stabilization heat treatment of CF10MC.

SPECIFICATION FOR STEEL CASTINGS SUITABLE FOR PRESSURE SERVICE

SA-487/SA-487M

(Identical with ASTM Specification A 487/A 487M-93.) 98

1. Scope

1.1 This specification covers low-alloy steels and martensitic stainless steels in the normalized and tempered, or quenched and tempered, condition suitable for pressure-containing parts. The weldability of the classes in this specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

1.2 Selection will depend on design, mechanical, and service conditions. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtained.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 487 and SI units for material ordered to Specification A 487M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
E 165 Practice for Liquid Penetrant Method
E 709 Practice for Magnetic Particle Examination

2.2 *American Society of Mechanical Engineers:*
ASME Boiler and Pressure Vessel Code, Section IX

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*
SP-55 Quality Standard for Steel Castings — Visual Method

3. General Conditions for Delivery

3.1 Material furnished to this specification shall con- 98
form to the applicable requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 ASTM designation and year of issue,

4.1.3 Grade and class of steel,

4.1.4 Options in the specification, and

4.1.5 The supplementary requirements desired including the standard of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in Table 1. Preliminary heat treatment prior to final heat treatment as well as multiple tempering is permitted.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by use of recording-type pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2. Product analysis tolerance shall conform to the product analysis tolerance shown in Specification A 703/A 703M. Product analysis tolerances for stainless grades are not presently applicable pending development of these limits.

7. Tensile Requirements

7.1 Tensile properties of steel used for the castings shall conform to the requirements prescribed in Table 3.

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal and repair of discontinuities, the casting shall be preheated to at least the minimum temperature in Table 4.

8.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair By Welding

9.1 For castings, other than those intended for use under ASME Boiler and Pressure Vessel Code, repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

9.2 On castings intended for use under the ASME Boiler and Pressure Vessel Code, repairs shall be made by procedures and welders qualified under Section IX of that code.

9.3 After repair welding, all castings shall be postweld heat treated in accordance with Table 4 or reheat treated in accordance with Table 1.

9.4 Weld repairs shall be inspected using the same quality standards as are used to inspect the castings. Re-examination of the weld repair by radiography when Supplementary Requirement S5 has been specified will not be necessary when an applicable surface inspection method was used to locate the discontinuity except for the following:

9.4.1 Weld repairs on castings which have leaked on hydrostatic test.

9.4.2 Weld repairs on castings in which the depth of any cavity prepared for repair welding is more than 20% of the wall thickness or 1 in. [25 mm], whichever is smaller.

9.4.3 Weld repairs on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2].

10. Product Marking

10.1 Castings shall be marked for material identification with the grade and class symbols (1-A, 4-C, CA15-A).

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TABLE 1
HEAT TREAT REQUIREMENT

Grade	Class	Austenitizing Temperature, min, °F [°C]	Media^A	Quenching Cool Below °F[°C]	Tempering Temperature, °F [°C]^B
1	A	1600 [870]	A	450 [230]	1100 [595]
1	B	1600 [870]	L	500 [260]	1100 [595]
1	C	1600 [870]	A or L	500 [260]	1150 [620]
2	A	1600 [870]	A	450 [230]	1100 [595]
2	B	1600 [870]	L	500 [260]	1100 [595]
2	C	1600 [870]	A or L	500 [260]	1150 [620]
4	A	1600 [870]	A or L	500 [260]	1100 [595]
4	B	1600 [870]	L	500 [260]	1100 [595]
4	C	1600 [870]	A or L	500 [260]	1150 [620]
4	D	1600 [870]	L	500 [260]	1150 [620]
4	E	1600 [870]	L	500 [260]	1100 [595]
6	A	1550 [845]	A	500 [260]	1100 [595]
6	B	1550 [845]	L	500 [260]	1100 [595]
7	A	1650 [900]	L	600 [315]	1100 [595]
8	A	1750 [955]	A	500 [260]	1250 [675]
8	B	1750 [955]	L	500 [260]	1250 [675]
8	C	1750 [955]	L	500 [260]	1250 [675]
9	A	1600 [870]	A or L	500 [260]	1100 [595]
9	B	1600 [870]	L	500 [260]	1100 [595]
9	C	1600 [870]	A or L	500 [260]	1150 [620]
9	D	1600 [870]	L	500 [260]	1150 [620]
9	E	1600 [870]	L	500 [260]	1100 [595]
10	A	1550 [845]	A	500 [260]	1100 [595]
10	B	1550 [845]	L	500 [260]	1100 [595]
11	A	1650 [900]	A	600 [315]	1100 [595]
11	B	1650 [900]	L	600 [315]	1100 [595]
12	A	1750 [955]	A	600 [315]	1100 [595]
12	B	1750 [955]	L	400 [205]	1100 [595]
13	A	1550 [845]	A	500 [260]	1100 [595]
13	B	1550 [845]	L	500 [260]	1100 [595]
14	A	1550 [845]	L	500 [260]	1100 [595]
16	A	1600 [870]^C	A	600 [315]	1100 [595]
CA15	A	1750 [955]	A or L	400 [205]	900 [480]
CA15	B	1750 [955]	A or L	400 [205]	1100 [595]
CA15	C	1750 [955]	A or L	400 [205]	1150 [620]^{D,E}
CA15	D	1750 [955]	A or L	400 [205]	1150 [260]^{D,E}
CA15M	A	1750 [955]	A or L	400 [205]	1100 [595]
CA6NM	A	1850 [1010]	A or L	200 [95]	1050–1150 [565–620]
CA6NM	B	1850 [1010]	A or L	200 [95]	1225–1275 [665–690]^{E,F} 1050–1150 [565–620]^G

^{A} A = air, L = Liquid.
^{B} Minimum temperature unless range is specified.
^{C} Double austenitize.
^{D} Double temper with the final temper at a lower temperature than the intermediate temper.
^{E} Air cool to below 200°F [95°C] after first temper.
^{F} Intermediate.
^{G} Final.

TABLE 2
CHEMICAL REQUIREMENTS (MAXIMUM PERCENT UNLESS RANGE IS GIVEN)

Grade	1.	2.	4.	6.	7.	8.	9.	10.	11.	12.
Class Type	ABC Vanadium	ABC Manganese-Molybdenum	ABCDE Nickel-Chromium-Molybdenum	AB Manganese Nickel-Chromium-Molybdenum	A Nickel-Chromium-Molybdenum-Vanadium[A]	ABC Chromium-Molybdenum	ABCDE Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum
Carbon	0.30	0.30	0.30	0.05–0.38	0.05–0.20	0.05–0.20	0.05–0.33	0.30	0.05–0.20	0.05–0.20
Manganese	1.00	1.00–1.40	1.00	1.30–1.70	0.60–1.00	0.50–0.90	0.60–1.00	0.60 to 1.00	0.50–0.80	0.40–0.70
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.60
Nickel	. . .	. . .	0.40–0.80	0.40–0.80	0.70–1.00	. . .	. . .	1.40–2.00	0.70–1.10	0.60–1.00
Chromium	. . .	. . .	0.40–0.80	0.40–0.80	0.04–0.80	2.00–2.75	0.75–1.10	0.55–0.90	0.50–0.80	0.50–0.90
Molybdenum	. . .	0.10–0.30	0.15–0.30	0.30–0.40	0.40–0.60	0.90–1.10	0.15–0.30	0.20–0.40	0.45–0.65	0.90–1.20
Vanadium	0.04–0.12	. . .	. . .	. . .	0.03–0.10	. . .	. . .	. . .	. . .	. . .
Boron	. . .	. . .	. . .	. . .	0.002–0.006	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	0.15–0.50	. . .	. . .	. . .	. . .	. . .
Residual Elements:										
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	0.50	0.50	. . .	. . .	. . .	. . .	0.50	. . .	. . .	. . .
Chromium	0.35	0.35	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Mo + W	0.25	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tungsten	. . .	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vanadium	. . .	0.03	0.03	0.03	. . .	0.03	0.03	0.03	0.03	0.03
Total content of residual elements	1.00	1.00	0.60	0.60	0.60	0.60	1.00	0.60	0.50	0.50

Grade	13.	14.	16.	CA15	CA15M	CA6NM
Class Type	AB Nickel-Molybdenum	A Nickel-Molybdenum	A Low Carbon Manganese-Nickel	ABCD Martensitic Chromium	A Martensitic Chromium	AB Martensitic Chromium Nickel
Carbon	0.30	0.55	0.12[B]	0.15	0.15	0.06
Manganese	0.80–1.10	0.80–1.10	2.10[B]	1.00	1.00	1.00
Phosphorus	0.04	0.04	0.02	0.040	0.040	0.04
Sulfur	0.045	0.045	0.02	0.040	0.040	0.03
Silicon	0.60	0.60	0.50	1.50	0.65	1.00
Nickel	1.40–1.75	1.40–1.75	1.00–1.40	1.00	1.0	3.5–4.5
Chromium	. . .	. . .	. . .	11.5–14.0	11.5–14.0	11.5–14.0
Molybdenum	0.20–0.30	0.20–0.30	. . .	0.50	0.15–1.0	0.4–1.0
Boron	. . .	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .
Residual Elements:						
Copper	0.50	0.50	0.20	0.50	0.50	0.50
Nickel	. . .	. . .	. . .	. . .	. . .	. . .
Chromium	0.40	0.40	0.20	. . .	. . .	. . .
Molybdenum	. . .	. . .	0.10	. . .	. . .	. . .
Tungsten	0.10	0.10	0.10	0.10	0.10	0.10
Vanadium	0.03	0.03	0.02	0.05	0.05	0.05
Total content of residual elements	0.75	0.75	0.50	0.50	0.50	0.50

[A] Proprietary steel composition.
[B] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 2.30%.

TABLE 3
REQUIRED MECHANICAL PROPERTIES

Previous Designation	Grade	Class	Tensile Strength,[A] min, ksi [MPa]	Yield Strength, min, ksi [MPa], at 0.2% Offset	Elongation, 2 in. [50 mm] or 4*d*, min, %	Reduction of Area, min, %	Hardness max, HRC	Max Thickness, in. [mm]
1N	1	A	85 [585]–110 [760]	55 [380]	22	40		
1Q	1	B	90 [620]–115 [795]	65 [450]	22	45		
	1	C	90 [620]	65 [450]	22	45	22 [235]	
2N	2	A	85 [585]–110 [750]	53 [365]	22	35		
2Q	2	B	90 [620]–115 [795]	65 [450]	22	40		
	2	C	90 [620]	65 [450]	22	40	22 [235]	
4N	4	A	90 [620]–115 [795]	60 [415]	18	40		
4Q	4	B	105 [725]–130 [895]	85 [585]	17	35		
	4	C	90 [620]	60 [415]	18	35	22 [235]	
	4	D	100 [690]	75 [515]	17	35	22 [235]	
4QA	4	E	115 [795]	95 [655]	15	35		
6N	6	A	115 [795]	80 [550]	18	30		
6Q	6	B	120 [825]	95 [655]	12	25		
7Q	7	A	115 [795]	100 [690]	15	30		2.5 [63.5]
8N	8	A	85 [585]–110 [760]	55 [380]	20	35		
8Q	8	B	105 [725]	85 [585]	17	30		
	8	C	100 [690]	75 [515]	17	35	22 [235]	
9N	9	A	90 [620]	60 [415]	18	35		
9Q	9	B	105 [725]	85 [585]	16	35		
	9	C	90 [620]	60 [415]	18	35	22 [235]	
	9	D	100 [690]	75 [515]	17	35	22 [235]	
	9	E	115 [795]	95 [655]	15	35		
10N	10	A	100 [690]	70 [485]	18	35		
10Q	10	B	125 [860]	100 [690]	15	35		
11N	11	A	70 [484]–95 [655]	40 [275]	20	35		
11Q	11	B	105 [725]–130 [895]	85 [585]	17	35		
12N	12	A	70 [485]– 95 [655]	40 [275]	20	35		
12Q	12	B	105 [725]–130 [895]	85 [585]	17	35		
13N	13	A	90 [620]–115 [795]	60 [415]	18	35		
13Q	13	B	105 [725]–130 [895]	85 [585]	17	35		
14Q	14	A	120 [825]–145 [1000]	95 [655]	14	30		
16N	16	A	70 [485]–95 [655]	40 [275]	22	35		
CA15A	CA15	A	140 [965]–170 [1170]	110 [760]–130 [895]	10	25		
CA15	CA15	B	90 [620]–115 [795]	65 [450]	18	30		
	CA15	C	90 [620]	60 [415]	18	35	22 [235]	
	CA15	D	100 [690]	75 [515]	17	35	22 [235]	
CA15M	CA15M	A	90 [620]–115 [795]	65 [450]	18	30		
CA6NM	CA6NM	A	110 [760]–135 [930]	80 [515]	15	35		
CA6NM	CA6NM	B	100 [690]	75 [520]	17	35	23 [255][B]	

[A] Minimum ksi, unless range is given.
[B] Test Methods and Definitions A 370, Table 3a does not apply to CA6NM. The conversion given is based on CA6NM test coupons. (For example, see ASTM STP 756.)

98 **TABLE 4**
MINIMUM PRE-HEAT AND POST WELD HEAT TREAT REQUIREMENTS

Grade	Class	Minimum Pre-Heat Temperature, °F [°C]	Post Weld Heat Treat, °F [°C]
1	A, B	200 [95]	1100 [595][A] minimum
1	C	200 [95]	1150 [620][A] minimum
2	A, B	200 [95]	1100 [595][A] minimum
2	C	200 [95]	1150 [620][A] minimum
4	A, B, E	200 [95]	1100 [595][A] minimum
4	C, D	200 [95]	1150 [620][A] minimum
6	A, B	300 [150]	1100 [595][A] minimum
7	A	300 [150]	1100 [595][A] minimum
8	A, B, C	300 [150]	1250 [675][A] minimum
9	A, B, E	300 [150]	1100 [595][A] minimum
9	C, D	300 [150]	1150 [620][A] minimum
10	A, B	300 [150]	1100 [595][A] minimum
11	A, B	300 [150]	1100 [595][A] minimum
12	A, B	300 [150]	1100 [595][A] minimum
13	A, B	400 [205]	1100 [595][A] minimum
14	A	400 [205]	1100 [595][A] minimum
16	A	50 [10]	1100 [595][A] minimum
CA15	A	400 [205]	1750 [955] air cool or liquid quench below 400°F [205°C] temper at 900°F [480°C] minimum
CA15	B	400 [205]	1100 [595][A] minimum
CA15	C, D	400 [205]	1150 [620][A] minimum
CA15M	A	400 [205]	1100 [595][A] minimum
CA6NM	A	50 [10]	Final temper between 1050 [565] and 1150 [620]
CA6NM	B	50 [10]	Intermediate PWHT between 1225 [665] and 1275 [690]
			Final temper PWHT 1050 [565] and 1150 [620][B]

[A] Post weld heat treat temperature must be at or below the final tempering temperature.

[B] The intermediate and final PWHT temperatures shall be the same as the intermediate and final tempering temperatures, respectively, as the original heat treatment of the castings. Cool to below 200°F (95°C) between the intermediate and final PWHT.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S8. Charpy Impact Test

S8.1 In addition to the requirements listed in S8 of Specification A 703/A 703M, the following specific requirements apply to this specification:

S8.1.1 When S8 is specified for Grades 1B, 2B, 4B, 6B, 7A, 8B, 9B, or 10B, impact properties shall be determined by performing a Charpy V-notch impact test at −50°F [−46°C] with a specific minimum average value of 15 ft-lb [20 J] and a specified minimum single value of 10 ft-lb [14 J]. Other temperatures may be used upon agreement between the manufacturer and the purchaser, in which case S8.1.3 shall apply. Other higher specified minimum average and single values may be used upon agreement between the manufacturer and the purchaser.

S8.1.2 Impact requirements for grades other than 1B, 2B, 4B, 6B, 7A, 8B, 9B, and 10B shall be agreed upon between the manufacturer and the purchaser.

S8.1.3 When and impact test tmeperature other than −50°F [−46°C] is used for those grades listed in S8.1.1, the lowest test temperature at which the material meets the impact requirements shall be stamped with low stress stamps immediately ahead of the material symbol on the raised pad (for example, 25 10B for +25°F [−4°C] and 025 10B for −25°F [−32°C]).

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service[1]

This standard is issued under the fixed designation A 516/A 516M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
55 [380]	55–75 [380–515]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade U.S. [SI]	Maximum Thickness, in. [mm]
55 [380]	12 [305]
60 [415]	8 [205]
65 [450]	8 [205]
70 [485]	8 [205]

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results of Specification A 20/A 20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1964. Last previous edition approved in 2005 as A 516/A 516M – 05$^{\epsilon 1}$.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-516/SA-516M in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates 1½ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300 °F [595 to 705 °C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

TABLE 1 Chemical Requirements

Elements	Composition, %			
	Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max^{A,B} :				
½ in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over ½ in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese^{B}:				
½ in. [12.5 mm] and under:				
Heat analysis	0.60–0.90	0.60–0.90^{C}	0.85–1.20	0.85–1.20
Product analysis	0.55–0.98	0.55–0.98^{C}	0.79–1.30	0.79–1.30
Over ½ in. [12.5 mm]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus,max^{A}	0.035	0.035	0.035	0.035
Sulfur, max^{A}	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

^{A} Applies to both heat and product analyses.

^{B} For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.

^{C} Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20 % manganese on heat analysis, and 0.79–1.30 % manganese on product analysis.

TABLE 2 Tensile Requirements

	Grade			
	55 [380]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	55–75 [380–515]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min,[A] ksi [MPa]	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %[B]	23	21	19	17
Elongation in 2 in. [50 mm], min, %[B]	27	25	23	21

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A 20/A20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirement is suitable for this application.

S54. Requirements for Carbon Steel Plate for Hydrofluoric Acid Alkylation Service

S54.1 Plates shall be provided in the normalized heat-treated condition.

S54.2 The maximum carbon equivalent shall be as follows:
Plate thickness less than or equal to 1 in. [25 mm]: CE maximum = 0.43
Plate thickness greater than 1 in. [25 mm]: CE maximum = 0.45

S54.3 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S54.4 Vanadium and niobium maximum content based on heat analysis shall be:
Maximum vanadium = 0.02 %
Maximum niobium = 0.02 %
Maximum vanadium plus niobium = 0.03 %
(Note: niobium = columbium)

S54.5 The maximum composition based on heat analysis of Ni + Cu shall be 0.15 %.

S54.6 The minimum C content based on heat analysis shall be 0.18 %. The maximum C content shall be as specified for the ordered grade.

S54.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S54.8 In addition to the requirements for product marking in the specification, an "HF-N" stamp or marking shall be provided on each plate to identify that the plate complies with this supplementary requirement.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 516/A 516M – 05$^{\epsilon 1}$) that may impact the use of this standard. (Approved March 1, 2006.)

(1) Footnote C was added to Table 1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 516/A 516M – 03) that may impact the use of this standard. (Approved March 1, 2005.)

(1) Keywords were added.
(2) Supplementary Requirement S1, for plates for HF alkylation service, was added.
(3) Table 1 was corrected editorially.

Designation: A 576 – 90b (Reapproved 2000)

Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality[1]

This standard is issued under the fixed designation A 576; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers hot-wrought special quality carbon steel bars. Special quality bar applications include forging, heat treating, cold drawing, machining, and many structural uses. A guide for the selection of steel bars is contained in Practice A 400.

1.2 The bars shall be furnished in the grades specified in Table 1. Sections and sizes of bar steel available are covered in Specification A 29/A 29M. Hot-wrought special quality carbon steel bars are produced in cut lengths and coils; the manufacturer should be consulted regarding sections and sizes available in coils, produced to a chemical composition.

1.3 Merchant quality hot-wrought carbon steel bars are covered in Specification A 575.

1.4 Some end uses may require superior surface quality, or special chemical restrictions, metallurgical characteristics, heat treatment, or surface finishes which the purchaser may obtain by designating one or more of the available Supplementary Requirements.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for[2]

A 400 Practice for Steel Bars, Selection Guide, Composition and Mechanical Properties[2]

A 575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades[2]

E 45 Practice for Determining the Inclusion Content of Steel[3]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

2.2 *SAE Standard:*

SAE J 1086 Recommended Practice for Numbering Metals and Alloys (UNS)[5]

3. Ordering Information

3.1 Orders under this specification should include the following, as required, to describe adequately the desired material:

3.1.1 Quantity (weight or number of bars),

3.1.2 Name of material (hot-wrought carbon steel bars),

3.1.3 Dimensions,

3.1.4 ASTM specification number and date of issue,

3.1.5 Deoxidation practice (see 4.2.1),

3.1.6 Grade designation or chemical composition limits (see 5.1 and Table 1),

3.1.7 Coarse or fine grain steel (4.2.2),

3.1.8 Test reports, if required (Section 7),

3.1.9 Additions to the specification and Supplementary Requirements, if required, and

3.1.10 End use.

NOTE 1—A typical ordering description is as follows: 10 000 lb, carbon steel bars, hot rolled 1 000 in. diameter by 10 ft, ASTM A 576 dated ___, killed steel, Grade 1018, test reports required, coarse grain Supplementary Requirement S10, welded industrial fan hubs and shafts.

4. Materials and Manufacture

4.1 *Melting Practice*—The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 *Deoxidation*:

4.2.1 Unless otherwise specified, the steel shall be rimmed, capped, semi-killed, or killed at the manufacturer's option.

4.2.2 If killed steel is specified, the purchaser may designate that the steel be made to coarse or fine austenitic grain size (see S10 or S11).

NOTE 2—Assured coarse grain size is not always possible since certain

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys, and is the direct responsibility of Subcommittee A01.15 on Bars.

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[2] *Annual Book of ASTM Standards*, Vol 01.05.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

elements or combination of elements or certain quantities of elements such as manganese, sulfur, and lead tend to produce grain refinement.

4.3 *Quality*—The bars shall be special quality.

4.4 *Hot Forming*—The bars shall be hot wrought, as wrought.

TABLE 1 Grade Designations and Chemical Requirements of Hot-Wrought Carbon Steel Bars

NOTE—Grade designations and compositions correspond to the respective AISI designations and compositions.

UNS Designation[A]	Grade	Heat Chemical Ranges and Limits, %			
		Carbon	Manganese	Phosphorus, max	Sulfur, max[B]
		Nonresulfurized Carbon Steels[C,D,E,F,G] Low Manganese 1.00 % max or less			
G10080	1008	0.10 max	0.30–0.50	0.040	0.050
G10100	1010	0.08–0.13	0.30–0.60	0.040	0.050
G10120	1012	0.10–0.15	0.30–0.60	0.040	0.050
G10150	1015	0.13–0.18	0.30–0.60	0.040	0.050
G10160	1016	0.13–0.18	0.60–0.90	0.040	0.050
G10170	1017	0.15–0.20	0.30–0.60	0.040	0.050
G10180	1018	0.15–0.20	0.60–0.90	0.040	0.050
G10190	1019	0.15–0.20	0.70–1.00	0.040	0.050
G10200	1020	0.18–0.23	0.30–0.60	0.040	0.050
G10210	1021	0.18–0.23	0.60–0.90	0.040	0.050
G10220	1022	0.18–0.23	0.70–1.00	0.040	0.050
G10230	1023	0.20–0.25	0.30–0.60	0.040	0.050
G10250	1025	0.22–0.28	0.30–0.60	0.040	0.050
G10260	1026	0.22–0.28	0.60–0.90	0.040	0.050
G10290	1029	0.25–0.31	0.60–0.90	0.040	0.050
G10300	1030	0.28–0.34	0.60–0.90	0.040	0.050
G10350	1035	0.32–0.38	0.60–0.90	0.040	0.050
G10370	1037	0.32–0.38	0.70–1.00	0.040	0.050
G10380	1038	0.35–0.42	0.60–0.90	0.040	0.050
G10390	1039	0.37–0.44	0.70–1.00	0.040	0.050
G10400	1040	0.37–0.44	0.60–0.90	0.040	0.050
G10420	1042	0.40–0.47	0.60–0.90	0.040	0.050
G10430	1043	0.40–0.47	0.70–1.00	0.040	0.050
G10440	1044	0.43–0.50	0.30–0.60	0.040	0.050
G10450	1045	0.43–0.50	0.60–0.90	0.040	0.050
G10460	1046	0.43–0.50	0.70–1.00	0.040	0.050
G10490	1049	0.46–0.53	0.60–0.90	0.040	0.050
G10500	1050	0.48–0.55	0.60–0.90	0.040	0.050
G10530	1053	0.48–0.55	0.70–1.00	0.040	0.050
G10550	1055	0.50–0.60	0.60–0.90	0.040	0.050
G10600	1060	0.55–0.65	0.60–0.90	0.040	0.050
G10700	1070	0.65–0.75	0.60–0.90	0.040	0.050
G10780	1078	0.72–0.85	0.30–0.60	0.040	0.050
G10800	1080	0.75–0.88	0.60–0.90	0.040	0.050
G10840	1084	0.80–0.93	0.60–0.90	0.040	0.050
G10900	1090	0.85–0.98	0.60–0.90	0.040	0.050
G10950	1095	0.90–1.03	0.30–0.50	0.040	0.050
G15130	1513	0.10–0.16	1.10–1.40	0.040	0.050
G15180	1518	0.15–0.21	1.10–1.40	0.040	0.050
G15220	1522	0.18–0.24	1.10–1.40	0.040	0.050
G15240	1524	0.19–0.25	1.35–1.65	0.040	0.050
G15250	1525	0.23–0.29	0.80–1.10	0.040	0.050
G15260	1526	0.22–0.29	1.10–1.40	0.040	0.050
G15270	1527	0.22–0.29	1.20–1.50	0.040	0.050
G15360	1536	0.30–0.37	1.20–1.50	0.040	0.050
G15410	1541	0.36–0.44	1.35–1.65	0.040	0.050
G15470	1547	0.43–0.51	1.35–1.65	0.040	0.050
G15480	1548	0.44–0.52	1.10–1.40	0.040	0.050
G15510	1551	0.45–0.56	0.85–1.15	0.040	0.050
G15520	1552	0.47–0.55	1.20–1.50	0.040	0.050
G15610	1561	0.55–0.65	0.75–1.05	0.040	0.050
G15660	1566	0.60–0.71	0.85–1.15	0.040	0.050
G15720	1572	0.65–0.76	1.00–1.30	0.040	0.050
		Resulfurized Carbon Steels[C,E,G]			
G11090	1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13
G11100	1110	0.08–0.13	0.30–0.60	0.040	0.08–0.13
G11160	1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23
G11170	1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
G11180	1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13
G11190	1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33
G11320	1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13

TABLE 1 *Continued*

UNS Designation[A]	Grade	Heat Chemical Ranges and Limits, %			
		Carbon	Manganese	Phosphorus, max	Sulfur, max[B]
G11370	1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
G11390	1139	0.35–0.43	1.35–1.65	0.040	0.13–0.20
G11400	1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13
G11410	1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
G11440	1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33
G11450	1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07
G11460	1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13
G11510	1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13

Rephosphorized and Resulfurized Carbon Steel[E,G,H]

Designation	Grade	Carbon	Manganese	Phosphorus	Sulfur	Lead
G12110	1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15	...
G12120	1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	...
G12130	1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	...
G12150	1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	...
...	12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35

[A] New designations established in accordance with Practice E 527 and SAE J 1086.

[B] Maximum unless otherwise indicated.

[C] When silicon is required, the following ranges and limits are commonly specified: 0.10 %, max, 0.10 to 0.20 %, 0.15 to 0.35 %, or 0.20 to 0.40 %.

[D] Copper can be specified when required as 0.20 % minimum.

[E] When lead is required as an added element to a standard steel, a range of 0.15 to 0.35 % incl, is specified. Such a steel is identified by inserting the letter “L” between the second and third numerals of the grade designation, for example, 10 L 45. A cast or heat analysis is not determinable when lead is added to the ladle stream.

[F] When boron treatment is specified for killed steels, the steels can be expected to contain 0.0005 to 0.003% boron.

[G] The elements bismuth, calcium, selenium or tellurium may be added as agreed between purchaser and supplier.

[H] It is not common practice to produce these steels to specified limits for silicon because of its adverse effect on machinability.

5. Chemical Composition

5.1 The heat analysis shall conform to the requirements for chemical composition specified in Table 1 for the grade specified, or to such other limits as may be specified using the ranges and limits in Table 2.

6. Workmanship, Finish, and Appearance

6.1 *Descaling*—When descaled bars are required, S15 on Pickling or S16 on Blast Cleaning must be specified.

6.2 The bars shall be free of visible pipe and conditioned as necessary to remove injurious surface imperfections.

7. Certification and Test Reports

7.1 When specified by the purchaser, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis test results for the specified elements and for copper, chromium, nickel, molybdenum, vanadium and columbium shall be furnished. When the amount of an element present is less than 0.02 %, the analysis may be reported as <0.02 %. The report shall include the name of the manufacturer, ASTM designation number and year date and revision letter, if any, type and grade, heat number, and size.

7.2 When supplementary requirements are specified, the report shall include a statement of compliance with the requirement or the results of tests when the requirement involves measured test values such as S12 on Restricted Incidental Elements.

8. General Requirements

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 29/A 29M, unless otherwise provided herein.

9. Keywords

9.1 carbon steel bars; hot-wrought steel bars; steel bars

TABLE 2 Heat Chemical Ranges and Limits of Hot-Wrought Carbon Steel Bars

Element	Chemical Ranges and Limits, %		
	When Maximum of Specified Element is:	Range	Lowest Maximum
Carbon[A]	...	...	0.06
	to 0.12 incl	...	...
	over 0.12–0.25 incl	0.05	...
	over 0.25–0.40 incl	0.06	...
	over 0.40–0.55 incl	0.07	...
	over 0.55–0.80 incl	0.10	...
	over 0.80	0.13	...
Manganese	...	...	0.35
	to 0.40 incl	0.15	...
	over 0.40–0.50 incl	0.20	...
	over 0.50–1.65 incl	0.30	...
Phosphorus	to 0.040 incl	...	0.040
	over 0.040–0.08 incl	0.03	...
	over 0.08–0.13 incl	0.05	...
Sulfur	to 0.050 incl	. . .	0.050
	over 0.050–0.09 incl	0.03	...
	over 0.09–0.15 incl	0.05	...
	over 0.15–0.23 incl	0.07	...
	over 0.23–0.50 incl	0.09	...
Silicon[B]	...	...	0.10
	to 0.10 incl	...	...
	over 0.10–0.15 incl	0.08	...
	over 0.15–0.20 incl	0.10	...
	over 0.20–0.30 incl	0.15	...
	over 0.30–0.60 incl	0.20	...
Copper	When copper is required 0.20 min is generally specified		
Lead[C,D]	When lead is required, a range of 0.15–0.35 is specified		
Boron		0.0005 min	
Bismuth[E]			
Calcium[E]			
Selenium[E]			
Tellurium[E]			

[A] The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.10 %. When the maximum manganese limit exceeds 1.10 %, add 0.01 to the carbon ranges shown above.
[B] It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.
[C] A heat analysis for lead is not determinable, since lead is added to the ladle stream while each ingot is poured.
[D] It is not common practice to produce these steels to specified limits for silicon because of its adverse effect on machinability.
[E] Element specification range as agreed to between purchaser and supplier.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply when specified by the purchaser.

S1. Cold-Working Quality

S1.1 This classification encompasses bars subject to severe cold plastic deformation such as, but not limited to, upsetting, heading, forging, forward or backward extrusion.

S1.2 If the type of steel or chemical composition does not have adequate cold working characteristics, appropriate thermal treatments should be specified.

S1.3 When S1 is specified, the bars shall be produced by manufacturing practices and subjected to mill tests and inspection and freedom from injurious surface imperfections to the extent that the bars shall be suitable for the manufacture of identified parts. The quality requirements of individual application vary.

S2. Axle-Shaft Quality

S2.1 Bars shall be suitable for use in the manufacture of power-driven axle shafts of the automotive or truck type.

S3. Scrapless Nut Quality

S3.1 Bars shall be suitable for the production of scrapless nuts from round bars involving cold plastic deformation, namely piercing, upsetting, and forming, with consequent expansion in diameter.

S4. Special Surface Quality

S4.1 Special surface steels are produced with exacting control and appropriate inspection and surface preparation to minimize the frequency and degree of seams and other surface imperfections.

S5. Annealing

S5.1 The steel shall be furnished annealed.

S6. Spheroidize Annealing

S6.1 The steel shall be spheroidize annealed.

S7. Special Internal Soundness Requirement

S7.1 The steel shall be produced with special internal soundness, that is, relative freedom from segregation and porosity, as evaluated by means of a macroetch test performed on representative billet samples. The test shall consist of deep etching a cross section in a hot-acid solution and with a visual examination to evaluate soundness. An alternative method consisting of fracturing a billet section and examining the fracture surface to evaluate soundness may be used with purchaser approval.

S8. Nonmetallic Inclusion Requirement (Note S1)

S8.1 A microscopical examination of longitudinal sections to determine the nature and frequency of nonmetallic inclusions shall be made as prescribed in Practice E 45. The acceptance limits shall be specified by the purchaser.

NOTE S1—Much of the sulfur in resulfurized steels is present as sulfide inclusions. For this reason, those steels are not generally produced to inclusion rating and S9 may not be specified.

S9. Special Hardenability Requirement

S9.1 Special heat treating (hardenability) is a term used when the purchaser specifies as a requirement, the ability of a steel to heat treat to specified mechanical property values which the purchaser must meet after his heat treatment. Care should be taken so that the desired mechanical property values are compatible with the chemical composition, size, and cross section of the steel.

S10. Grain Size (Coarse)

S10.1 The steel shall conform to the coarse austenitic grain size requirement of Specification A 29/A 29M.

S11. Grain Size (Fine)

S11.1 The steel shall conform to the fine austenitic grain size requirement of Specification A 29/A 29M.

S11.1.1 When aluminum is used as a grain refining element, the fine grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.015 % acid soluble aluminum, or alternately, 0.020 % total aluminum. The aluminum content shall be reported. The grain size test specified in S11.1 shall be the referee test.

S11.1.2 When specified on the order, one grain size test per heat shall be made. The test result shall be reported.

S12. Restricted Incidental Elements

S12.1 The steel shall not exceed the limits for copper, nickel, chromium, molybdenum, or other elements as shown on the purchase order.

S13. Stress Relieving

S13.1 The steel shall be stress relieved by heating to a temperature specified by the purchaser or to a temperature selected by the manufacturer.

S14. Special Straightness

S14.1 The bars shall be produced with special straightness (refer to Specification A 29/A 29M for tolerances).

S15. Pickling

S15.1 The surface of the bars shall be descaled by pickling.

S16. Blast Cleaning

S16.1 The surface of the bars shall be descaled by blast cleaning.

S17. Coating

S17.1 The bars shall be oiled, limed, or phosphate-coated as specified by the purchaser. The purchaser shall also specify the method of cleaning (S15 or S16); otherwise the bars shall be descaled by pickling or blasting at the manufacturer's option.

S18. Restricted Heat Chemical Ranges

S18.1 Restricted heat chemical ranges on one or more elements may be specified by the purchaser if the manufacturer agrees to melt to the requested restriction.

Designation: A 743/A 743M – 03

Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application[1]

This standard is issued under the fixed designation A 743/A 743M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers iron-chromium and iron-chromium-nickel alloy castings for general corrosion-resistant application. The grades covered by this specification represent types of alloy castings suitable for broad ranges of application which are intended for a wide variety of corrosion environments.

NOTE 1—For alloy castings for severe corrosion-resistant service, reference should be made to Specification A 744/A 744M. For general heat-resistant alloy castings, reference should be made to Specification A 297/A 297M. For nickel alloy castings for corrosion-resistant service, reference should be made to Specification A 494/A 494M.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 743 and SI units for material ordered to Specification A 743M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant, for General Application[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 447/A447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[3]

A 494/A494M Specification for Castings, Nickel and Nickel Alloy[3]

A 744/A744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service[3]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the material adequately:

4.1.1 Description of the casting by pattern number or drawing,

4.1.2 Grade,

4.1.3 Heat treatment,

4.1.4 Options in the specification, and

4.1.5 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 Castings shall be heat treated in accordance with the requirements in Table 1.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

***A Summary of Changes section appears at the end of this standard.**

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
CF8, CG3M, CG8M, CG12, CF20, CF8M, CF8C,CF16F, CF16Fa	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CH10, CH20, CE30, CK20	Heat to 2000°F [1093°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CA15, CA15M, CA40, CA40F	(*1*) Heat to 1750°F [955°C] minimum, air cool and temper at 1100°F [595°C] minimum, or (*2*) Anneal at 1450°F [790°C] minimum.
CB30, CC50	(*1*) Heat to 1450°F [790°C] minimum, and air cool, or (*2*) Heat to 1450°F [790°C] minimum, and furnace cool.
CF3, CF3M, CF3MN	(*1*) Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting to temperature, and cool rapidly. (*2*) As cast if corrosion resistance is acceptable.
CN3M	Heat to 2150°F [1175°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN3MN	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN7M, CG6MMN	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN7MS	Heat to 2100°F [1150°C] minimum, 2150°F [1180°C] maximum, hold for sufficient time (2 h minimum) to heat casting to temperature and quench in water.
CA6NM	Heat to 1850°F [1010°C] minimum, air cool to 200°F [95°C] or lower prior to any optional intermediate temper and prior to the final temper. The final temper shall be between 1050°F [565°C] and 1150°F [620°C].
CA6N	Heat to 1900°F [1040°C], air cool, reheat to 1500°F [815°C], air cool, and age at 800°F [425°C], holding at each temperature sufficient time to heat casting uniformly to temperature.
CF10SMnN	Heat to 1950°F [1065°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CA28MWV	(*1*) Heat to 1875–1925°F [1025–1050°C], quench in air or oil, and temper at 1150°F [620°C] minimum, or (*2*) Anneal at 1400°F [760°C] minimum.
CK3MCuN	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CK35MN	Heat to 2100-2190F [1150-1200C], hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CB6	Heat between 1800°F [980°C] and 1920°F [1050°C], forced air, cool to 120°F [50°C] maximum, and temper between 1100°F and 1160°F [595°C and 625°C].

TABLE 2 Chemical Requirements

NOTE—CD4MCu has been deleted from A 743/A 743M and added to A 890/A 890M. CD4MCu may now be supplied and purchased in compliance with A 890/A 890M. The chemical and mechanical property requirements of CD4MCu were identical in A 743/A 743M and A 890/A 890M at the time of removal from A 743/A 743M.

Grade (UNS)	Type	Composition, %													
		Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Nitrogen
CF8 (J92600)	19 Chromium, 9 Nickel	0.08	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	...	...	...	...	...	...	...
CG12 (J93001)	22 Chromium, 12 Nickel	0.12	1.50	2.00	0.04	0.04	20.0–23.0	10.0–13.0	...	...	...	...	...	...	...
CF20 (J92602)	19 Chromium, 9 Nickel	0.20	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	...	...	...	...	...	...	...
CF8M (J92900)	19 Chromium, 10 Nickel, with Molybdenum	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	2.0–3.0	...	...	...	...	...	...
CF8C (J92710)	19 Chromium, 10 Nickel, with Columbium	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	...	[A]	...	...	...	...	...
CF16F (J92701)	19 Chromium, 9 Nickel, Free Machining	0.16	1.50	2.00	0.17	0.04	18.0–21.0	9.0–12.0	1.50 max	...	0.20–0.35	...	...	...	...
CF16Fa	19 Chromium, 9 Nickel, Free Machining	0.16	1.50	2.00	0.04	0.20–0.40	18.0–21.0	9.0–12.0	0.40–0.80	...	...	...	...	...	...
CH10 (J93401)	25 Chromium, 12 Nickel	0.10	1.50	2.00	0.04	0.04	22.0–26.0	12.0–15.0	...	. . .	...	...	...	...	...

TABLE 2 *Continued*

Grade (UNS)	Type	Composition, %													
		Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Nitrogen
CH20 (J93402)	25 Chromium, 12 Nickel	0.20	1.50	2.00	0.04	0.04	22.0–26.0	12.0–15.0	...	...	...	...	...	...	...
CK20 (J94202)	25 Chromium, 20 Nickel	0.20	2.00	2.00	0.04	0.04	23.0–27.0	19.0–22.0	...	...	...	...	...	...	...
CE30 (J93423)	29 Chromium, 9 Nickel	0.30	1.50	2.00	0.04	0.04	26.0–30.0	8.0–11.0	...	...	...	...	...	...	...
CA15 (J91150)	12 Chromium	0.15	1.00	1.50	0.04	0.04	11.5–14.0	1.00 max	0.50 max	...	...	...	...	...	...
CA15M (J91151)	12 Chromium	0.15	1.00	0.65	0.040	0.040	11.5–14.0	1.0 max	0.15–1.0	...	...	...	...	...	...
CB30 (J91803)	20 Chromium	0.30	1.00	1.50	0.04	0.04	18.0–21.0	2.00 max	...	...	...	[B]	...	...	...
CC50 (J92615)	28 Chromium	0.50	1.00	1.50	0.04	0.04	26.0–30.0	4.00 max	...	...	...	...	...	...	...
CA40 (J91153)	12 Chromium	0.20–0.40	1.00	1.50	0.04	0.04	11.5–14.0	1.0 max	0.5 max	...	...	...	...	...	...
CA40F (J91154)	12 Chromium, Free Machining	0.20–0.40	1.00	1.50	0.04	0.20–0.40	11.5–14.0	1.0 max	0.5 max	...	...	...	...	...	...
CF3 (J92500)	19 Chromium, 9 Nickel	0.03	1.50	2.00	0.04	0.04	17.0–21.0	8.0–12.0	...	...	...	...	...	...	...
CF10SMnN (J92972)	17 Chromium, 8.5 Nickel with Nitrogen	0.10	7.00–9.00	3.50–4.50	0.060	0.030	16.0–18.0	8.0–9.0	...	...	...	...	...	...	0.08–0.18
CF3M (J92800)	19 Chromium, 10 Nickel, with Molybdenum	0.03	1.50	1.50	0.04	0.04	17.0–21.0	9.0–13.0	2.0–3.0	...	...	...	...	...	...
CF3MN (J92804)	19 Chromium, 10 Nickel, with Molybdenum, and Nitrogen	0.03	1.50	1.50	0.040	0.040	17.0–22.0	9.0–13.0	2.0–3.0	...	...	...	...	...	0.10–0.20
CG6MMN (J93790)		0.06	4.00–6.00	1.00	0.04	0.03	20.5–23.5	11.5–13.5	1.50–3.00	0.10–0.30	...	...	...	0.10–0.30	0.20–0.40
CG3M (J92999)	19 Chromium, 11 Nickel, with Molybdenum	0.03	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .
CG8M (J93000)	19 Chromium, 11 Nickel, with Molybdenum	0.08	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	...	...	...	...	...	...
CN3M (J94652)		0.03	2.0	1.0	0.03	0.03	20.0–22.0	23.0–27.0	4.5–5.5	...	...	...	...	...	...
CN3MN (J94651)	21 Chromium, 24 Nickel with Molybdenum and Nitrogen	0.03	2.00	1.00	0.040	0.010	20.0–22.0	23.5–25.5	6.0–7.0	...	...	0.75 max	...	...	0.18–0.26
CN7M (N08007)	20 Chromium, 29 Nickel, with Copper and Molybdenum	0.07	1.50	1.50	0.04	0.04	19.0–22.0	27.5–30.5	2.0–3.0	...	...	3.0–4.0	...	...	...
CN7MS (J94650)	19 Chromium, 24 Nickel, with Copper and Molybdenum	0.07	1.00	2.50–3.50	0.04	0.03	18.0–20.0	22.0–25.0	2.5–3.0	...	...	1.5–2.0	...		
CA6NM (J91540)	12 Chromium, 4 Nickel	0.06	1.00	1.00	0.04	0.03	11.5–14.0	3.5–4.5	0.40–1.0	...	...	...	...	...	...
CA6N	11 Chromium, 7 Nickel	0.06	0.50	1.00	0.02	0.02	10.5–12.5	6.0–8.0	...	...	...	...	...	...	...

TABLE 2 *Continued*

Grade (UNS)	Type	Composition, %													
		Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Nitrogen
CA28MWV (J91422)	12 Chromium, with Molybdenum, Tungsten and Vanadium	0.20–0.28	0.50–1.00	1.0	0.030	0.030	11.0–12.5	0.50–1.00	0.90–1.25	...	...	...	0.90–1.25	0.20–0.30	...
CK3MCuN (J93254)	20 Chromium 18 Nickel, with Copper and Molybdenum	0.025	1.20	1.00	0.045	0.010	19.5–20.5	17.5–19.5	6.0–7.0	. . .	. . .	0.50–1.00	. . .	. . .	0.180–0.240
CK35MN	23 Chromium, 21 Nickel, with Molybdenum and Nitrogen	0.035	2.00	1.00	0.035	0.020	22.0-24.0	20.0-22.0	6.0-6.8	. . .	. . .	0.40	. . .	. . .	0.21-0.32
CB6 (J91804)	16 Chromium, 4 Nickel	0.06	1.00	1.00	0.04	0.03	15.5–17.5	3.5–5.5	0.5 max	. . .	. . .	. . .	. . .	. . .	. . .

[A] Grade CF8C shall have a columbium content of not less than eight times the carbon content and not more than 1.0%. If a columbium-plus-tantalum alloy in the approximate Cb:Ta ratio of 3:1 is used for stabilizing this grade, the total columbium-plus-tantalum content shall not be less than nine times the carbon content and shall not exceed 1.1%.

[B] For Grade CB30 a copper content of 0.90 to 1.20% is optional.

NOTE 2—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat treat temperatures are specified; however, it is sometimes necessary to heat treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

7. Chemical Requirements

7.1 The chemical requirements are shown in Table 2.

8. Repair by Welding

8.1 Repair welding of Grade CA28MWV is not permitted unless by agreement between the manufacturer and the purchaser.

8.2 When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated in accordance with Table 3. Weld repairs shall be subject to the same quality standards as are used to inspect the castings.

8.3 Post weld heat treatment, if required, shall be in accordance with Table 1.

8.3.1 The martensitic grades CA6NM, CA15, CA15M, CB6, and CA40 shall be retempered after weld repairing, except that local tempering will be permitted if, in the opinion of the manufacturer, furnace heat treating will be damaging to the finished surface of a machined casting. Heat treatment, other than tempering, of grades CA6NM, CA15, CA15M, CB6, and CA40 after weld repairing shall be performed only when agreed upon between the manufacturer and the purchaser. Weld repair on Grade CA40F is not recommended because of the risk of local hardening and possible cracking in the heat affected zone.

8.3.2 Post weld heat treatment is not required on the other grades of this specification. When post weld heat treatment is believed necessary for adequate corrosion resistance in the service environment, castings should be ordered in accordance with Specification A 744/A 744M.

TABLE 3 Minimum Preheat Temperatures

Grade	Minimum Preheat Temperatures	
	°F	°C
CA15, CA15M CA40, CA28MWV	400	[205]
Others	50	[10]

9. Product Marking

9.1 Castings shall be marked for material identification with the ASTM specification number (A 743/A 743M) and grade symbol, that is, CF8, CA15, CB30, etc. In addition, the manufacturer's name or identification mark and the pattern number shall be cast or stamped using the low-stress stamps on all castings. Small-size castings may be such that marking must be limited consistent with the available area. The marking of heat numbers on individual castings shall be agreed upon between the manufacturer and the purchaser. Marking shall be in such position as not to injure the usefulness of the casting.

10. Keywords

10.1 corrosion resistant; iron-chromium; iron-chromium-nickel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in A781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Magnetic Particle Examination

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S4. Ultrasonic Examination

S5. Examination of Weld Preparation

S6. Certification

S7. Prior Approval of Major Weld Repairs

S11. Intergranular Corrosion Test

S11.1 An intergranular corrosion test shall be performed in accordance with the appropriate practice for the particular grade involved, as listed in Practices A 262, or as agreed upon with the purchaser. Intergranular corrosion tests on stabilized or 0.03 % carbon maximum grades (CF3, CF3M, CF8C, and CG3M) shall be made on sensitized specimens. On all other grades of chromium-nickel steels, intergranular corrosion tests shall be made on specimens representative of the as-shipped condition.

S12 Tension Test

S12.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. The results shall conform to the requirements specified in Table S12.1.

S12.2 Test bars shall be poured in separately cast keel blocks similar to Fig. 1 or Fig. 2 or Fig. 3 of A 781.

S12.3 Tension test specimens may be cut from heat-treated castings, or from as-cast castings if no heat treatment is specified for the castings, instead of from test bars, when agreed upon between the manufacturer and the purchaser.

S12.4 Test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 4 and 5 of Test Methods and Definitions A 370, and shall be tested in accordance with Test Methods and Definitions A 370.

S12.5 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

S12.6 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S13. Post Weld-Heat Treatment

S13.1 Weld repairs shall be considered major in the case of a casting which has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All other weld repairs shall be considered minor.

S13.2 Grades CF8, CG3M, CG8M, CG12, CF20, CF8M, CF8C, CF16F, CF16Fa, CH10, CH20, CE30, CK20, CF3, CF3M, CF3MN, CN7M, CN7MS, CN3MN, CB30, CC50, CA6N, and CK3MCuN shall be heat treated after major weld repairs, but it is not required after minor repairs except by agreement between the manufacturer and the purchaser.

S14. Hardness Tests

S14.1 Brinell tests on non-austenitic grades shall be conducted. Grades CA15, CA15M, CB30, and CC50 shall have a Brinell hardness of 241 HB maximum. Grade CA6NM shall have a Brinell hardness of 285 HB maximum, Grade CA40 and CA40F, 269 HB maximum, and Grade CA28MWV, 302–352 HB, except for the annealed condition, when the Brinell hardness of this grade shall not exceed 269 HB.

S14.2 The location where the Brinell hardness reading is to be taken and the frequency of such Brinell hardness inspection of the castings shall be established by agreement between the manufacturer and the purchaser.

S15. Low Ferrite in CF8

S15.1 When low ferrite or non-magnetic properties are required, the mechanical property requirements and volume fraction of ferrite as determined by S 31, A 890/A 890M, shall be by agreement between the manufacturer and the purchaser.

TABLE S12.1 Tensile Requirements

Grade	Type	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. [50 mm], min, %[A]	Reduction of Area, min, %
		ksi	[MPa]	ksi	[MPa]		
CF8	19 Chromium, 9 Nickel	70[B]	[485][B]	30[B]	[205][B]	35	...
CG12	22 Chromium, 12 Nickel	70	[485]	28	[195]	35	...
CF20	19 Chromium, 9 Nickel	70	[485]	30	[205]	30	...
CF8M	19 Chromium, 10 Nickel, with Molybdenum	70	[485]	30	[205]	30	...
CF8C	19 Chromium, 10 Nickel with Columbium	70	[485]	30	[205]	30	...
CF16F and CF16Fa	19 Chromium, 9 Nickel, Free Machining	70	[485]	30	[205]	25	...
CH20 and CH10	25 Chromium, 12 Nickel	70	[485]	30	[205]	30	...
CK20	25 Chromium, 20 Nickel	65	[450]	28	[195]	30	...
CE30	29 Chromium, 9 Nickel	80	[550]	40	[275]	10	...
CA15 and CA15M	12 Chromium	90	[620]	65	[450]	18	30
CB30	20 Chromium	65	[450]	30	[205]	...	...
CC50	28 Chromium	55	[380]	...	...	...	...
CA40	12 Chromium	100	[690]	70	[485]	15	25
CA40F	12 Chromium, Free Machining	100	[690]	70	[485]	12	...
CF3	19 Chromium, 9 Nickel	70	[485]	30	[205]	35	...
CF10SMnN	17 Chromium, 8.5 Nickel with Nitrogen, 9 Nickel	85	[585]	42	[290]	30	...
CF3M	19 Chromium, 10 Nickel, with Molybdenum	70	[485]	30	[205]	30	...
CF3MN	19 Chromium, 10 Nickel, with Molybdenum, and Nitrogen	75	[515]	37	[255]	35	...
CG6MMN	Chromium-Nickel-Manganese-Molybdenum	85	[585]	42	[290]	30	...
CG3M	19 Chromium, 11 Nickel, with Molybdenum	75	[515]	35	[240]	25	. . .
CG8M	19 Chromium, 11 Nickel, with Molybdenum	75	[520]	35	[240]	25	...
CN3M		63	[435]	25	[170]	30	...
CN3MN	21 Chromium, 24 Nickel, with Molybdenum, and Nitrogen	80	[550]	38	[260]	35	...
CN7M	20 Chromium, 29 Nickel, with Copper and Molybdenum	62	[425]	25	[170]	35	...
CN7MS	19 Chromium, 24 Nickel, with Copper and Molybdenum	70	[485]	30	[205]	35	...
CA6NM	12 Chromium, 4 Nickel	110	[755]	80	[550]	15	35
CA6N	11 Chromium, 7 Nickel	140	[965]	135	[930]	15	50
CA28MWV[C]	12 Chromium, with Molybdenum, Tungsten, and Vanadium	140	[965]	110	[760]	10	24
CK3MCuN	20 Chromium 18 Nickel, with Copper and Molybdenum	80	[550]	38	[260]	35	...
CK35MN	23 Chromium, 21 Nickel, with Molybdenum and Nitrogen	83	[570]	41	[280]	35	...
CB6	16 Chromium, 4 Nickel	115	[790]	85	[580]	16	35

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[B] For low ferrite or nonmagnetic castings of this grade, the following values shall apply: tensile strength, min, 65 ksi [450 MPa]; yield point, min, 28 ksi [195 MPa].
[C] These mechanical properties apply only when heat-treatment (1) has been used.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 743/A 743M – 98a) that may impact the use of this standard.

(1) UNS numbers were added to Table 2 and removed elsewhere.

(2) Hyphens were deleted from alloy designations.

Designation: A 790/A 790M – 05b

Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 790/A 790M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification[2] covers seamless and straight-seam welded ferritic/austenitic steel pipe intended for general corrosive service, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 Optional supplementary requirements are provided for pipe when a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.3 Appendix X1 of this specification lists the dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the *M* designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as nominal diameter, size, and nominal size.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys and Feroalloys

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI Standards:*[4]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *SAE Standard:*[5]

SAE J 1086

2.4 *Other Standard:*[6]

SNT-TC-1A Personal Qualification and Certification in Nondestructive Testing

2.5 *AWS Standard*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminology A 941.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (ferritic/austenitic steel pipe),

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

Current edition approved September 15, 2005. Published October 2005. Originally approved in 1981. Last previous edition approved in 2005 as A 790/A 790M – 05a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA–790 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

[6] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

***A Summary of Changes section appears at the end of this standard.**

4.1.3 Process (seamless or welded),
4.1.4 Grade (see Table 1),
4.1.5 Size (NPS designator or outside diameter and schedule number of average wall thickness),
4.1.6 Length (specific or random) (see Section 11),
4.1.7 End finish (section on ends of Specification A 999/A 999M),
4.1.8 Optional requirements (product analysis, Section 9; hydrostatic test or nondestructive electric test, Section 14),
4.1.9 Test report required (section on certification of Specification A 999/A 999M),
4.1.10 Specification designation, and
4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Manufacture*:

6.1.1 The pipe shall be made by the seamless or an automatic welding process, with no addition of filler metal in the welding operation.

6.1.2 At the manufacturer's option, pipe may be either hot-finished or cold-finished.

6.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

6.2 *Discard*—A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

6.3 All pipe shall be furnished in the heat-treated condition as shown in Table 1. For seamless pipe, as an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes shall be individually quenched in water or rapidly cooled by other means, except for UNS S32950, which shall be air cooled.

TABLE 1 Heat Treatment

UNS Designation	Temperature °F [°C]	Quench
S31200	1920–2010 [1050–1100]	Rapid cooling in water
S31260	1870–2010 [1020–1100]	Rapid cooling in air or water
S31500	1800–1900 [980–1040]	Rapid cooling in air or water
S31803	1870–2010 [1020–1100]	Rapid cooling in air or water
S32003	1850–2050 [1010–1120]	Rapid cooling in air or water
S32101	1870 [1020]	Quenched in water or rapidly cooled by other means
S32205	1870–2010 [1020–1100]	Rapid cooling in air or water
S32304	1700–1920 [925–1050]	Rapid cooling in air or water
S32520	1975–2050 [1080–1120]	Rapid cooling in air or water
S32550	1900 [1040] min	Rapid cooling in air or water
S32707	1975–2050 [1080–1120]	Rapid cooling in air or water
S32750	1880–2060 [1025–1125]	Rapid cooling in air or water
S32760	2010–2085 [1100–1140]	Rapid cooling in air or water
S32808	1920–2100 [1050–1150]	Rapid cooling in air or water
S32900	1700–1750 [925–955]	Rapid cooling in air or water
S32906	1870–2100 [1020–1150]	Rapid cooling in air or water
S32950	1820–1880 [990–1025]	Air cool
S39274	1920–2060 [1025–1125]	Rapid cooling in air or water
S39277	1975–2155 [1080–1180]	Rapid cooling in air or water

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements as prescribed in Table 2.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified.

9. Product Analysis

9.1 At the request of the purchaser's inspector, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot, shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

9.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.3 If the analysis of one of the tests specified in 8.1 or 9.1 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

10. Tensile and Hardness Properties

10.1 The material shall conform to the tensile and hardness properties prescribed in Table 3.

11. Lengths

11.1 Pipe lengths shall be in accordance with the following regular practice:

11.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft (see Note 2) with the permissible range of 15 to 24 ft (see Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

TABLE 2 Chemical Requirements[A]

UNS Designation[B]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31200	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	0.14–0.20	. . .	. . .
S31260	0.030	1.00	0.030	0.030	0.75	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31500	0.030	1.20–2.00	0.030	0.030	1.40–2.00	4.2–5.2	18.0–19.0	2.50–3.00	0.05–0.10	. . .	. . .
S31803	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	. . .	. . .
S32003	0.030	2.00	0.030	0.020	1.00	3.0–4.0	19.5-22.5	1.50–2.00	0.14–0.20	. . .	. . .
S32101	0.040	4.0–6.0	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	0.20–0.25	0.10–0.80	. . .
S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.14–0.20	. . .	. . .
S32304	0.030	2.50	0.040	0.040	1.00	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	. . .
S32520	0.030	1.5	0.035	0.020	0.80	5.5–8.0	24.0–26.0	3.0–5.0	0.20–0.35	0.5–3.00	. . .
S32550	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32707	0.030	1.50	0.035	0.010	0.50	5.5–9.5	26.0–29.0	4.0–5.0	0.30–0.50	1.0	Co 0.5–2.0
S32750	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.5	. . .
S32760	0.05	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00 40 min[C]
S32808	0.030	1.10	0.030	0.030	0.50	7.0–8.2	27.0–27.9	0.80–1.20	0.30–0.40	. . .	W 2.10–2.50
S32900	0.08	1.00	0.040	0.030	0.75	2.5–5.0	23.0–28.0	1.00–2.00	. . .	. . .	. . .
S32906	0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.50–2.60	0.30–0.40	0.80	. . .
S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	. . .	. . .
S39274	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
S39277	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	0.23–0.33	1.20–2.00	W 0.8–1.2

[A] Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.

[B] New designation established in accordance with Practice E 527 and SAE J1086.

[C] % Cr + 3.3 × % Mo + 16 × % N.

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max	
				HBW	HRC
S31200	100 [690]	65 [450]	25	280	. . .
S31260	100 [690]	65 [450]	25	. . .	. . .
S31500	92 [630]	64 [440]	30	290	30
S31803	90 [620]	65 [450]	25	290	30
S32003	90 [620]	65 [450]	25	290	30
S32101					
t ≤ 0.187 in. [5.00 mm]	101 [700]	77 [530]	30	290	. . .
t > 0.187 in. [5.00 mm]	94 [650]	65 [450]	30	290	. . .
S32205	95 [655]	65 [450]	25	290	30
S32304	87 [600]	58 [400]	25	290	30
S32520	112 [770]	80 [550]	25	310	. . .
S32550	110 [760]	80 [550]	15	297	31
S32707	133 [920]	101 [700]	25	318	34
S32750	116 [800]	80 [550]	15	300	32
S32760[A]	109 [750]	80 [550]	25	270	. . .
S32808	116 [800]	80 [550]	15	310	32
S32900	90 [620]	70 [485]	20	271	28
S32906					
Wall below 0.40 in. (10 mm)	116 [800]	94 [650]	25	300	32
Wall 0.40 in. (10 mm) and above	109 [750]	80 [550]	25	300	32
S32950	100 [690]	70 [480]	20	290	30
S39274	116 [800]	80 [550]	15	310	. . .
S39277	120 [825]	90 [620]	25	290	30

[A] Prior to A 790/A 790M – 04, the tensile strength value for UNS 32760 was 109–130 ksi [750–895 MPa].

NOTE 2—This value applies when the inch-pound designation of this specification is the basis of purchase. When the *M* designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

11.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be less than the specified length and no more than ¼ in. [6 mm] over it.

11.1.3 No jointers are permitted unless otherwise specified.

12. Workmanship, Finish, and Appearance

12.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted, in the Permissible Variations in Wall Thickness Section of Specification A 999/A 999M.

13. Mechanical Tests Required

13.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from 2 pipes for lots of more than 100 pipes.

13.2 *Mechanical Testing Lot Definition* —The term *lot* for mechanical tests applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the same heat of steel and subjected to the same finishing treatment as defined as follows:

13.2.1 Where the heat treated condition is obtained, consistent with the requirements of 6.3, in a continuous heat treatment furnace or by directly obtaining the heat treated condition by quenching after hot forming, the lot shall include all pipe of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed or all pipe of the same size and heat, hot formed and quenched in the same production run.

13.2.2 Where final heat treatment is obtained, consistent with the requirements of 6.3, in a batch-type heat-treatment furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or smaller range, the lot shall be the larger of (a) each 200 ft [60 m] or fraction thereof or (b) that pipe heat treated in the same batch furnace charge.

13.2.3 Where the final heat treatment is obtained, consistent with the requirements of 6.3, in a batch-type heat-treatment furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or smaller range, the term *lot* for mechanical tests applies to the pipe heat treated in the same batch furnace charge, provided that such pipe is of the same nominal size and wall thickness (or schedule) and is produced from the same heat of steel.

13.3 *Flattening Test*—For pipe heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For pipe heat treated by the continuous process, or by direct quenching after hot forming, this test shall be made on a sufficient number of pipes to constitute 5 % of the lot, but in no case less than two lengths of pipe.

13.3.1 For welded pipe with a diameter equal to or exceeding NPS 10, a transverse guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipes or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two pipes from each lot (see 13.2).

14. Hydrostatic or Nondestructive Electric Test

14.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

14.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M, except that the value for S to be used in the calculation of the hydrostatic test pressure shall be equal to 50 % of the specified minimum yield strength of the pipe.

14.3 *Nondestructive Electric Test*:

Nondestructive electric tests shall be in accordance with Practices E 213 or E 309.

14.3.1 As an alternative to the hydrostatic test, and when specified by the purchaser, each pipe shall be examined with a nondestructive test in accordance with Practices E 213 or E 309. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

14.3.1.1 The following information is for the benefit of the user of this specification:

14.3.1.2 The reference standards defined in 14.3.1.3-14.3.1.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

14.3.1.3 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

14.3.1.4 The eddy-current testing (ET) referenced in this specification (see Practice E 426) has the capability of detecting significant discontinuities, especially the short abrupt type.

14.3.1.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

14.4 *Time of Examination*—Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

14.5 *Surface Condition*:

14.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

14.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

14.6 *Extent of Examination*:

14.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 14.6.2.

14.6.2 The existence of end effects is recognized and the extent of such effects shall be determined by the manufacturer and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

14.7 *Operator Qualifications*—The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

14.8 *Test Conditions*:

14.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

14.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max
On specified walls up to 0.150 in.—50 KHz max
On specified walls over 0.150 in.—10 KHz max

14.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in. If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

14.9 *Reference Standards*—Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

14.9.1 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12 ½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

14.9.2 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

14.9.2.1 *Drilled Hole*— The reference standard shall contain three or more holes equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
	0.039 in. (1 mm)
above ½ to 1¼	0.055 in. (1.4 mm)
above 1¼ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

14.9.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. (6.4-mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12 ½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.9.2.3 *Longitudinal Notch*—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe to have a depth not exceeding 12 ½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

14.10 *Standardization Procedure*:

14.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness, grade, and heat treatment condition), and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

14.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown, or when a problem is suspected.

14.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

14.10.4 The signal-to-noise ratio for the reference standard shall be 2 ½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, and so forth shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

14.10.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed or the transducer(s), coil(s), or sensor(s) adjusted and the unit restandardized. But all pipe tested since the last acceptable standardization must be retested for acceptance.

14.11 *Evaluation of Imperfections*:

14.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

14.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 12 and 13. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

14.11.3 If the test signals were produced by visual imperfections such as: (*1*) scratches, (*2*) surface roughness, (*3*) dings, (*4*) straightener marks, (*5*) cutting chips, (*6*) steel die stamps, (*7*) stop marks, or (*8*) pipe reducer ripple. The pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. (0.1 mm) or 12 ½ % of the specified wall thickness (whichever is greater).

14.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

14.11.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

15. Repair by Welding

15.1 For welded pipe of size NPS 6 or larger with a specified wall thickness of 0.188 in. [4.8 mm] or more, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedures specified for plate defects in the section on Repair by Welding of Specification A 999/A 999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Except as allowed by 15.3.1, weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filter rod qualified to the most current AWS Specification A5.9 as the grade of pipe being repaired as given in Table 4.

15.3.1 Subject to approval by the purchaser, it shall be permissible for weld repairs to be made with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal, if needed for corrosion resistance or other properties.

TABLE 4 Pipe and Filler Metal Specification

Pipe	Filler Metal	
UNS Designation	AWS A5.9 Class	UNS Designation
S31803	ER2209	S39209
S32205	ER2209	S39209
S31200	ER2553	S39553

15.4 Pipes that have had weld seam repairs with filler metal shall be identified with the symbol "WR" and shall be so stated and identified on the certificate of tests. If filler metal other than that listed in Table 4 is used, the filler metal shall be identified on the certificate of tests.

15.5 Weld repairs shall be completed prior to any heat treatment.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the manufacturer's private identifying mark and whether the pipe is seamless or welded. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

17. Keywords

17.1 duplex stainless steel; ferritic/austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTSFOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe over NPS 5 there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe over NPS 8.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crops ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

APPENDIX

(Nonmandatory Information)

X1. Table X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI B36.19-1965)

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	. . .	. . .	0.049[B]	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	. . .	. . .	0.065[B]	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	. . .	. . .	0.065[B]	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065[B]	1.65	0.083[B]	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065[B]	1.65	0.083[B]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[B]	1.65	0.109[B]	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065[B]	1.65	0.109[B]	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065[B]	1.65	0.109[B]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[B]	1.65	0.109[B]	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120[B]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[B]	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120[B]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[B]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[B]	2.77	0.134[B]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[B]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[B]	2.77	0.148[B]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[B]	3.40	0.165[B]	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156[B]	3.96	0.180[B]	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156[B]	3.96	0.188	4.78	. . .	. . .	. . .	. . .
16	16.000	406.40	0.165[B]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
18	18.000	457.20	0.165[B]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
20	20.000	508.00	0.188[B]	4.78	0.218[B]	5.54	. . .	. . .	. . .	. . .
22	22.000	558.80	0.188[B]	4.78	0.218[B]	5.54	. . .	. . .	. . .	. . .
24	24.000	609.60	0.218[B]	5.54	0.250	6.35	. . .	. . .	. . .	. . .
30	30.000	762.00	0.250	6.35	0.312	7.92	. . .	. . .	. . .	. . .

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 790/A 790M – 05, that may impact the use of this specification. (Approved September 15, 2005)

(*1*) Revised Si content in Table 2 for UNS S32906 from 0.50 % to 0.80 %.
(*2*) Changed the annealing temperature for UNS S32906 in Table 1 from 1900–1980 °F [1040–1080°C] to 1870–2100 °F [1020–1150 °C].
(*3*) Added Austenitic-Ferritic Grade UNS S32707 to Tables 1-3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 790/A 790M – 05, that may impact the use of this specification. (Approved June 1, 2005)

(*1*) Added new Grade S32808 to Tables 1-3.
(*2*) Editorially corrected Tables 1-3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 790/A 790M – 04a, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Added stainless steel 32101 to Tables 1-3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 790/A 790M – 04, that may impact the use of this specification. (Approved June 1, 2004)

(*1*) Revised Table 3 to remove the maximum tensile strength value for grade S32760.

(*2*) Revised quenching requirement for S31260 in Table 1.

(*3*) Section 15 and Table 4 were added to cover weld seam repair by welding with addition of filler metal.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 790/A 790M – 03, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Corrected editorial mistake in the Silicon value for S32906 in Table 2.
(*2*) Revised tensile strength for S32205 in Table 3.
(*3*) Changed Note 3 to paragraph 13.2.
(*4*) Added direct quenching after hot forming option to new paragraph 13.2, clarified lot definition, and renumbered paragraph 13.3.

(*5*) Changed "may" to "shall" and added water quench/rapid cooled exclusion for UNS 32950 in paragraph 6.3.

Standard Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application[1]

This standard is issued under the fixed designation A 890/A 890M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers a group of cast duplex stainless steels (austenitic/ferritic).

1.2 The duplex stainless steel alloys offer a combination of enhanced mechanical properties and corrosion resistance when properly balanced in composition and properly heat treated. Ferrite levels are not specified, but these alloys will develop a range of approximately 30 to 60 % ferrite with the balance austenite.

1.3 The values stated in either inch-pound units or metric (SI) units are to be regarded separately as standard. Within the text the metric (SI) units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 732/A732M Specification for Castings, Investment, Carbon and Low-Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[4]

E 562 Practice for Determining Volume Fraction by Systematic Manual Point Count[5]

E 1245 Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis[5]

3. Ordering Information

3.1 Orders for material to this specification shall include the following, as required, to describe the material adequately:

3.1.1 Description of casting by pattern or drawing number (dimensional tolerance shall be included on the casting drawing),

3.1.2 Specification designation and grade including year of issue,

3.1.3 Options in the specification (See 9.1), and

3.1.4 Supplementary requirements desired, including the standards of acceptance.

4. Process

4.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD).

5. Heat Treatment

5.1 Castings shall be heat treated in accordance with the requirements in Table 1.

NOTE 1—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
1A, 1B, 1C	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
2A	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
3A	Heat to 1950°F [1070°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
4A	Heat to 2050°F [1120°C] minimum for sufficient time to heat casting uniformly to temperature and water quench, or the casting may be furnace cooled to 1850°F [1010°C] minimum, hold for 15 min minimum and then water quench. A rapid cool by other means may be employed in lieu of water quench.
5A	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting to temperature, furnace cool to 1910°F [1045°C] minimum, quench in water or rapid cool by other means.
6A	Heat to 2010°F [1100°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or cool rapidly by other means.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Oct. 1, 2003. Published October 2003. Originally approved in 1988. Last previous edition approved in 1999 as A 890/A 890M – 99.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

7. General Requirements

7.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

8. Repair by Welding

8.1 The composition of the deposited weld metal may be similar to that of the casting or may be suitably alloyed to achieve the desired corrosion resistance and mechanical properties.

8.2 Weld repairs shall be subject to the same quality standards as are used to inspect the castings.

8.3 When post weld/heat treatment is believed necessary for adequate corrosion resistance or impact resistance, Supplementary Requirement S33 Post Weld/Heat Treatment shall be included in the purchase order.

9. Product Marking

9.1 Castings shall be marked for material identification with the specification designation and grade. In addition, the manufacturer's name or identification mark and the pattern number shall be cast or stamped using low-stress stamps on all castings. Small-size castings may be such that marking must be limited consistent with the available area. The marking of heat numbers on individual castings shall be agreed upon between the manufacturer and the purchaser. Marking shall be in such position as not to injure the usefulness of the casting.

10. Keywords

10.1 austenite; duplex stainless steel; ferrite; stainless steel; steel castings

TABLE 2 Chemical Requirements

Grade	1A	1B	1C[A]	2A
Type	25Cr-5Ni-Mo-Cu	25Cr-5Ni-M0-Cu-N	25Cr-6Ni-Mo-Cu-N	24Cr-10Ni-Mo-N
UNS	J93370	J93372	J93373	J93345
ACI	CD4MCu	CD4MCuN	CD3MCuN	CE8MN
Composition:				
Carbon, max	0.04	0.04	0.030	0.08
Manganese, max	1.00	1.0	1.20	1.00
Silicon, max	1.00	1.0	1.10	1.50
Phosphorus, max	0.040	0.04	0.030	0.04
Sulfur, max	0.040	0.04	0.030	0.04
Chromium	24.5–26.5	24.5–26.5	24.0-26.7	22.5–25.5
Nickel	4.75–6.00	4.7–6.0	5.6-6.7	8.0–11.0
Molybdenum	1.75–2.25	1.7–2.3	2.9-3.8	3.0–4.5
Copper	2.75–3.25	2.7–3.3	1.40-1.90	. . .
Tungsten	. . .	. . .	. . .	. . .
Nitrogen		0.10–0.25	0.22-0.33	0.10–0.30

Grade	3A	4A	5A[A]	6A[A]
Type	25Cr-5Ni-Mo-N	22Cr-5Ni-Mo-N	25Cr-7Ni-Mo-N	25Cr-7Ni-Mo-N
UNS	J93371	J92205	J93404	J93380
ACI	CD6MN	CD3MN	CE3MN	CD3MWCuN
Composition:				
Carbon, max	0.06	0.03	0.03	0.03
Manganese, max	1.00	1.50	1.50	1.00
Silicon, max	1.00	1.00	1.00	1.00
Phosphorus, max	0.040	0.04	0.04	0.030
Sulfur, max	0.040	0.020	0.04	0.025
Chromium	24.0–27.0	21.0–23.5	24.0–26.0	24.0–26.0
Nickel	4.0–6.0	4.5–6.5	6.0–8.0	6.5–8.5
Molybdenum	1.75–2.5	2.5–3.5	4.0–5.0	3.0–4.0
Copper	. . .	1.00, max	. . .	0.5–1.0
Tungsten	. . .	. . .	. . .	0.5–1.0
Nitrogen	0.15–0.25	0.10–0.30	0.10–0.30	0.20–0.30

[A] % Cr + 3.3 % Mo + 16 % N $\geq$ 40.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those that are ordinarily considered suitable for use with this specification are listed below by title only. Others enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S5. Examination of Weld Preparation

S6. Certification

S7. Prior Approval of Major Weld Repairs

S9. Charpy Impact Test

S10. Hardness Test

S12. Test Report

S13. Unspecified Elements

S31. Estimating Ferrite Content

S31.1 Ferrite contents shall be determined by point count (Practice E 562), by other quantitative metallographic methods such as image analysis (Practice E 1245), by measurement of magnetic response, or by other methods upon agreement between the manufacturer and the purchaser. Frequency of testing and location of tests shall be by agreement between the manufacturer and the purchaser.

S32. Tensile Requirements

S32.1 One tensile test shall be made from each heat and shall conform to the tensile requirements specified in Table S32.1. Test bars shall be poured in special blocks from the same heat as the castings represented. (See S32.4.)

S32.2 The bar from which the test specimen is removed shall be heat-treated in production furnaces to the same procedure as the castings it represents.

S32.3 Test specimens may be cut from heat-treated castings, at the producer's option, instead of from test bars.

S32.4 Test coupons may be cast integrally or as separate cast blocks in accordance with Figs. 1 and 2 of Specification A 781/A 781M. Tension coupons shall be machined to the form and dimensions of Fig. 4 of Test Methods and Definitions A 370, except when investment castings are ordered. When investment castings are ordered, the manufacturer may prepare

TABLE S32.1 Tensile Requirements

Grade	1A	2A	3A	4A
Type	25Cr-5Ni-Mo-Cu	24Cr-10Ni-Mo-N	25Cr-5Ni-Mo-N	22Cr-5Ni-Mo-N
Tensile strength, ksi [MPa], min	100 [690]	95 [655]	95 [655]	90 [620]
Yield strength (0.2 % offset), ksi [MPa], min	70 [485]	65 [450]	65 [450]	60 [415]
Elongation in 2 in. [50 mm], %, min[A]	16	25	25	25
Grade	5A	6A	1B	1C
Type	25Cr-7Ni-Mo-N	25Cr-7Ni-Mo-N	25Cr-5Ni-Mo-Cu-N	25Cr-6Ni-Mo-Cu-N
Tensile strength, ksi [MPa], min	100 [690]	100 [690]	100 [690]	100 [690]
Yield strength (0.2 % offset), ksi [MPa], min	75 [515]	65 [450]	70 [485]	65 [450]
Elongation in 2 in. [50 mm], %, min[A]	18	25	16	25

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.

test specimens in accordance with S3.2 of Specification A 732/A 732M. Testing shall be in accordance with Test Methods and Definitions A 370.

S32.5 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heat.

S32.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

S33. Post Weld/Heat Treatment

S33.1 Castings shall be heat-treated after major weld repairs, but heat treatment after minor weld repairs is not required except upon agreement between the manufacturer and the purchaser.

S33.2 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic testing or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2}[65 cm^2]. All other weld repairs shall be considered minor.

S33.3 Post weld heat treatment shall be in accordance with Table 1.

S34. Prior Approval of Weld Material

S34.1 The purchaser must give approval of all weld filler materials to be used prior to any weld repairs.

S35. Heat Treatment of Test Material

S35.1 Test material for each heat shall be heat-treated with the castings it represents.

Designation: A 400 – 69 (Reapproved 2006)

Standard Practice for Steel Bars, Selection Guide, Composition, and Mechanical Properties[1]

This standard is issued under the fixed designation A 400; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers the selection of steel bars according to section and to the mechanical properties desired in the part to be produced. This is not a specification for the procurement of steel. Applicable procurement specifications are listed in Section 5.

1.2 Several steel compositions intended for various sections and mechanical property requirements are presented in Tables 1-6. The criteria for placing a steel composition in one of the three general class designations, Classes P, Q, and R (described in Section 4) are as follows:

1.2.1 *Classes P and Q* should be capable of developing the mechanical properties shown in Tables 1-4 by liquid quenching from a suitable austenitizing temperature, and tempering at 800°F (427°C) or higher. A hardness indicated by tests made at a location shown in Fig. 1, A, B, or C, is taken as evidence that a composition is capable of meeting other equivalent mechanical properties shown in the tables. Normal good shop practices are assumed, with control of austenitizing and tempering temperatures, and mild agitation of the part in the quenching bath.

1.2.2 *Class R* should be capable of developing the mechanical properties shown in Tables 5 and 6 as hot rolled, by cold drawing, or by cold drawing with additional thermal treatment. The locations for obtaining tension tests are described in 6.2.

1.3 It is not implied that the compositions listed in the tables are the only ones satisfactory for a certain class and mechanical property requirement. Steels with lower alloy contents are often satisfactory through the use of special processing techniques.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 108 Specification for Steel Bar, Carbon and Alloy, Cold-Finished

A 304 Specification for Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements

A 311/A 311M Specification for Cold-Drawn, Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements

A 322 Specification for Steel Bars, Alloy, Standard Grades

A 633/A 633M Specification for Normalized High-Strength Low-Alloy Structural Steel Plates

A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties

3. Significance and Use

3.1 If the desired mechanical properties are as described in 4.1.1 for material identified as Classes P-1 through P-7, or in 4.1.2 for material identified as Classes Q-1 through Q-7, the strength level desired can be based on hardness or the equivalent tensile or yield strength as shown in Tables 1-4. If the desired mechanical properties are as set forth in 4.1.3 for material identified as Classes R-1 through R-6, the strength level is based on yield strength as shown in Tables 5 and 6.

3.2 The user, after determining the mechanical property requirements of the critical section (that carrying the greatest stress) of the part, should select the composition or compositions from Tables 1-6 that fulfills these requirements and is most suitable for processing.

4. Classification

4.1 Steel bar compositions under this practice are classified according to mechanical property requirements and the critical section size of the part to be produced, as follows:

4.1.1 *Classes P-1 through P-7* comprise bars for parts to operate under severe service conditions requiring high yield

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.15 on Bars.

Current edition approved March 1, 2006. Published April 2006. Originally approved in 1956. Last previous edition approved in 2000 as A 400 – 69 (2000).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 1 Steels for Moderately Quenched Parts—Classes P-1 Through P-7
(Applicable to oil-quenching or equivalent rate of heat-removal.)

NOTE 1—Steels listed as approved for a certain section or strength may be used for lighter sections and lower strengths.

NOTE 2—Steel composition numbers correspond to SAE, AISI, or ASTM designations. Those in italics are no longer considered standard grades due to decreased usage.

NOTE 3—An H-steel with the same grade designation as a standard SAE-AISI steel is capable of meeting the same section and strength requirements as the standard steel (see Specification A 304), and is the preferred method of specification.

NOTE 4—Steels having a maximum carbon content of 0.40 % or over, or a hardness of HB 293 or over after heat-treating, are not recommended for applications involving welding.

Desired Minimum Hardness		Equivalent Tensile Strength, psi[A]	Equivalent Yield Strength, psi[A]	Minimum[B] As-Quenched Hardness		Class							
						P-1		P-2	P-3	P-4	P-5	P-6	P-7
						Diameter of Round (or Distance Between Faces of Square or Hexagonal) Sections, in.[C]							
						To ½ , incl		Over ½ to 1, incl	Over 1 to 1½ , incl	Over 1½ to 2, incl	Over 2 to 2½ , incl	Over 2½ to 3, incl	Over 3 to 3½ , incl
						Thickness of Flat Sections, in.[C]							
HB	HRC			HB	HRC	To 0.3, incl		Over 0.3 to 0.6, incl	Over 0.6 to 1, incl	Over 1 to 1.3, incl	Over 1.3 to 1.6, incl	Over 1.6 to 2.0, incl	Over 2.0 to 2.3, incl
229 to 293, incl	20 to 33, incl	110 000 to 145 000, incl	90 000 to 125 000, incl	388	42	1330 4130 5132 8630	 *50B30*						
Over 293 to 341, incl	Over 33 to 38, incl	Over 145 000 to 170 000, incl	Over 125 000 to 150 000, incl	409	44	1335 *3135* 4042 5135	94B30	*3140* *4135* *4640* 8640 8740	4137		4142	9840	4337
Over 341 to 388, incl	Over 38 to 42, incl	Over 170 000 to 190 000, incl	Over 150 000 to 170 000, incl	455	48	1340 *3140* 4047 *4135* 5140 8637 *TS14B50* *50B40*		4137 *6145* 8642 8645 *8742*	4140 *TS4140* 94B40		4145 9840	4147 *4337* *86B45*	4340
Over 388 to 429, incl	Over 42 to 45, incl	Over 190 000 to 205 000, incl	Over 170 000 to 185 000, incl	496	51	1345 *4063* *4068* 4140 *4640* 5145 5150 8640 8642	8645 8740 *8742* 9260 *9261* *TS4140* 50B46 50B44 50B50	5147 5155 5160 6150 *9262* *94B40*	4142 4145 *4337* *8650* 8655 50B60 51B60 81B45	*8660* *9840*	4147 4161 4340 *86B45*	4150 4161 *TS4150*	E4340 *9850*

[A] 1 psi = 0.006895 MPa.
[B] Minimum as-quenched hardness for obtaining desired hardness after tempering at 800°F (427°C) or higher.
[C] 1 in. = 25.4 mm.

strength (90 000 psi (621 MPa) and over), good ductility, and relatively high notch toughness. The applicable section sizes, identified as Classes P-1 through P-7, are shown in Table 7. The steel compositions suitable for Classes P-1 through P-7 and for various desired mechanical properties are listed in Tables 1 and 2.

4.1.2 *Classes Q-1 through Q-7* comprise bars for parts operating under moderate service conditions requiring moderate to high yield strength (75 000 to 185 000 psi (517 to 1276 MPa)), corresponding tensile-strength levels, and good ductility. The applicable section sizes, identified as Classes Q-1 through Q-7, are shown in Table 7. The steel compositions suitable for Classes Q-1 through Q-7 and various desired mechanical properties are listed in Tables 3 and 4.

4.1.3 *Classes R-1 through R-6* comprise bars for parts requiring a lower yield strength (30 000 to 120 000 psi (207 to 827 MPa)), with fair to good ductility. The applicable section sizes, identified as Classes R-1 through R-6, are shown in Table 7. The steel compositions capable of developing the various desired mechanical properties are listed in Tables 5 and 6.

5. Applicable Procurement Specifications

5.1 For procurement of steel, it is recommended that the following ASTM specifications of latest issue be used: Specification A 108, Specification A 304, Specification A 311/A 311M, Specification A 322, Specification A 633/A 633M, and Specification A 675/A 675M.

TABLE 2 Steels for Drastically Quenched Parts—Classes P-1 Through P-7
(Applicable to water-quenching or equivalent rate of heat-removal — See Note 5)

NOTE 1—Steels listed as approved for heavier sections or higher strengths may be used in the same conditions for lighter sections and lower strengths.

NOTE 2—Steel composition numbers correspond to ASE, AISI, or ASTM designations. Those in italics are no longer considered standard grades due to decreased usage.

NOTE 3—An H-steel with the same grade designation as a standard SAE-AISI steel is capable of meeting the same section and strength requirements as the standard steel (see Specification A 304), and is the preferred method of specification.

NOTE 4—Steels having a maximum carbon content of 0.40 % or over, or a hardness of HB 293 or over after heat-treating, are not recommended for applications involving welding.

NOTE 5—Parts made of steel with a carbon content of 0.33 % or higher, where the section is under 1 1/2 in. (38.1 mm) should not be quenched in water without careful exploration for quench-cracking.

Desired Minimum Hardness		Equivalent Tensile Strength, psi^A	Equivalent Yield Strength, psi^A	Minimum^B As-Quenched Hardness		Class						
						P-1	P-2	P-3	P-4	P-5	P-6	P-7
						Diameter of Round (or Distance Between Faces of Square or Hexagonal) Sections, in.^{C}						
						To ½ , incl	Over ½ to 1, incl	Over 1 to 1½ , incl	Over 1½ to 2, incl	Over 2 to 2½ , incl	Over 2½ to 3, incl	Over 3 to 3½ , incl
						Thickness of Flat Sections, in.^{C}						
HB	HRC			HB	HRC	To 0.3, incl	Over 0.3 to 0.6, incl	Over 0.6 to 1.0, incl	Over 1.0 to 1.3, incl	Over 1.3 to 1.6, incl	Over 1.6 to 2.0, incl	Over 2.0 to 2.3, incl
229 to 293, incl	20 to 33, incl	110 000 to 145 000, incl	90 000 to 125 000, incl	388	42	8625 8627	4130 5130 8630 *50B30*	94B30				
Over 293 to 341, incl	Over 33 to 38, incl	Over 145 000 to 170 000, incl	Over 125 000 to 150 000, incl	409	44	*4032* 4037 4130 5130 8630 *TS14B35* *508B30*	1330 5132 94B30	1335 5135 5140 *50B40*		1340^D *3135*^{D} *4640* 8637^D 8640 8740	*3140* *4135*	4137 *4337* *9840*

^{A} 1 psi = 0.006895 MPa.
^{B} Minimum as-quenched hardness for obtaining desired hardness after tempering at 800°F (427°C) or higher.
^{C} 1 in. = 25.4 mm.
^{D} These steels have insufficient hardenability for Class P-4, because of difference in test locations, but are satisfactory for other smaller sizes.

6. Location at Which Desired Properties Are Obtained

6.1 *Classes P-1 Through P-7 and Q-1 Through Q-7*—The mechanical properties shown in Tables 1-4 are based on obtaining hardness test specimens from the locations shown in Fig. 1, A, B, and C. For bars, the location should be at least twice the diameter or minimum distance between faces from an end; and for flat sections, at least twice the thickness from an edge.

6.2 *Classes R-1 Through R-6*—The mechanical properties shown in Tables 5 and 6 are based on obtaining tension test specimens from the following locations:

6.2.1 Center of bars or plates under 1½ in. (38.1 mm) in diameter or in distance between parallel surfaces, and

6.2.2 Mid-radius or a quarter of the distance between parallel faces from the surface for larger sections.

7. Hardness Criteria for Quenched and Tempered Parts

7.1 *Classes Q-1 Through Q-7*—To obtain the properties stated in 4.1.2 at the locations shown in Fig. 1, A, B, and C, a microstructure containing a minimum of 50 % martensite is necessary.

8. Keywords

8.1 steel bars

TABLE 3 Steels for Moderately Quenched Parts—Classes Q-1 Through Q-7
(Applicable to oil-quenching or equivalent rate of heat-removal.)

NOTE 1—Steels listed as approved for heavier sections or higher strengths may be used in the same conditions for lighter sections and lower strengths.

NOTE 2—Steel composition numbers correspond to ASE, AISI, or ASTM designations. Those in italics are no longer considered standard grades due to decreased usage.

NOTE 3—An H-steel with the same grade designation as a standard SAE-AISI steel is capable of meeting the same section and strength requirements as the standard steel (see Specification A 304), and is the preferred method of specification.

NOTE 4—Steels having a maximum carbon content of 0.40 % or over, or a hardness of HB 293 or over after heat-treating, are not recommended for applications involving welding.

Desired Minimum Hardness		Equivalent Tensile Strength, psi[A]	Equivalent Yield Strength, psi[A]	Minimum[B] As-Quenched Hardness		Class						
						Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7
						Diameter of Round (or Distance Between Faces of Square or Hexagonal) Sections, in.[C]						
						To ½, incl	Over ½ to 1, incl	Over 1 to 1½, incl	Over 1½ to 2, incl	Over 2 to 2½, incl	Over 2½ to 3, incl	Over 3 to 3½, incl
						Thickness of Flat Sections, in.[C]						
HB	HRC			HB	HRC	To 0.3, incl	Over 0.3 to 0.6, incl	Over 0.6 to 1.0, incl	Over 1.0 to 1.3, incl	Over 1.3 to 1.6, incl	Over 1.6 to 2.0, incl	Over 2.0 to 2.3, incl
187 to 293, incl	91 (R_b) to 33, incl	95 000 to 145 000, incl	75 000 to 125 000, incl	388	42	1330 8630 4130 *50B30* 5132	8637	3140 8740	4140 *TS4140* 94B40		4142	
Over 293 to 341, incl	Over 33 to 38, incl	Over 145 000 to 170 000, incl	Over 125 000 to 150 000, incl	409	44	1335 *4042* 50B30 5135 94B30	*3140* 8740 *4135* *4640* 8640	4137 *TS4140* 4140 8642 8645 *8742*	81B45	4142	4145	4147 *4337* *9840* *86B45*
Over 341 to 388, incl	Over 38 to 42, incl	Over 170 000 to 190 000, incl	Over 150 000 to 170 000, incl	455	48	1340 8637 *3135* *TS14B50* *3140* *50B40* 4047 *4135* 5140	1345 *8742* 4137 *TS4140* 4140 50B50 5150 8642 8645	4142 *94B40* 5147 5155 6150	51B60	4145 8655 *9840*	4147 *4337* *86B45*	4150 4340 *TS4150*
Over 388 to 429, incl	Over 42 to 45, incl	Over 190 000 to 205 000, incl	Over 170 000 to 185 000, incl	496	51	1345 8645 4047 8740 *4063* *8742* *4068* 9260 4140 *TS4140* *4640* 50B46 5145 50B44 5150 50B50 8640 8642	4142 5147 5155 6150 *9261* *94B40*	4145 *4337* 5160 *8650* 8655 *9262* 50B60 51B60 81B45	*9840*	4147 4340 *8660* *86B45*	4150 *TS4150*	E4340 *9850*

[A] 1 psi = 0.006895 MPa.
[B] Minimum as-quenched hardness for obtaining desired hardness after tempering at 800°F (427°C) or higher.
[C] 1 in. = 25.4 mm.

TABLE 4 Steels for Drastically Quenched Parts—Classes Q-1 Through Q-7
(Applicable to water-quenching or equivalent rate of heat-removal—See Note 5)

NOTE 1—Steels listed as approved for heavier sections or higher strengths may be used in the same conditions for lighter sections and lower strengths.

NOTE 2—Steel composition numbers correspond to SAE, AISI, or ASTM designations. Those in italics are no longer considered standard grades due to decreased usage.

NOTE 3—An H-steel with the same grade designation as a standard SAE-AISI steel is capable of meeting the same section and strength requirements as the standard steel (see Specification A 304), and is the preferred method of specification.

NOTE 4—Steels having a maximum carbon content of 0.40 % or over, or a hardness of HB 293 or over after heat-treating, are not recommended for applications involving welding.

NOTE 5—Parts made of steel with a carbon content of 0.33 % or higher, where the section is under 1½ in. (38.1 mm) should not be quenched in water without careful exploration for quench-cracking.

Desired Minimum Hardness		Equivalent Tensile Strength, psi[A]	Equivalent Yield Strength, psi[A]	Minimum[B] As-Quenched Hardness		Class						
						Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7
						Diameter of Round (or Distance Between Faces of Square or Hexagonal) Sections, in.[C]						
						To ½, incl	Over ½ to 1, incl	Over 1 to 1½, incl	Over 1½ to 2, incl	Over 2 to 2½, incl	Over 2½ to 3, incl	Over 3 to 3½, incl
						Thickness of Flat Sections, in.[C]						
HB	HRC			HB	HRC	To 0.3, incl	Over 0.3 to 0.6, incl	Over 0.6 to 1.0, incl	Over 1.0 to 1.3, incl	Over 1.3 to 1.6, incl	Over 1.6 to 2.0, incl	Over 2.0 to 2.3, incl
187 to 293, incl	91 (HRB) to 33, incl	95 000 to 145 000, incl	75 000 to 125 000, incl	388	42	1000 series, from 1024 to 1040, incl[E] 8625 8627	4037 4130 5130 5132 8630 *50B30*	5135 94B30		5140[D] 8637 *50B40*[D]	*4640*	*3140* 8740
Over 293 to 341, incl	Over 33 to 38, incl	Over 145 000 to 170 000, incl	Over 125 000 to 150 000, incl	409	44	1036 to 1045,[E] incl *4032* 8630	1330 *5046* 5135 94B30	1335		1340[D] *3135*[D] *3140* 8637[D]	*4135* 8640 8740	4137 4140 8642 8645 *8742* *TS4140*
Over 341 to 388, incl	Over 38 to 42, incl	Over 170 000 to 190 000, incl	Over 150 000 to 170 000, incl	455	48	1335 4037 *TS14B35* 4130 *5046* *50B30* 5130 5132 5135 94B30 *8635*	*3135* *4042* 4047	1340 *3140* *4135* 5140 8637 *50B40*		1345 50B44[D] 4137 *4640*[D] 5145[D] 5150 8640[D] 8642 8740[D] 50B50	4140 8645 *8742* *TS4140*	4142 *4337* 5147 6150 *8650* *9840* 81B45 *94B40*

[A] 1 psi = 0.006895 MPa.
[B] Minimum as-quenched hardness for obtaining desired hardness after tempering at 800°F (427°C) or higher.
[C] 1 in. = 25.4 mm.
[D] These steels have insufficient hardenability for Class Q-4 parts because of different location of test specimens, but are satisfactory for smaller sections.
[E] For these steels, the yield to tensile-strength ratio will usually be lower than 80 %.

TABLE 5 Steels for Parts Manufactured From Hot Rolled[A] and Cold Drawn[B,C] Bars—Classes R-1 Through R-6

NOTE 1—Steels listed as approved for heavier section or higher strengths may be used in the same conditions for lighter sections and lower strengths.

NOTE 2—Steel composition numbers correspond to ASE, AISI, or ASTM designations. Those in italics are no longer considered standard grades due to decreased usage. Hot-rolled 1000 series steels with a maximum carbon content of 0.40 % only are approved for welding. Only cold-drawn 1000 series steels used in the strength level and section thickness for which hot-rolled steels of the same composition are approved may be welded, and in this case caution should be exercised to see that excessive grain growth does not occur in the heat-affected zone.

Desired Minimum Yield Strength, psi[D]	Class			
	R-1	R-2	R-3 and R-4	R-5 and R-6
	Diameters of Round or Approximately Round Sections, in.[E]			
	To ½ , incl	Over ½ to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl
	Thickness of Flat Sections, in.[E]			
	To 0.3, incl	Over 0.3 to 0.6, incl	Over 0.6 to 1.3, incl	Over 1.3 to 2.0, incl
Over 30 000 to 35 000, incl	HR 1016 HR 1020 HR 1018 HR 1019	HR 1016 HR 1020 HR 1018 HR 1022 HR 1019	HR 1018 HR 1019 HR 1021	HR 1018 HR 1022 HR 1030
Over 35 000 to 40 000, incl	HR 1022 HR 1030	HR 1030 HR 1035	HR 1030 HR 1035	HR 1035
Over 40 000 to 45 000, incl	HR 1035	HR 1040	CD 1010 HR 1040	CD 1010 HR 1045 CD 1015 HR 1040
Over 45 000 to 50 000, incl	CD 1010 HR 1040 HR 1045	CD 1010 CD 1015 HR 1045	CD 1015 HR 1045 HR 1137	CD 1020 HR 1137 *CD 1115* HR 1050
Over 50 000 to 55 000, incl	CD 1015 HR 1050 HR 1137	CD 1020 HR 1137 *CD 1115* HR 1141 HR 1050	CD 1018 CD 1115 CD 1020 HR 1050 HR 1141 CD 1025 HR 1144	CD 1018 HR 1141 CD 1019 HR 1141 CD 1025
Over 55 000 to 60 000, incl	CD 1018 CD 1115 CD 1025 CD 1019 HR 1141 CD 1020 HR 1144	CD 1018 HR 1144 CD 1019 CD 1025	CD 1019 CD 1120 CD 1022 CD 1117	CD 1022 *CD 1120* CD 1117 CD 1118

[A] Hot-rolled bars are indicated in table by prefix “HR.”

[B] Cold-drawn bars are indicated in table by prefix “CD.” These bars are produced by normal practice in cold-drawing and with no stress relief. Bars cold-finished by turning, grinding, turning and polishing, etc., are not covered under cold-drawn bars, as such cold-finished bars have the properties of hot-rolled bars.

[C] Classification of cold-drawn steels by size and yield-strength level in this table is based on yield-strength determinations at 0.2 % offset, or as determined by 0.005 in./in. elongation under load for yield strengths up to 90 000 psi, incl, and by 0.006 in./in. elongation under load for yield strengths above 90 000 psi.

[D] 1 psi = 0.006895 MPa.

[E] 1 in. = 25.4 mm.

TABLE 6 Steels for Parts Produced From Cold-Drawn and Cold-Drawn Stress-Relieved Bars—Classes R-1 Through R-6[A,B]

NOTE 1—Steels listed as approved for heavier section or higher strengths may be used in the same conditions for lighter sections and lower strengths.

NOTE 2—Steel composition numbers correspond to ASE, AISI, or ASTM designations. Those in italics are no longer considered standard grades due to decreased usage.

NOTE 3—Steels in conditions listed in this table are not approved for applications involving welding.

Desired Minimum Yield Strength, psi[C]	Class			
	R-1	R-2	R-3 and R-4	R-5 and R-6
	Diameters of Round or Approximately Round Sections, in.[D]			
	To ½, incl	Over ½ to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl
	Thickness of Flat Sections, in.[D]			
	To 0.3, incl	Over 0.3 to 0.6, incl	Over 0.6 to 1.3, incl	Over 1.3 to 2.0, incl
Over 60 000 to 65 000, incl	CD 1022 CD 1117 *CD 1120*	CD 1022 CD 1117 CD 1118 *CD 1120*	CD 1030 CD 1118	CD 1030
Over 65 000 to 70 000, incl	CD 1030 CDT 1040 CD 1118	CD 1030 CD 1035 CDT 1045	CD 1035 CDT 1137 CDT 1040 CDT 1050	CD 1035 CD 1050 CDT 1141 CDT 1045
Over 70 000 to 75 000, incl	CD 1035 CDT 1045	CDT 1137 CDT 1040 CDT 1050	CD 1040 CDT 1141 CDT 1045	CD 1045 CDT 1040 CDT 1144 CDT 1137 CDT 1050
Over 75 000 to 80 000, incl	CDT 1137 CDT 1040 CDT 1050	CD 1040 CDT 1141 CDT 1045	CD 1045 CDT 1040 CDT 1144 CDT 1137 CDT 1050	CD 1137 CDT 1045 CDT 1040 CDT 1141 CD 1050
Over 80 000 to 85 000, incl	CD 1040 CDT 1141 CDT 1045	CD 1045 CDT 1040 CDT 1144 CDT 1137 CDT 1050	CD 1137 CDT 1045 CDT 1040 CDT 1141 CD 1050	CD 1141 CDT 1137 CDT 1045 CDT 1040 CDT 1144 CDT 1050
Over 85 000 to 90 000, incl	CD 1045 CDT 1040 CDT 1144 CDT 1137 CDT 1050	CD 1137 CDT 1045 CDT 1040 CDT 1141 CD 1050	CD 1141 CDT 1137 CDT 1145 CDT 1040 CDT 1144 CDT 1050	CD 1144 CDT 1141 CDT 1137 CDT 1045 CDT 1050
Over 90 000 to 95 000, incl	CD 1137 CDT 1045 CDT 1040 CDT 1141 CD 1050	CD 1141 CDT 1137 CDT 1045 CDT 1050 CDT 1144 CDT 1050	CD 1144 CDT 1141 CDT 1137 CDT 1045 CDT 1050	CDT 1144 CDT 1141 CDT 1137 CDT 1050
Over 95 000 to 100 000, incl	CD 1141 CDT 1137 CDT 1045 CDT 1040 CDT 1144 CDT 1050	CD 1144 CDT 1141 CDT 1137 CDT 1045 CDT 1050	CDT 1144 CDT 1141 CDT 1137 CDT 1050	CDT 1144 CDT 1141
Over 100 000 to 105 000, incl	CD 1144 CDT 1141 CDT 1137 CDT 1045 CDT 1050	CDT 1144 CDT 1141 CDT 1137 CDT 1050	CDT 1144 CDT 1141	CDT 1144
Over 105 000 to 110 000, incl	CDT 1144 CDT 1141 CDT 1137 CDT 1050	CDT 1144 CDT 1141	CDT 1144	
Over 110 000 to 115 000, incl	CDT 1144 CDT 1141	CDT 1144		
Over 115 000 to 120 000, incl	CDT 1144			

[A] Conditions and treatments of bars are indicated in this table by the symbols shown below. Bars cold-finished by turning, grinding, turning and polishing, etc., are not covered, as such bars have the properties of hot-rolled bars.
"CD" = Bars produced by normal practice in cold-drawing, and with no stress relief.
"CDT" = Cold-drawn bars with subsequent thermal treatment. Heavier than normal drafts may be required.
[B] Classification of cold-drawn steels by size and yield-strength level in this table is based on yield-strength determinations at 0.2 % offset or as determined by 0.005 in./in. elongation under load for yield strengths up to 90 000 psi, and by 0.006 in./in. elongation under load for yield strengths above 90 000 psi.
[C] 1 psi = 0.006895 MPa.
[D] 1 in. = 25.4 mm.

TABLE 7 Applicable Classes for Critical Section Size

Round, Square, Hexagonal, etc., Sections, Diameter or Dimension Between Opposite Faces, in.[A]		Flat Sections, Thickness, in.[A]		Applicable Class
Over	To and Including	Over	To and Including	
. . .	½	. . .	0.3	P-1, Q-1, or R-1
½	1	0.3	0.6	P-2, Q-2, or R-2
1	1½	0.6	1.0	P-3, Q-3, or R-3
1½	2	1.0	1.3	P-4, Q-4, or R-4
2	2½	1.3	1.6	P-5, Q-5, or R-5
2½	3	1.6	2.0	P-6, Q-6, or R-6
3	3½	2.0	2.3	P-7 or Q-7

[A] 1 in. = 25.4 mm.

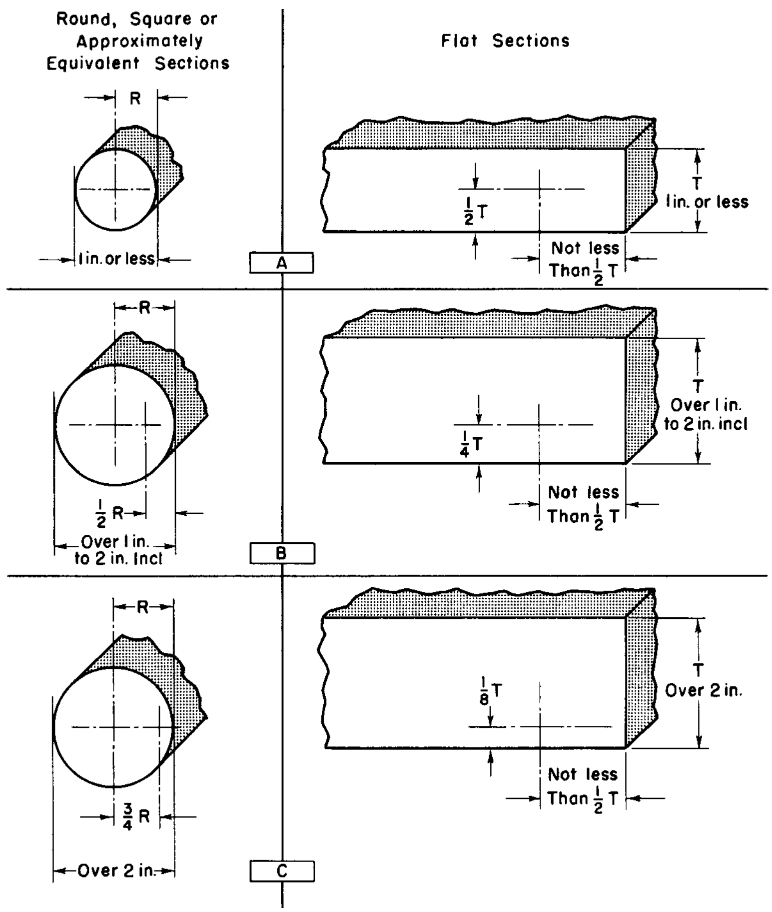

FIG. 1 Locations in Typical Cross Sections of Steel Bars at Which Desired Properties Are Obtained

Designation: A 488/A 488M – 07

Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[1]

This standard is issued under the fixed designation A 488/A 488M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers the qualification of procedures, welders, and operators for the fabrication and repair of steel castings by electric arc welding.

1.1.1 Qualifications of a procedure and either or both the operator or welder under Section IX of the ASME Boiler and Pressure Vessel Code shall automatically qualify the procedure and either or both the operator or welder under this practice. P-number designations in the ASME grouping of base metals for qualification may be different than the category numbers listed in Table 1. Refer to Appendix X1 for a comparison of ASTM category numbers with the corresponding ASME P-Number designations.

1.2 Each manufacturer or contractor is responsible for the welding done by his organization and shall conduct the tests required to qualify his welding procedures, welders, and operators.

1.3 Each manufacturer or contractor shall maintain a record of welding procedure qualification tests (Fig. 1), welder or operator performance qualification tests (Fig. 2), and welding procedure specification (Fig. 3), which shall be made available to the purchaser's representative on request.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this practice.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 128/A 128M Specification for Steel Castings, Austenitic Manganese

A 148/A 148M Specification for Steel Castings, High Strength, for Structural Purposes

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 351/A 351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service

A 356/A 356M Specification for Steel Castings, Carbon, Low Alloy, and Stainless Steel, Heavy-Walled for Steam Turbines

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 389/A 389M Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service

A 494/A 494M Specification for Castings, Nickel and Nickel Alloy

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[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1963. Last previous edition approved in 2006 as A 488/A 488M – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

TABLE 1 Categories of Base Materials

Category Number	Material Description	ASTM Specification	Grades
1	Carbon steel (carbon less than 0.35 %, tensile strength less than or equal to 70 ksi [480 MPa]).	A 27/A 27M	all grades
		A 216/A 216M	WCA, WCB
		A 352/A 352M	LCB, LCA
		A 356/A 356M	1
		A 732/A 732M	1A, 2A
		A 757/A 757M	A1Q
		A 958	SC 1020, SC 1025, SC 1030, SC 1040, SC 1045, CLASSES 65/35, 70/36
2	Carbon steel (tensile strength greater than 70 ksi [480 MPa]). Carbon-manganese steel (tensile strength equal to or greater than 70 ksi but less than 90 ksi [620 MPa]).	A 148/A 148M	80-40
		A 216/A 216M	WCC
		A 352/A 352M	LCC
		A 732/A 732M	2Q, 3A
		A 757/A 757M	A2Q
		A 958	SC 1030, SC 1040, SC 1045, CLASSES 80/40, 80/50
3	Carbon and carbon-manganese steel (tensile strength equal to or greater than 90 ksi [620 MPa]).	A 732/A 732M	3Q, 4A, 4Q, 5N
		A 958	SC 1045, CLASSES 90/60, 105/85, 115/95
4	Low-alloy steel (annealed, normalized, or normalized and tempered. Tensile strength less than 85 ksi [585 MPa]).	A 148/A 148M	80-50
		A 217/A 217M	WC1, WC4, WC5, WC6, WC9
		A 352/A 352M	LC1, LC2, LC3, LC4
		A 356/A 356M	2, 5, 6, 8
		A 389/A 389M	C23, C24
		A 487/A 487M	11A, 12A, 16A
		A 757/A 757M	B2N, B3N, B4N
		A 958	SC 4130, SC 4140, SC 8620, SC 8625, SC 8630, CLASSES 65/35, 70/36, 80/40, 80/50
5	Low-alloy steel (annealed, normalized, or normalized and tempered. Tensile strength equal to or greater than 85 ksi [585 MPa]).	A 148/A 148M	90-60, 105-85
		A 217/A 217M	C5, C12, C12A, WC11
		A 356/A 356M	9, 10, 12
		A 487/A 487M	1A, 1C, 2A, 2C, 4A, 4C, 6A, 8A, 9A, 9C, 10A, 13A
		A 732/A 732M	6N, 15A
		A 757/A 757M	D1N1, D1N2, D1N3, E2N1, E2N2, E2N3
		A 958	SC 4340, CLASSES 90/60, 105/85
6	Low-alloy steel (quenched and tempered)	A 148/A 148M	90-60, 105-85, 115-95, 130-115, 135-125, 150-135, 160-145, 165-150, 165-150L, 210-180, 210-180L, 260-210, 260-210L
		A 352/A 352M	LC2-1, LC1, LC2, LC3, LC4, LC9
		A 487/A 487M	1B, 1C, 2B, 2C, 4B, 4C, 4D, 4E, 6B, 7A, 8B, 8C, 9A, 9B, 9C, 9D, 9E, 10B, 11B, 12B, 13B, 14A
		A 732/A 732M	7Q, 8Q, 9Q, 10Q, 11Q, 12Q, 13Q, 14Q
		A 757/A 757M	B2Q, B3Q, B4Q, C1Q, D1Q1, D1Q2, D1Q3, E1Q, E2Q1, E2Q2, E2Q3
		A 958	SC 4140, SC 4130, SC 4340, SC 8620, SC 8625, SC 8630, CLASSES 115/95, 130/115, 135/125, 150/135, 160/145, 165/150, 210/180
7	Ferritic stainless steel	A 743/A 743M	CB-30, CC-50
8	Martensitic stainless steel	A 217/A 217M	CA-15
		A 352/A 352M	CA6NM
		A 356/A 356M	CA6NM
		A 487/A 487M	CA15-A, CA15-B, CA15-C, CA15-D, CA15M-A, CA6NM-A, CA6NM-B
		A 743/A 743M	CA-15, CA-15M, CA6NM, CA-40, CA6N, CB6
		A 757/A 757M	E3N
9	Low-carbon austenitic stainless steel (carbon equal to or less than 0.03 %)	A 351/A 351M	CF-3, CF-3A, CF-3M, CF-3MA, CF-3MN, CK-3MCUN, CG3M, CN3MN
		A 743/A 743M	CF-3, CF-3M, CF-3MN, CK-3MCUN, CN-3M, CG3M, CN3MN
		A 744/A 744M	CF-3, CF-3M, CK-3MCUN, CG3M , CN3MN
10	Unstabilized austenitic stainless steel (carbon greater than 0.03 %)	A 351/A 351M	CE-8MN, CF-8, CF-8A, CF-8M, CF-10, CF-10M, CG-8M, CH-8, CH-10, CH-20, CG6MMN,

Category Number	Material Description	ASTM Specification	Grades
			CF10S1MNN, CE20N
		A 447/A 447M	Type I
		A 743/A 743M	CF-8, CG-12, CF-20, CF-8M, CF-16F, CF10SMNN, CH-20, CG-8M, CE-30, CG6MMN, CH10, CF16Fa
		A 744/A 744M	CF-8, CF-8M, CG-8M
11	Stabilized austenitic stainless steel	A 351/A 351M	CF-8C, CF-10MC, CK-20, HK-30, HK-40, HT-30, CN-7M, CT-15C
		A 447/A 447M	Type II
		A 743/A 743M	CF-8C, CN-7M, CN-7MS, CK-20
		A 744/A 744M	CF-8C, CN-7M, CN-7MS
12	Duplex (austenitic-ferritic) stainless steel	A 351/A 351M	CD3MWCuN, CD-4MCU
		A 872/A 872M	J93183, J93550
		A 890/A 890M	1A, 1B, 2A, 3A, 4A, 5A, 6A
		A 995/A 995M	1B, 2A, 3A, 4A, 5A, 6A
13	Precipitation-hardened austenitic stainless steel	A 747/A 747M	CB7CU-1, CB7CU-2
14	Nickel-base alloys	A 494/A 494M	CW-12MW, CY-40 Class 1, CY-40 Class 2, CZ-100, M-35-1, M-35-2, M-30C, N-12MV, N-7M, CW-6M, CW-2M, CW-6MC, CX-2MW, CU5MCUC
		A 990	CW2M
15	Steel Castings, Austenitic Manganese	A 128/A 128M	A, B-1, B-2, B-3, B-4, C, D, E-1, E-2, F

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service

A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening

A 757/A 757M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing and Other Applications, for Low-Temperature Service

A 872/A 872M Specification for Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments

A 890/A 890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application

A 958 Specification for Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades

A 990 Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure Retaining Parts for Corrosive Service

A 995/A 995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts

2.2 *American Society of Mechanical Engineers:*[3]

ASME Boiler and Pressure Vessel Code, Section IX

2.3 *American Welding Society:*[4]

ANSI/AWS 3.0 Definitions for Welding and Cutting

3. Terminology

3.1 *Definitions*—Definitions of terms relating to welding shall be in agreement with the definitions of the American Welding Society, ANSI/AWS A3.0.

4. Weld Orientation

4.1 *Orientation*—The orientation of welds with respect to horizontal and vertical planes of reference are classified into four positions, namely, flat, horizontal, vertical, and overhead as shown in Fig. 4. Test material shall be oriented as shown in Fig. 4; however, an angular deviation of ±15° from the specified horizontal and vertical planes is permitted during welding.

4.2 *Flat Position* (Fig. 4(*a*))—This position covers plate in a horizontal plane with the weld metal deposited from above, or pipe or a cylindrical casting with its axis horizontal and rolled during welding so that the weld metal is deposited from above.

4.3 *Horizontal Position* (Fig. 4(*b*))—This position covers plate in a vertical plane with the axis of the weld horizontal, or pipe or a cylindrical casting with its axis vertical and the axis of the weld horizontal.

4.4 *Vertical Position* (Fig. 4(*c*))—In this position, the plate is in a vertical plane with the axis of the weld vertical.

4.5 *Overhead Position* (Fig. 4(*d*))—In this position, the plate is in a horizontal plane with the weld metal deposited from underneath.

4.6 *Horizontal Fixed Position* (Fig. 4(*e*))—In this position, the pipe or cylindrical casting has its axis horizontal and the

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

RECOMMENDED FORM FOR MANUFACTURER'S RECORD OF WELDING PROCEDURE QUALIFICATION TESTS

Procedure No. _______ Date: _______ Welding Process: _______
Material Specification: _______ to _______ of category No. _______ to category No. _______
Plate Thickness: _______ Thickness Range Qualified _______
Filler Metal F Group No. _______ Weld Deposit A-Group No.: _______
Flux Designation: _______ Gas Composition: _______
Gas Flow Rate: _______ Backing Strip, if any: _______
Preheat Temperature Range: _______ Single or Multiple Pass: _______
Position of Groove: _______ Filler Wire Diameter: _______
Trade Name: _______ Type of Backing: _______
Forehand or Backhand: _______ Amps: _______ Volts _______ Inches/min: _______
Postheat Temperature _______ Time at Temperature _______

TENSION TEST RESULTS

Specimen No.	Width	Dimensions Thickness	Area	Ultimate Total Load, lb	Ultimate Unit Stress, psi	Nature of Failure and Location

GUIDED BEND TEST RESULTS

Specimen No.	Results	Specimen No.	Results

Welder's Name: _______ Clock No. _______ Stamp. No. _______
Who by virtue of these tests meets the welder performance qualification.
Test Conducted By: _______ Test No. _______
per _______
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of ASTM Standard _______
Signed: _______
Manufacturer or Contractor

Date: _______

FIG. 1 Report Form 1

RECOMMENDED FORM FOR MANUFACTURER'S OR CONTRACTOR'S RECORD OF WELDER OR OPERATOR PERFORMANCE QUALIFICATION TESTS

Welder or Operator's Name: Stamp No. ______
Clock No. ______ Welding Process: ______
Position: ______
In accordance with Procedure No. ______
Material Specification: ______ to ______ of category No. ______ to category No. ______
Plate Thickness: ______ Range of Thickness Qualified: ______
Filler Metal Specification No. ______ Group No. F. ______
Filler Metal A-Group No. ______ Filler Metal Diameter ______
Trade Name: ______ Flux Designation or Gas Analysis: ______
Was Backing Strip Used? ______

GUIDED BEND TEST RESULTS

Specimen No.	Results	Specimen No.	Results

Test Conducted By: ______ Laboratory Test No. ______
per ______
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with ASTM Standard ______ .
Signed: ______
Manufacturer or Contractor
Date: ______

FIG. 2 Report Form 2

REPORT FORM 3

RECOMMENDED FORM FOR WELDING PROCEDURE SPECIFICATION

1. Title

Welding of[A]_____ steel castings.

[A] Indicate general material description, such as carbon, Cr-Mo, 12 Cr, etc.

2. Specification No. __________ **Rev.** __________
Date __________

3. Scope

3.1 Procedure Specification No. _____ covers the welding of[A]_____ steel castings using the[B]_____ welding process.

[A] Indicate general material description in the Title.

[B] Indicate specific welding process, such as shielded metal arc, etc.

4. Base Material

4.1 The base material shall conform to the specification for[A]_____ which is found in materials category number[B]_____.

[A] Insert reference to ASTM designation or indicate chemical analysis and physical properties.

[B] Indicate category number from Table 1.

4.2 Base material shall be in the[A]_____ heat treated condition before welding.

[A] Indicate heat treatment before welding.

5. Filler Metal

5.1 The filler metal shall conform to ANSI/AWS Specification[A]_____ which is found in weld metal analysis group A _____[B].

[A] Indicate appropriate American Welding Society specification number and filler metal classification (e.g., A5.1 E7018).

[B] Indicate A Number from Table 4.

5.2 Flux for submerged arc welding shall conform to the following nominal composition:[A]_____.

[A] Indicate chemical composition or trade designation.

5.3 Shielding gas for gas shielded arc welding shall conform to the following nominal composition:[A]_____.

[A] Indicate the single gas or proportional parts of mixed gases and flow rates.

6. Preparation of Base Material

6.1 Metal removal shall be performed by[A]_____.

[A] Indicate method of metal removal, such as chipping, grinding, carbon arc cutting, frame cutting, etc. Also indicate whether preheat is required during metal removal.

6.2 Configuration of the weld preparation for partial penetration welds shall conform to the following geometry:[A]_____.

[A] Indicate minimum root radius and minimum side wall angle.

6.3 Configuration of the weld preparation for full penetration welds shall conform to the following geometry:[A]_____.

[A] Indicate minimum side wall angle.

6.4 Backing plates shall be used for welding full penetration welds. Backing plates shall be made from[A]_____ steel and shall fit the back of the cavity with a minimum gap of[B]_____.

[A] Indicate material of backing plate.

[B] Indicate dimension of maximum gap.

6.5 Surfaces of the weld preparation shall be cleaned of all oil, grease, dirt, scale, slag, shot blasting grit, or any foreign material which may be harmful to the quality of the weld. Surfaces of backing plates when used shall also meet the same cleanliness requirements.

6.6 All surfaces of the weld preparation shall be inspected as follows:[A]_____.

[A] Indicate type of inspection.

7. Preheat

7.1 Preheat and interpass temperature shall be maintained in the range from[A]_____ to[B]_____ during _____[C].

[A] Indicate minimum temperature.

[B] Indicate maximum temperature.

[C] Indicate if preheat maintenance is during welding or until postweld heat treatment is performed.

7.2 Preheat for tack welding of backing plates is the same as required for welding.

7.3 Minimum temperature before applying heat shall be[A]_____.

[A] Indicate temperature.

7.4 Local preheating to the temperatures indicated may be performed so that the heated area completely surrounds the weld preparation for a minimum distance of[A]_____ in any direction.

[A] Indicate minimum distance for local preheating.

8. Welding Position

8.1 Welds shall be made in the[A]_____ position.

[A] Indicate position or positions in which the welding will be performed. See Fig. 4.

9. Electrical Characteristics

9.1 The current used shall be _____[A]. The base material shall be attached to the _____[B] welding electrode lead.

[A] Indicate whether direct or alternating current. If direct, state whether non-pulsed or pulsed. If pulsed, state frequency.

[B] Indicate whether electrode positive (EP) or electrode negative (EN) output terminal of power supply is used.

Electrode Wire Diameter[A]	Amperage[A]	Range[A]	Voltage[A]
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

[A] Indicate for each diameter of electrode, the amperage, the range of amperage permitted, and the voltage requirements. For welding processes using wire, indicate wire diameter, wire feed speed, and current requirements.

9.2 Electrodes subject to moisture absorption must be stored and handled to maintain dryness according to the following:[A]_____.

[A] Where applicable, indicate electrode care instructions.

10. Welding Details

10.1 The width of any pass of welding shall not exceed[A]_____ times the size of the filler metal used.

[A] Indicate the number for controlling the maximum width.

10.2 Craters shall be properly filled before each interruption of the arc.

10.3 Slag or flux shall be removed on any bead before depositing the next successive bead.

10.4 Interpass inspection shall be performed according to the following:[A]_____.

[A] Indicate degree of interpass inspection required.

10.5 Peening shall be performed according to the following:[A]_____.

[A] Indicate the degree of peening required. Indicate any limits on peening first and last layers.

11. Post-Weld Heat Treatment

11.1 Post-weld heat treatment shall consist of the following:[A]_____.

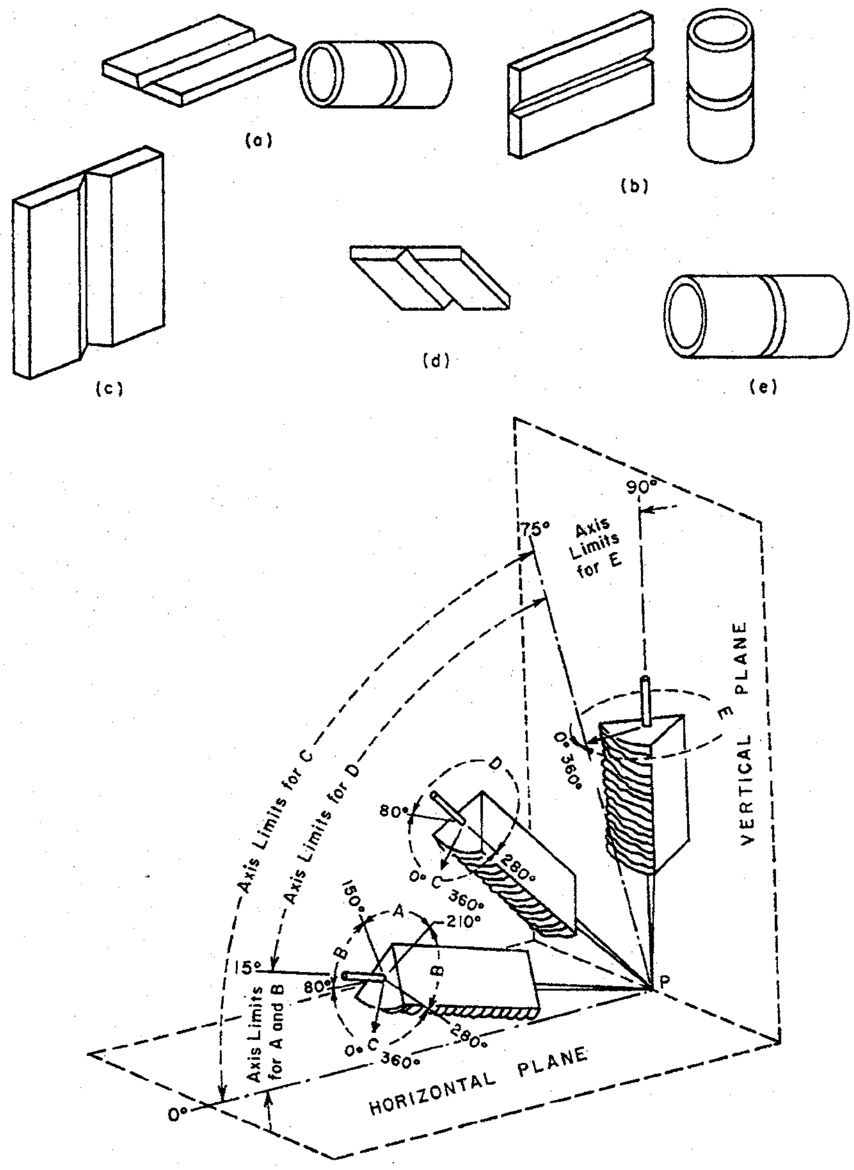
[A] Indicate the heating and cooking rates, holding temperatures and times.

12. Inspection

12.1 Inspection of the completed weld shall be performed according to the following:[A]_____.

[A] Indicate degree of inspection.

FIG. 3 Report Form 3



Tabulation of Positions of Groove Welds

Position	Diagram Reference	Inclination of Axis, °	Rotation of Face,°
Flat	A	0 to 15	150 to 210
Horizontal	B	0 to 15	80 to 150 210 to 280
Overhead	C	0 to 80	0 to 80 280 to 360
Vertical	D E	15 to 80 80 to 90	80 to 280 0 to 360

NOTE 1—(*a*) Flat Position; (*b*) Horizontal Position; (*c*) Vertical Position; (*d*) Overhead Position; (*e*) Horizontal Fixed Position

FIG. 4 Orientation of Welds

TABLE 2 Type and Number of Test Specimens and Range of Thicknesses Qualified—(Procedure)

Thickness, *t*, of Test Plate or Pipe as Welded, in. [mm]	Range of Thicknesses Qualified[A]		Type and Number of Tests Required[B]			
	min, in. [mm]	max	Reduced Section Tension	Side Bend	Face Bend	Root Bend
1⁄16 to 3⁄8 [1.6 to 9.5], incl	1⁄16 [1.6]	2*t*[C]	2	. . .	2	2
Over 3⁄8 [9.5], under 3⁄4 [19.0]	3⁄16 [4.8]	2*t*	2	. . .	2	2
3⁄4 [19.0] to under 1½ [38.1]	3⁄16 [4.8]	2*t*	2	4	. . .	. . .
1½ [38.1] and over	3⁄16 [4.8]	8 [203]	2	4	. . .	. . .

[A] For repair welding, the minimum thickness requirements do not apply.
[B] Either the face- and root-bend tests or the side-bend tests may be used for thicknesses from 3⁄8 to 3⁄4 in. [9.5 to 19.0 mm].
[C] The maximum thickness qualified with pipe smaller than 5 in. [127 mm] is two times the thickness of the pipe but not more than 3⁄4 in. [19.0 mm].

welding groove in a vertical plane. Welding shall be done without rotating the pipe or casting so that the weld metal is deposited from the flat, vertical, and overhead position.

4.7 *Qualification*—Qualification in the horizontal, vertical, or overhead position shall qualify also for the flat position. Qualification in the horizontal fixed position, or in the horizontal and vertical and overhead positions, shall qualify for all positions (Fig. 4(*f*)).

5. Preparation of Test Plate

5.1 Procedure qualification testing shall be performed on cast or wrought material having the same category number as the casting being welded. Test material shall be subjected to the same heat treatment before and after welding as will be applied to the casting. If the castings are not to be postweld heat treated, then the test material is not to be postweld heat treated. Test plate material for performance qualification testing is covered in 12.2.

5.2 The dimensions of the test plate shall be such as to provide the required number of test specimens.

5.3 The test joint shall be welded using the type of welding groove proposed in the welding procedure. The dimensions of the welding groove are not essential variables of the welding procedure.

5.4 The thickness of the test plate shall depend on the range of thickness to be qualified as shown in Table 2 and Table 3.

5.5 The joint preparation shown in Fig. 5 shall qualify the supplier for all welding on steel castings.

5.6 Where pipe or a cylindrical casting is used for qualification, it is recommended that a minimum nominal diameter of 5 in. [125 mm] and a minimum thickness of 3⁄8 in. [10 mm] be used.

6. Types of Tests

6.1 Four types of tests are used in the qualification procedure as follows:

6.1.1 *Tension Test*—Tests in direct tension are used in the procedure qualification to measure the strength of groove-weld joints.

6.1.2 *Bend Test*—Guided bend tests are used in the procedure and performance qualification tests to check the degree of soundness and ductility of groove-weld joints.

6.1.3 *Charpy Impact Test*—Charpy V-notch impact test specimens are used in the procedure qualification to determine the impact strength of weld metal deposited in groove-type joints.

6.1.4 *Radiographic Test*—Radiographic examination in accordance with 12.6 of a length of weld may be used to prove the ability of operators and welders to make sound welds.

7. Tension Test

7.1 *Specimens*—Tension tests shall be in accordance with the requirements of 7.1.1 or 7.1.2.

7.1.1 All thicknesses of plate may be tested using reduced-section specimens in accordance with the requirements of Fig. 6. All thicknesses of pipe or cylindrical castings having an outside diameter greater than 3 in. [75 mm] may be tested using reduced-section specimens in accordance with the requirements of Fig. 7.

7.1.1.1 A single specimen of full-plate or full-pipe thickness shall be used for thicknesses up to and including 1 in. [25 mm].

7.1.1.2 For plate or pipe thicknesses greater than 1 in. [25 mm], single or multiple specimens may be used.

7.1.1.3 When multiple specimens are used, each set shall represent a single required tension test. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set.

7.1.1.4 When multiple specimens are necessary, the entire thickness shall be mechanically cut into a minimum number of approximately equal strips of a size that can be tested in the available equipment. Each specimen shall be tested and meet the requirements of 7.1.4.

7.1.2 Turned specimens in accordance with the requirements of Fig. 8 may be used for tension tests.

7.1.2.1 For thicknesses up to and including 1 in. [25 mm], a single-turned specimen may be used, which shall be a specimen of the largest diameter possible for the test coupon thickness.

7.1.2.2 For thicknesses greater than 1 in. [25 mm], multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the metal surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to the metal surfaces shall not exceed 5⁄8 in. [16 mm] from the surface.

7.1.2.3 When multiple specimens are used, each set shall represent a single required tension test. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set. Each specimen shall be tested and meet the requirements of 7.1.4.

7.1.3 The weld shall be in the center of the reduced section.

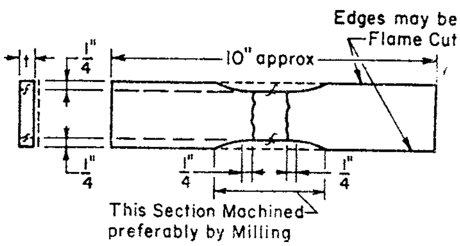
7.1.4 In order to meet the requirements of the tension test, specimens shall have a tensile strength not less than the

TABLE 3 Type and Number of Test Specimens and Thickness Limits Qualified—(Performance)

Thickness, *t*, of Test Plate or Pipe as Welded, in. [mm]	Thickness Qualified	Type and Number of Tests Required[A]		
		Side Bend	Face Bend	Root Bend
Up to ⅜ [9.5], incl	2*t*	. . .	1	1
Over ⅜ [9.5], under ¾ [19.0][B]	2*t*	. . .	1	1
Over ⅜ [9.5], under ¾ [19.0][B]	2*t*	2	. . .	. . .
¾ [19.0], and over	max to be welded	2	. . .	. . .

[A] A total of four specimens are required to qualify for Position 1(e) of Fig. 4. Refer to Fig. 17 and Fig. 18.
[B] Either the face- and root-bend tests or the side-bend tests may be used for thicknesses from ⅜ to ¾ in. [9.5 to 19.0 mm].

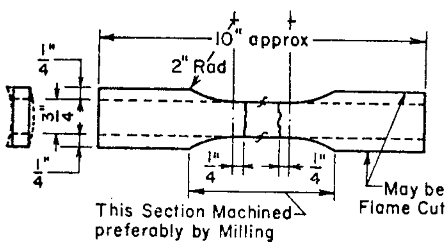
FIG. 5 Joint Preparation



Metric Equivalents

in.	¼	10
[mm]	[6]	[255]

FIG. 6 Reduced-Section Tension Specimen for Plate



Metric Equivalents

in.	¼	¾	2	10
[mm]	[6]	[20]	[50]	[255]

FIG. 7 Reduced-Section Tension Specimen for Pipe

specified tensile strength of the base material. If the specimen breaks in the base metal outside of the weld or fusion line, the test shall be accepted as meeting the requirements, provided the strength is not more than 5 % below the specified minimum tensile strength of the base metal.

7.2 *Tension Test*—Tension tests shall be conducted in accordance with Test Methods and Definitions A 370.

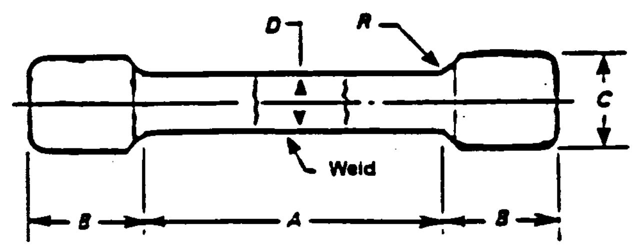
8. Guided Bend Test

8.1 *Specimens*—Guided bend test specimens shall be prepared by cutting the test plate or pipe to form specimens of approximately rectangular cross section. The cut surfaces shall be designated the sides of the specimen. The other two surfaces shall be called the face and root surfaces, the face surface having the greater width of weld. Guided bend test specimens are of three types depending on which surface (side, face, or root) is on the convex (outer) side of the bent specimen. (Fig. 9 and Fig. 10.)

8.1.1 *Side Bend*—The weld is transverse to the longitudinal axis of the specimen, which is bent so that one of the side surfaces becomes the convex surface of the bent specimen.

8.1.2 *Face Bend*—The weld is transverse to the longitudinal axis of the specimen, which is bent so that the face surface becomes the convex side of the bent specimen.

NOTE 1—Reduced section *A* should not be less than width of weld plus 20.

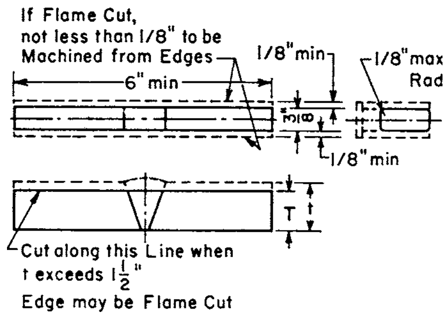


	Standard Dimensions, in.			
	(a) 0.505 Specimen[A]	(b) 0.353 Specimen[B]	(c) 0.252 Specimen[C]	(d) 0.188 Specimen[D]
A—Length of reduced section	[Note]	[Note]	[Note]	[Note]
D—Diameter	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.188 ± 0.003
R—Radius of fillet	⅜ , min	¼ , min	3⁄16 , min	⅛ , min
B—Length of end section	1⅜ , approx.	1⅛ , approx.	⅞ , approx.	½ , approx.
C—Diameter of endsection	¾	½	⅜	¼

[A] Use maximum diameter specimen (a), (b), (c), or (d) that can be cut from the section.
[B] Weld should be in center of reduced section.
[C] Where only a single coupon is required, the center of the specimen should be midway between the surfaces.
[D] The ends may be threaded or shaped to fit the holders of the testing machine in such a way that the load is applied axially.

FIG. 8 Alternate Reduced-Section Tension Specimen

NOTE 1—For plates over 1½ in. [38.1 mm] thick, cut specimen into approximately equal strips between ¾ in. [20 mm] and 1½ in. [40 mm] wide and test each strip.



Metric Equivalents

in.	⅛	⅜	1½	6
[mm]	[3]	[10]	[40]	[155]

FIG. 9 Side-Bend Specimen

8.1.3 *Root Bend*—The weld is transverse to the longitudinal axis of the specimen, which is bent so that the root surface becomes the convex side of the bent specimen.

8.2 *Guided Bend Tests*—Table 2 and Table 3 give the number and type of guided bend specimens that are to be used in the procedure and performance qualification tests.

8.2.1 Specimens of base metal thicknesses over 1.5 in. [38 mm] may be cut into approximately equal strips between ¾ in. [19 mm] and 1.5 in. [38 mm] wide for testing, or the specimens may be bent at full width. If multiple specimens are used, one complete set shall be made for each required test. Each specimen shall be tested and meet the requirements of 8.2.3.

8.2.2 Guided bend specimens shall be bent in jigs that are in substantial accordance with Figs. 11-13. The side of the specimen turned toward the gap of the jig shall be the face for face-bend specimens, the root for root-bend specimens, and the side with the greater number of defects, if any, for side-bend specimens. The specimen shall be forced into the die by applying load on the plunger until the curvature of the specimen is such that a ⅛-in. [3.2-mm] diameter wire cannot be inserted between the die and the specimen, or so that the specimen is bottom ejected if the alternate roller type jig is used. When using the wrap-around jig (Fig. 13), the side of the specimen turned toward the roller shall be the face for face-bend specimens, the root for root-bend specimens, and the side with the greater defects, if any, for side-bend specimens. When specimens wider than 1.5 in. [38.1 mm] are to be bent, the test jig mandrel must be at least 0.25 in. [6.4 mm] wider than the specimen width.

8.2.3 In order to meet the requirements of this test, the guided bend specimens shall have no cracks or other open defects exceeding ⅛ in. [3.2 mm] measured in any direction on the convex surface of the specimen after bending. However, cracks occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from slag inclusions or other internal defects.

8.2.4 Where the ductility of the parent metal is such as to render it incapable of meeting the bend test requirements of 8.2.2 and 8.2.3, the bend test shall be conducted in the following manner: A bend bar comprised of parent metal heat treated to the ductility and strength requirements of the applicable specification shall be bent to failure. The side-bend specimen shall then be capable of being bent to within 5° of the angle thus determined.

9. Charpy Impact Test

9.1 *Application*—Charpy V-notch impact tests of the weld metal and heat-affected zone shall be made when such tests are required for the parent metal by the material specification, or specified by the purchaser, and shall apply to the qualification of the welding procedure for fabrication and repair. When postweld heat treatment consists of a full reheat treatment of the welded part, thus eliminating the HAZ, impact testing of the HAZ shall not be required.

9.2 *Test Methods*—Test methods for Charpy V-notch impact tests shall be in accordance with Test Methods and Definitions A 370 and conducted at the same temperature as required for the parent metal.

9.2.1 *Test Specimens*—Each set of three weld metal impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch is normal to the surface of the material and one face of the specimen shall be within 1⁄16 in. [1.6 mm] of the surface of the metal. Heat-affected zone coupons for impact specimens shall be taken transverse to the weld and etched to define the heat-affected zone. The notch shall be cut normal to the material surface in the heat-affected zone to include as much heat-affected zone as possible in the resulting fracture (Fig. 14(*a*)). Where the material thickness permits, the axis of a heat-affected zone specimen may be inclined to allow the root of the notch to align parallel to the fusion line (Fig. 14(*b*)).

9.2.2 *Acceptance Criteria*—Acceptance criteria for the weld metal and heat-affected zone shall be the same as that required by the material specification for the parent metal.

10. Procedure Qualification

10.1 Each manufacturer or contractor shall record in detail the welding procedure used in qualifying under this practice. A suggested form (Fig. 1) is included with this practice.

10.2 The number of tests required to qualify a procedure for various thickness ranges shall be as shown in Table 2, except only bend tests are required for Category 15 material.

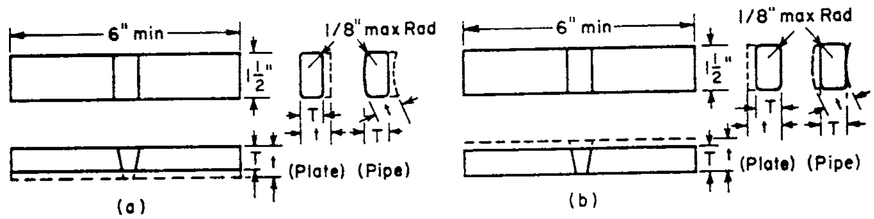
10.3 Test specimens shall be removed from the plate or pipe or cylindrical casting as shown in Figs. 15-18.

10.4 In order to qualify, test specimens shall meet the requirements of 7.1.4, 8.2.3, or 8.2.4.

11. Requalification of a Procedure

11.1 A welding procedure must be set up as a new procedure and must be requalified when any of the changes in essential variables listed in 11.1.1-11.1.12, inclusive, are made. Changes other than those listed may be made without requalification, provided the procedure is revised to show these changes.

11.1.1 A change from a base material listed under one category number in Table 1 to a material listed under another category number. When two base materials having different category numbers are welded together, a procedure qualification must be performed for the combination.



Metric Equivalents

in.	⅛	1½	6
[mm]	[3]	[40]	[155]

(*a*) Transverse Face-Bend Specimen—Plate and Pipe

t, in. [mm]	*T*, in. [mm] (all Ferrous Materials)
1⁄16 to ⅛ [1.6 to 3.2]	*t*
⅛ to ⅜ [3.2 to 9.5]	*t*
> ⅜ [9.5]	⅜ [9.5]

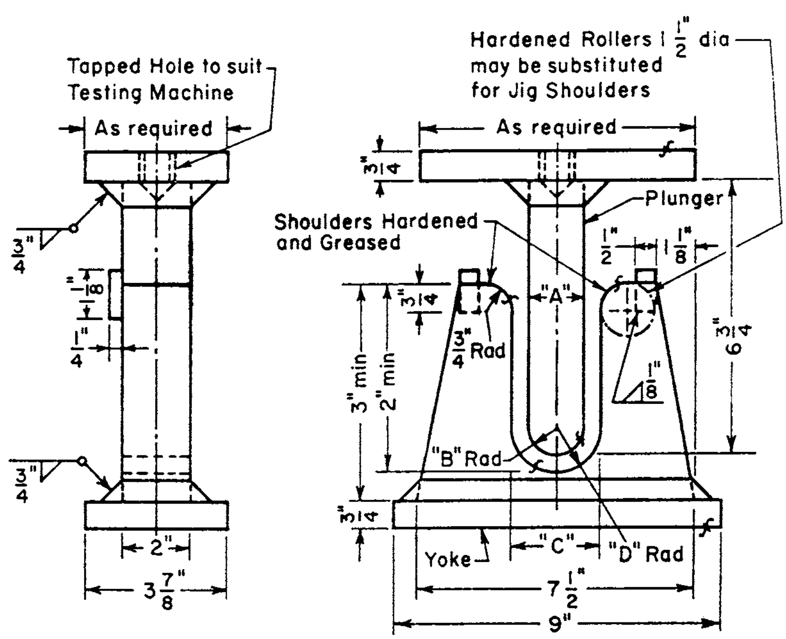
Metric Equivalents

in.	⅛	1½	6
[mm]	[3]	[40]	[155]

(*b*) Transverse Root-Bend Specimen—Plate and Pipe

Note—Weld reinforcement and backing strip or backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above.

FIG. 10 Transverse Face- and Root-Bend Specimens, for Pipe and Plate



Metric Equivalents

in.	⅛	¼	½	¾	1⅛	1½	2	3	3⅞	6¾	7½	9
[mm]	[3]	[5]	[15]	[20]	[30]	[40]	[50]	[75]	[100]	[170]	[190]	[230]

Specimen Thickness, in. [mm]	*A*, in. [mm]	*B*, in. [mm]	*C*, in. [mm]	*D*, in. [mm]
⅜ [9.5]	1½ [38.1]	¾ [19.0]	2⅜ [60.3]	1³⁄16 [30.2]
t	4*t*	2*t*	6*t* + ⅛ [3.2]	3*t* + 1⁄16 [1.6]

FIG. 11 Guided-Bend Test Jig

11.1.2 A change in the weld-deposit analysis or electrode type will require requalification under any of the following conditions:

11.1.2.1 A change from one A number in Table 4 to any other A number. Qualification with A No. 1 shall qualify for A No. 2 and vice versa. In lieu of an A number designation, the nominal chemical composition of the weld deposit shall be indicated on the Welding Material Specification (Fig. 3). Designation of nominal chemical composition may also be by reference to the AWS classification (where such exists), the manufacturer's trade designation, or other established procurement documents.

11.1.2.2 A change from one F number in Table 5 to any other F number.

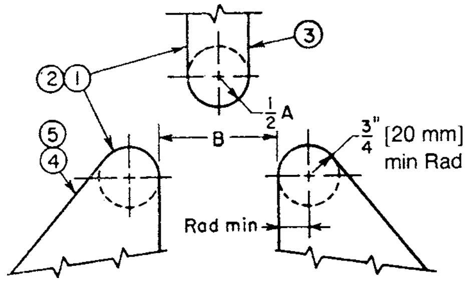


FIG. 12 Alternative Roller-Equipped Guided-Bend Test Jig

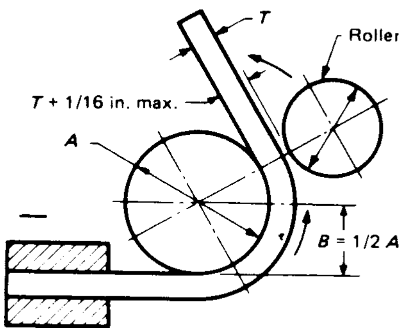


FIG. 13 Guided Bend Wrap-Around Jig

11.1.3 A decrease of 100°F [55°C] or more in the minimum specified preheat temperature.

11.1.4 A significant change in the post heat-treating temperature or time cycle.

11.1.5 A change in the method of backing up, or its omission if previously used.

11.1.6 A change in the welding process.

11.1.7 In submerged arc welding, where the alloy content of the weld metal is largely dependent upon the composition of the flux used, any change in any part of the welding procedure that would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the welding procedure specification.

11.1.8 In submerged arc welding, a change in the nominal composition or type of flux used (requalification is not required for a change in flux particle size).

11.1.9 For submerged arc welding, a change from a filler metal containing 1.75 to 2.25 % manganese to filler metal containing less than 1.00 % manganese or vice versa shall require requalification. The presence or absence of up to 0.5 % molybdenum in the filler metal analysis shall not require requalification.

11.1.10 For submerged arc welding, a change in filler metal analysis in Table 4 from one A number to another.

11.1.11 In gas metal arc welding and gas tungsten arc welding.

11.1.11.1 A change from the qualified single gas to any other single gas or to a mixture of gases, or a change in specified percentage composition of gas mixture.

11.1.11.2 A decrease of 10 % or more in the rate of flow of shielding gas or mixture.

11.1.12 For gas metal arc welding, a change in the consumable electrode from bare (solid) to flux cored, or vice versa.

11.1.13 Qualification of Category 10 base materials shall also qualify Category 9 base materials, and vice versa. Separate welding procedures are required for each category.

12. Performance Qualification of Welders or Operators

12.1 All welders and operators welding castings under this practice shall pass the welder qualification test. The welder or operator successfully performing the procedure qualification test is automatically qualified for performance.

12.1.1 Each welder or operator shall be qualified for each welding process (GTAW, GMAW, SMAW, FCAW, and so forth) he uses. The welder or operator successfully qualified with one procedure for a process is qualified to weld with any other welding procedure using the same welding process, unless requalification is required by Section 13.

12.2 *Test Plate*—The test plate or pipe or cylindrical casting shall be the same as that used in the procedure qualification with respect to groove dimensions, filler metal, and so forth. Groove dimensions as shown in Fig. 5 may be used. The welding procedure shall be in accordance with that given in the procedure qualification. For performance qualification, carbon steel plate, pipe, or cylindrical castings may be used for qualification of materials having a total alloy content of less than 6 %.

12.3 *Number of Tests*—The number and type of tests to qualify a performance shall be as shown in Table 3.

12.4 Test specimens shall be removed from the plate or pipe or cylindrical casting as shown in Figs. 15-18.

12.5 The guided bend test shall meet the requirements as specified in 8.2.3.

12.6 Alternative to the mechanical tests required in 12.3-12.5, the qualification test plate for welders and operators making groove welds using SMAW, GTAW, FCAW, or GMAW (except the short circuiting mode of transfer) processes may be examined by radiography using a technique shown by penetrameters to equal or exceed 2 % sensitivity. The weld to be radiographed shall be at least 6 in. [150 mm] long for welders and operators, or alternatively, a 3-ft [0.9-m] length of the first production weld made by a welding operator may be examined by radiography.

12.6.1 Final acceptance of the welds shall be based on the radiographic requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

12.6.2 If a production weld is selected for welder or operator qualification and it does not meet the radiographic standards, the welder or operator has failed the test. In the event the production weld requires welder or operator qualification, the entire production weld made by that welder or operator shall be radiographed and repaired by a qualified welder or operator. Alternatively, the entire weld shall be removed and replaced by a qualified welder or operator.

12.7 Each manufacturer or contractor shall maintain a record of the procedures, including essential variables, under which the welders and operators are examined. A suggested form for recording such information is shown in Fig. 2.

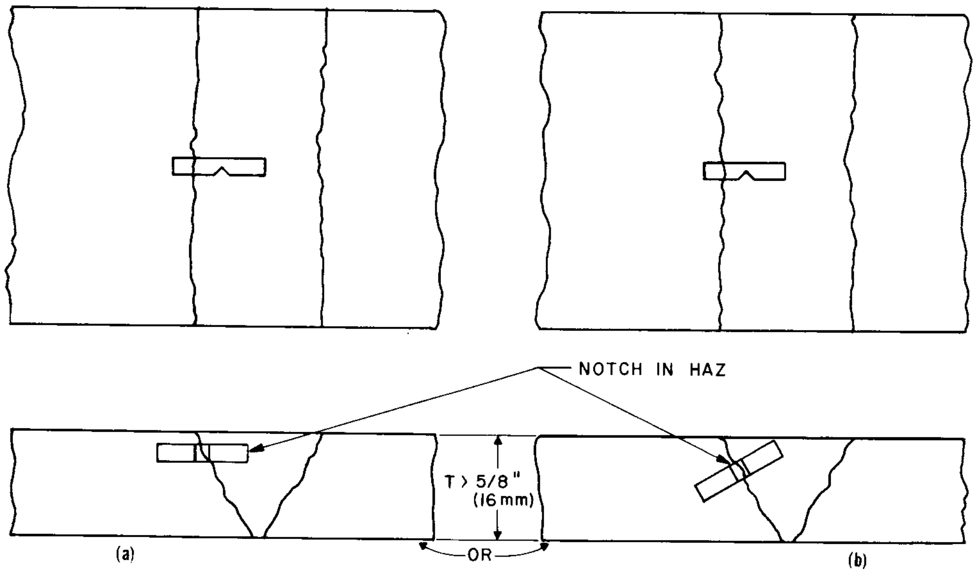


FIG. 14 Location of Notch in Charpy Specimens Shall Be In HAZ Midway Between Center and Surface

TABLE 4 A Numbers—Classification of Weld Metal Analysis for Procedure Qualification

A No.	Types of Weld Deposit	Analysis[A]					
		C, %	Cr, %	MO, %	Ni, %	Mn, %	Si, %
1	Mild steel	0.15				1.60	1.00
2	Carbon-molybdenum	0.15	0.50	0.40 to 0.65		1.60	1.00
3	Chromium (0.4 to 2 %)—molybdenum	0.15	0.40 to 2.00	0.40 to 0.65		1.60	1.00
4	Chromium (2 to 6 %)—molybdenum	0.15	2.00 to 6.00	0.40 to 1.50		1.60	2.00
5	Chromium (6 to 10.5 %)—molybdenum	0.15	6.00 to 10.50	0.40 to 1.50		1.20	2.00
6	Chromium-martensitic	0.15	11.00 to 15.00	0.70		2.00	1.00
7	Chromium-ferritic	0.15	11.00 to 30.00	1.00		1.00	3.00
8	Chromium-nickel	0.15	14.50 to 30.00	4.00	7.50 to 15.00	2.50	1.00
9	Chromium-nickel	0.30	25.00 to 30.00	4.00	15.00 to 37.00	2.50	1.00
10	Nickel to 4 %	0.15		0.55	0.80 to 4.00	1.70	1.00
11	Manganese-molybdenum	0.17		0.25 to 0.75	0.85	1.25 to 2.25	1.00
12	Nickel-chromium-molybdenum	0.15	1.50	0.25 to 0.80	1.25 to 2.80	0.75 to 2.25	1.00

[A] Single values shown above are maximum.

13. Requalification of Welders and Operators

13.1 A welder must be requalified when one of the changes in essential variables listed in 13.2 and 13.3 is made in the procedure, or as provided in 13.4 or 13.5.

13.2 A change in the weld deposit metal to a weld deposit metal having a different F number, or to a weld deposit metal not covered under Table 4. Qualification under any F number up to and including F4 shall qualify a welder for all lower F numbers.

13.3 A change in the method of backing up, or its omission if previously used.

13.4 When a welder has not used the specified process for three months or more.

13.5 When there is a reason to question his ability to make welds that meet this practice.

13.6 Requalification under 13.4 or 13.5 need only be made in a single thickness.

14. Retests

14.1 A welder or operator who fails to meet the requirements for one or more test specimens may be retested under the conditions described in 14.2 and 14.3.

14.2 When an immediate retest is made, the welder or operator shall make two test plates, each of which shall meet the requirements. If he fails these tests, he must undergo further training before a retest is permitted.

14.3 When a welder has had further training, a single retest is permitted.

15. Keywords

15.1 qualifications; steel castings; welding

TABLE 5 F Numbers—Grouping of Filler Metals for Qualification

F No.	ANSI/AWS Specification	ANSI/AWS Classification
1	SFA-5.1 & 5.5	EXX20, EXX22, EXX24, EXX27, EXX28
1	SFA-5.4	EXX25, EXX26
2	SFA-5.1 & 5.5	EXX12, EXX13, EXX14, EXX19
3	SFA-5.1 & 5.5	EXX10, EXX11
4	SFA-5.1 & 5.5	EXX15, EXX16, EXX18, EXX48
4	SFA-5.4 (other than austenitic and duplex)	EXX15, EXX16, EXX17
5	SFA-5.4 (austenitic and duplex)	EXX-15, EXX-16, EXX-17
6	SFA-5.2	RX
6	SFA-5.17	FXX-EXX, FXX-ECX
6	SFA-5.9	ERXX, ECXX, EQXX
6	SFA-5.18	ERXXS-X, EXXC-X, EXXC-XX
6	SFA-5.20	EXXT-X
6	SFA-5.22	EXXXT-X
6	SFA-5.23	FXX-EXXX-X, FXX-ECXXX-X, FXX-EXXX-XN, FXX-ECXXX-XN
6	SFA-5.25	FESXX-EXXXXX-EW
6	SFA-5.26	EGXXS-X, EGXXT-X
6	SFA-5.28	ERXXS-X, EXXC-X
6	SFA-5.29	EXXTX-X
6	SFA-5.30	INXXXX
41	SFA-5.11	ENi-1
41	SFA-5.14	ERNi-1
41	SFA-5.30	IN61
42	SFA-5.11	ENiCu-7
42	SFA-5.14	ERNiCu-7
42	SFA-5.14	ERNiCu-8
42	SFA-5.30	IN60
43	SFA-5.11	ENiCrFe-1
43	SFA-5.11	ENiCrFe-2
43	SFA-5.11	ENiCrFe-3
43	SFA-5.11	ENiCrFe-4
43	SFA-5.11	ENiCrFe-7
43	SFA-5.11	ENiCrFe-9
43	SFA-5.11	ENiCrFe-10
43	SFA-5.11	ENiCrCoMo-1
43	SFA-5.11	ENiCrMo-2
43	SFA-5.11	ENiCrMo-3
43	SFA-5.11	ENiCrMo-6
43	SFA-5.11	ENiCrMo-12
43	SFA-5.14	ERNiCr-3
43	SFA-5.14	ERNiCr-4
43	SFA-5.14	ERNiCr-6
43	SFA-5.14	ERNiCrFe-5
43	SFA-5.14	ERNiCrFe-6
43	SFA-5.14	ERNiCrFe-7
43	SFA-5.14	ERNiCrFe-8
43	SFA-5.14	ERNiCrFe-11
43	SFA-5.14	ERNiCrCoMo-1
43	SFA-5.14	ERNiCrMo-2
43	SFA-5.14	ERNiCrMo-3
43	SFA-5.30	IN82
43	SFA-5.30	IN62
43	SFA-5.30	IN62A
44	SFA-5.11	ENiMo-1
44	SFA-5.11	ENiMo-3
44	SFA-5.11	ENiMo-7
44	SFA-5.11	ENiMo-8
44	SFA-5.11	ENiMo-9
44	SFA-5.11	ENiMo-10
44	SFA-5.11	ENiCrMo-4
44	SFA-5.11	ENiCrMo-5
44	SFA-5.11	ENiCrMo-7
44	SFA-5.11	ENiCrMo-10
44	SFA-5.11	ENiMo-13
44	SFA-5.11	ENiMo-14
44	SFA-5.14	ERNiMo-1
44	SFA-5.14	ERNiMo-2, ERNiMo-3
44	SFA-5.14	ERNiMo-7 (Alloy B-2)
44	SFA-5.14	ERNiMo-8
44	SFA-5.14	ERNiMo-9
44	SFA-5.14	ERNiMo-10
44	SFA-5.14	ERNiCrMo-4
44	SFA-5.14	ERNiCrMo-5
44	SFA-5.14	ERNiCrMo-7 (Alloy C-4)
44	SFA-5.14	ERNiCrMo-10

TABLE 5 *Continued*

F No.	ANSI/AWS Specification	ANSI/AWS Classification
44	SFA-5.14	ERNiCrMo-13
44	SFA-5.14	ERNiCrMo-14
44	SFA-5.14	ERNiCrWMo-1
45	SFA-5.11	ENiCrMo-1
45	SFA-5.11	ENiCrMo-9
45	SFA-5.11	ENiCrMo-11
45	SFA-5.14	ERNiCrMo-1
45	SFA-5.14	ERNiFeCr-1
45	SFA-5.14	ERNiCrMo-8
45	SFA-5.14	ERNiCrMo-9
45	SFA-5.14	ERNiCrMo-11
71	SFA-5.13	EFeMn-A, EFeMn-B,EFeMn-C,EFeMn-D, EFeMn-E, EFeMn-F, EFeMnCr

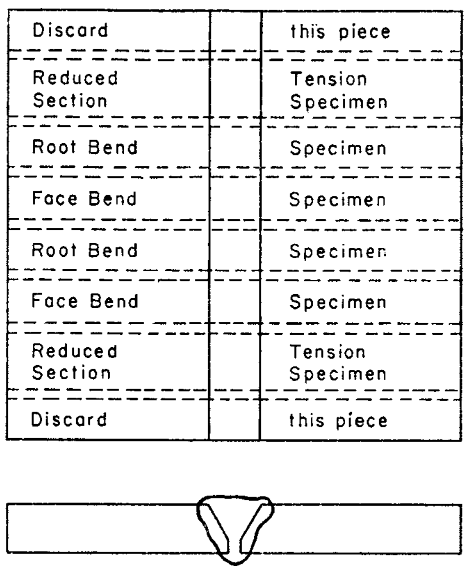


FIG. 15 Order of Removal of Test Specimens from Test Plate 1⁄16 to 3⁄4 in. [1.6 to 19.0 mm] Thick

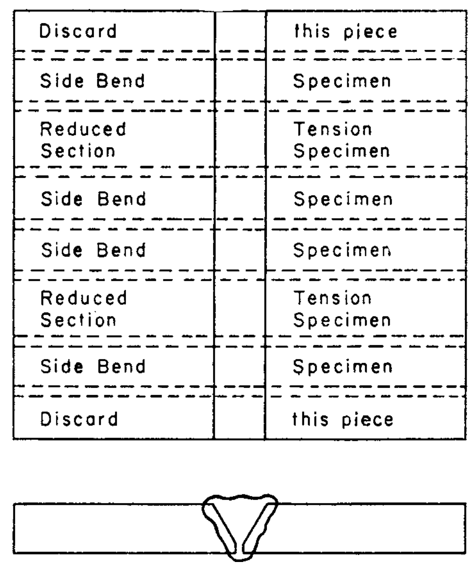


FIG. 16 Order of Removal of Test Specimens from Welded Test Plates over 3⁄4 in. [19.0 mm] Thick (May be Used for Thicknesses 3⁄8 to 3⁄4 in. [9.5 to 19.0 mm])

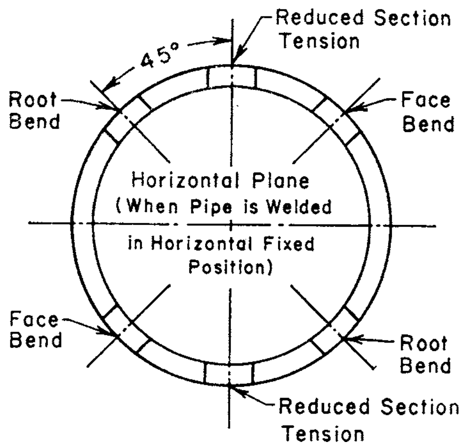


FIG. 17 Order of Removal of Test Specimens from Welded Pipe or Cylindrical Castings 1⁄16 to 3⁄4 in. [1.6 to 19.0 mm] Thick

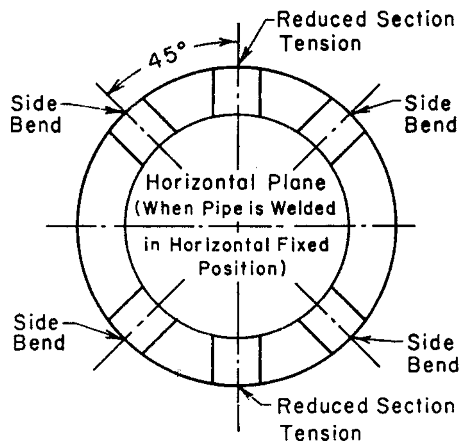


FIG. 18 Order of Removal of Test Specimens from Welded Pipe or Cylindrical Castings over 3⁄4 in. [19.0 mm] Thick (May be Used for Thicknesses 3⁄8 to 1⁄4 in. [9.5 to 19.0 mm])

APPENDIX

(Nonmandatory Information)

X1. PRACTICE A 488/A 488M CATEGORY NUMBER AND CORRESPONDING ASME P NUMBER

X1.1 Listed in Table X1.1 for information are the Practice A 488/A 488M categories of base metal casting specifications for welding qualifications and the corresponding P number designations from Section IX of the ASME Boiler and Pressure Vessel Code.

TABLE X1.1 ASTM Categories of Base Metal Casting Specifications and Corresponding P Number Designations

NOTE 1—The P numbers are under the jurisdiction of the ASME Boiler and Pressure Vessel Code and may be subject to change subsequent to the effective date of this specification.

ASTM			A 488/A 488M Category No.	ASME	
Specification	Grade	Class		P No.	Group No.
A 216/A 216M	WCA		1	1	1
	WCB		1	1	2
	WCC		2	1	2
A 217/A 217M	WC1		4	3	1
	WC4		4	4	1
	WC5		4	4	1
	WC6		4	4	1
	WC9		4	5A	1
	C5		5	5B	1
	C12		5	5B	1
	CA-15		8	6	3
A 351/A 351M	CF3		9	8	1
	CF3A		9	8	1
	CF8		10	8	1
	CF8A		10	8	1
	CF10		10	8	1
	CF10M		10	8	1
	CF3M		9	8	1
	CF8M		10	8	1
	CF8C		11	8	1
	CH8		10	8	2
	CH20		10	8	2
	CK20		11	8	2
	CN7M		11	45	. . .
	CG6MMN		10	8	3
	CG8M		10	8	1
	CD4MCU		12	10H	1
	CE8MN		10	10H	1
	CT15C		11	45	. . .
A 352/A 352M	CA6NM		8	6	4
	LCA		1	1	1
	LCB		1	1	1
	LCC		2	1	2
	LC1		4	3	1
	LC2		4/6	9A	1
	LC3		4/6	9B	1
	LC4		4/6	9C	1
	LC2-1		4/6	11A	5
A 487/A 487M	8	A	5	5B	1
	8B		6	5C	4
	8C		6	5C	4
	CA-15A		8	6	3
	CA-15B		8	6	3
	CA-15C		8	6	3
	CA-15D		8	6	3
	CA-15M	A	8	6	3
	CA 6NM	A	8	6	
	1	A	5	10A	1
	1	B	6	10A	1
	2	A	5	10F	1
	2	B	6	10F	1
	4	A	5	10F	1
	4	B	6	11A	3
	16	A	4	1	2
	4	E	6	11A	3

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 488/A 488M-06) that may impact the use of this standard. (Approved May 1, 2007.)

(*1*) Added reference to A 958.

(*2*) Added Grades from A 958 to Table 1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 488/A 488M (04)) that may impact the use of this standard. (Approved Sept. 1, 2006.)

(*1*) In Section 2 added reference to A 128/A 128M.

(*2*) In section 10.2 added exception for Category 15 materials.

(*3*) Revised Fig. 4.

(*4*) In Table 1added Category 15.

(*5*) In Table 5 added F No. 71.