

(内部资料)

美国材料试验
学会 (ASTM)

ASTM A335/A335M-2011

高温用无缝铁素体合金钢管子
**Standard Specification for
Seamless Ferritic Alloy-Steel Pipe for
High-Temperature Service¹**

美国材料试验学会 (ASTM)



高温用无缝铁素体合金钢管子

本标准是以固定代号 **A335/A335M** 发布的。其后的数字表示原文本正式通过的年号；在有修订的情况下，为上一次的修订年号；圆括号中数字为上一次重新确认的年号。上标符号（ε）表示对上次修改或重新确定的版本有编辑上的修改。

本标准经批准业已用于国防部所有机构。

1.适用范围

1.1 本标准适用于高温用名义壁厚和最小壁厚的铁素体无缝合金钢管。按本标准订货的管子应适合于弯管、卷边（热流通轧收口）及类似的成形加工，以及熔化焊。可根据设计、工作条件、力学性能及高温特性进行选用。

1.2 本标准适用于一些级别的铁素体钢（注1），其化学成分列于表1。

注 1：在本标准中，铁素体钢的定义为含Cr小于等于10%的低、中合金钢。

1.3 提供了选用性的补充要求（S1到S7）。当要求时，按这些补充要求进行附加试验，当有这样的要求时应在订货单中连同所要求的这些试验次数一起给予说明。

1.4 以英寸—磅单位或SI单位表示的数值均可作为标准值。本文中 SI 单位表示的值列于括号内。由于各单位制表示的数值不能与另一种单位制进行精确换算，因此每一种单位制必须独立使用。两种单位制的数值混合使用可能导致与本标准不一致的结果。除非订货单中规定采用“M”标志（即SI单位），材料将以英寸—磅单位供货。

注 2：本标准以无量纲标号 NPS（管子名义尺寸）代替如“名义直径”，“尺寸”和“名义尺寸”之类以往惯用术语。

2.引用文件

2.1 ASTM 标准

A999/A999M 合金钢与不锈钢管通用要求

E92 金属材料维氏硬度试验方法

E213 金属管和管道超声波检验规程

E309 钢管制品采用磁饱和的涡流检验规程

E381 钢棒、方钢、钢坯、锻件浸蚀检验方法

E527 合金和金属的统一编号方法（UNS）

E570 铁磁性钢管材制品的漏磁通检验规程

2.2 ASME标准

B36.10M 焊接与无缝锻造钢管

2.3 AWS规范

A5.5/A5.5M 保护金属电弧焊用低合金钢电极

A5.23/A5.23M 埋弧焊用低合金钢电极和焊剂

A5.28/A5.28M 气体保护弧焊用低合金钢电极和焊条

A5.29/A5.29M 管状焊条电弧焊用低合金钢电极

2.4 其他文件

SNT-TC-1A 无损检测人员资格评定和证书推荐规程

SAE J 1086 金属和合金的编号方法（UNS）

3.订货须知

3.1 订购本标准所列材料的订购单应包含以下必需的内容并予以充分地说明：

- 3.1.1 数量（英尺、米或根数），
- 3.1.2 材料名称（无缝合金钢管子），
- 3.1.3 级别（表 1），
- 3.1.4 制造方法（热精整或冷拔），
- 3.1.5 下列形式之一表示的尺寸：
 - 3.1.5.1 NPS（管子公称尺寸）和壁厚序列号，
 - 3.1.5.2 外径和公称壁厚，
 - 3.1.5.3 外径和最小壁厚，
 - 3.1.5.4 内径和公称壁厚，
 - 3.1.5.5 内径和最小壁厚。
- 3.1.6 长度（定尺或不定尺）。
- 3.1.7 端部加工（A999/A999M 标准中端部一节）。
- 3.1.8 选用要求（本标准的第 8、12 及 13 节。见 A999/A999M 标准中水压试验要求一节及无缝管的允许重量偏差）。
- 3.1.9 标准号
- 3.1.10 特殊要求或任何选用的补充要求，或两者。

4.一般要求

- 4.1 按本标准提供的材料，除在这里另有规定外，应符合现行版本的 A999/A999M 标准的相应要求。

表1 化学成分要求

级别	UNS 标号 ^A	成分, %							
		C	Mn	P≤	S≤	Si	Cr	Mo	其它
P1	K11522	0.10-0.20	0.30-0.80	0.025	0.025	0.10-0.50	...	0.44-0.65	...
P2	K11547	0.10-0.20	0.30-0.61	0.025	0.025	0.10-0.30	0.50-0.81	0.44-0.65	...
P5	K41545	≤0.15max	0.30-0.60	0.025	0.025	≤0.50	4.00-6.00	0.45-0.65	...
P5b	K51545	≤0.15max	0.30-0.60	0.025	0.025	1.00-2.00	4.00-6.00	0.45-0.65	...
P5c	K41245	≤0.12max	0.30-0.60	0.025	0.025	≤0.50	4.00-6.00	0.45-0.65	... ^B
P9	S50400	≤0.15max	0.30-0.60	0.025	0.025	0.25-1.00	8.00-10.00	0.90-1.10	...
P11	K11597	0.05-0.15	0.30-0.60	0.025	0.025	0.50-1.00	1.00-1.50	0.44-0.65	...
P12	K11562	0.05-0.15	0.30-0.61	0.025	0.025	≤0.50	0.80-1.25	0.44-0.65	...
P15	K11578	0.05-0.15	0.30-0.60	0.025	0.025	1.15-1.65	...	0.44-0.65	...
P21	K31545	0.05-0.15	0.30-0.60	0.025	0.025	≤0.50	2.65-3.35	0.80-1.06	...
P22	K21590	0.05-0.15	0.30-0.60	0.025	0.025	≤0.50	1.90-2.60	0.87-1.13	...
P23	K41650	0.04-0.10	0.10-0.60	≤0.030	≤0.010	≤0.50	1.90-2.60	0.05-0.30	V0.20-0.30 Cb0.02-0.08 B0.0010-0.006 N≤0.015 Al≤0.030 W 1.45-1.75 Ni 0.40max Ti 0.005-0.060 Ti/N≥3.5 ^C
P24	K30736	0.05-0.10	0.30-0.70	≤0.020	≤0.010	0.15-0.45	2.20-2.60	0.90-1.10	V0.20-0.30 Ti0.06-0.10 N≤0.012 Al≤0.02 B 0.0015-0.007
P36	K21001	0.10-0.17	0.80-1.20	≤0.030	≤0.025	0.25-0.50	≤0.30	0.25-0.50	Ni 1.00-1.30 Cu 0.50-0.80 Cb 0.015-0.045 V≤0.02 N≤0.02 Al≤0.050
P91	K91560	0.08-0.12	0.30-0.60	0.020	0.010	0.25-0.50	8.00-9.50	0.85-1.05	V 0.18-0.25 N 0.030-0.070 Ni≤0.40 Al≤0.020 Cb 0.06-0.10 Ti≤0.01 Zr≤0.01

表1 化学成分要求 (续)

级别	UNS 标号 ^A	成分, %							
		C	Mn	P≤	S≤	Si	Cr	Mo	其它
P92	K92460	0.07-0.13	0.30-0.60	0.020	0.010	≤0.50	8.50-9.50	0.30-0.60	V 0.15-0.25 N 0.03-0.07 Ni≤0.40 Al≤0.02 Cb≤0.04-0.09 W 1.5-2.00 B 0.001-0.006 Ti≤0.01 Zr≤0.01
P12 ₂	K92930	0.07-0.14	≤0.70	0.020	0.010	≤0.50	10.00-11.50	0.25-0.60	V 0.15-0.30 W 1.50-2.50 Cu 0.30-1.70 Cb 0.04-0.10 B 0.0005-0.005 N 0.040-0.100 Ni≤0.50 Al≤0.020 Ti≤0.01 Zr≤0.01
P91 ₁	K91061	0.09-0.13	0.30-0.60	≤0.020	≤0.010	0.10-0.50	8.5-9.5	0.90-1.10	V 0.18-0.25 Ni≤0.40 Cb 0.060-0.10 B 0.0003-0.006 N 0.04-0.09 Al≤0.02 W 0.90-1.10 Ti≤0.01 Zr≤0.01

A 新标号是按照 ASTM E527 及 SAE J1086 标准, 金属和合金编号实用规程 (UNS) 确定的。

B P5C级别应具有不小于 4 倍碳含量和不大于 0.70% 的钛含量, 或 8-10 倍碳含量的铌含量。

C 作为一种选择, 可用该比值的最小值替代, 在淬透状态时材料的最小硬度应为 275HV, 淬透状态定义为奥氏体化之后, 但在回火之前冷却至室温的状态。硬度试验应在产品的中间厚度处进行。对于每个热处理批次, 硬度试验频率应为两个产品样本, 硬度试验结果应在材料试验报告中报告。

表 2 热处理要求^A

级别	热处理类型	正火温度 (最低或范围) F[°C]	冷却温度	亚临界点下退火或回火温度 (最低或范围) F[°C]
P1	完全或等温退火	...	...	...
	正火和回火	...	...	1200[650]
	亚临界点下退火	...	...	1200-1300[650-750]
P2	完全或等温退火	...	...	...
	正火和回火	...	...	1200[650]
	亚临界点下退火	...	...	1200-1300[650-750]
P5	完全或等温退火	...	...	...
	正火和回火	...	...	1250[675]
P5b	完全或等温退火	...	...	...
	正火和回火	...	...	1250[675]
P5c	亚临界点下退火	...	...	1325-1375[715-745]
P9	完全或等温退火	...	...	...
	正火和回火	...	...	1250[675]
P11	完全或等温退火	...	...	...
	正火和回火	...	...	1200[650]
P12	完全或等温退火	...	...	...
	正火和回火	...	...	1200[650]
	亚临界点下退火	...	...	1200-1300[650-705]
P15	完全或等温退火	...	...	...
	正火和回火	...	...	1200[650]
P21	完全或等温退火	...	...	...
	正火和回火	...	...	1250[675]
P22	完全或等温退火	...	...	...
	正火和回火	...	...	1250[675]
P23	正火和回火	1900-1975[1040-1080]	空冷或加速冷 却	1350-1470[730-800]
P24	正火和回火	1800-1870[980-1020]	空冷或加速冷 却	1350-1420[730-770]
P36	正火和回火 ^B	1650[900]	...	1100[595]
P91	正火和回火	1900-1975[1040-1080]	...	1350-1470[730-800] ^C
	淬火和回火 ^D	1900-1975[1040-1080]	...	1350-1470[730-800]
P92	正火和回火	1900-1975[1040-1080]	E	1350-1470[730-800]
P122	正火和回火	1900-1975[1040-1080]	...	1350-1470[730-800]
P911	正火和回火	1900-1975[1040-1080]	E	1350-1435[740-780]

A 表中省略号（...）表示无要求。

B 作为一种可选择的方法，P36级，C2类钢应通过空气加速或通过液体淬火从奥氏体化温度开始冷却。

C 除了买方规定补充要求S7时。

D 当厚度大于3in[75mm]时，制造商与买方双方都同意时，应允许进行淬火和回火。

E 当截面厚度大于3in[75mm]时，应允许从正火温度开始加速冷却。

表3 拉伸性能要求

	级别								
	P1,P2	P12	P23	P24	P91	P92,P911 P36类别1	P122	P36类别 2	其它所 有
最小抗 拉强度: ksi MPa	55 380	60 415	74 510	85 585	85 585	90 620	90 620	95.5 660	60 415
最小抗 拉强度: ksi MPa	30 205	32 220	58 400	60 415	60 415	64 440	58 400	66.5 460	30 205

表4 延伸率要求

标距2in。或 50mm (或4D) 的最小延伸 率, %	除P23, P36, P91、P92和P122外 的所有级别		P23, P24, P91、P92,P122和P911 级别		P36
	纵向	横向	纵向	横向	
壁厚 \geq 5/16in。 (8mm) 条状 试样及所有全 截面试验小尺 寸试样的基本 延伸率	30	20	20	---	15
当使用标距为 2in 或 50mm 的 标准圆形试 样, 或标距为4D小 尺寸比例试样 时	22	14	20	13	---
从壁厚 5/16in (8mm) 条状试样每减 薄 1/32in(0.8mm) 时, 从基本延 伸率所应减小 的百分数	1.50 ^A	1.00 ^A	1.00 ^A	---	1.00 ^A

A 表5给出了计算的最小值。

表 5 计算最小伸长率值

壁厚		标距2in或50mm伸长率最小值			
		除P23, P36, P91、P92和P122外的所有级别		P23, P24, P91、P92, P122 和P911级别	P36
in	mm	纵向	横向	纵向	纵向
5/16(0.312)	8	30	20	20	15
9/32(0.218)	7.2	28	19	19	14
1/4(0.250)	6.4	27	18	18	13
7/32(0.219)	5.6	26	--	17	12
3/16(0.188)	4.8	24	--	16	11
5/32(0.156)	4	22	--	15	10
1/8(0.125)	3.2	21	--	14	9
3/32(0.094)	2.4	20	--	13	8
1/16(0.062)	1.6	18	--	12	7

表 6 外径的允许偏差

NPS (DN) 标识	上偏差		下偏差	
	in	mm	in	mm
1/8~1-1/2(6~40)	1/64(0.015)	0.40	1/64(0.015)	0.40
>1-1/2~4 (4~100)	1/32(0.031)	0.79	1/32(0.031)	0.79
>4~8 (100~200)	1/16(0.062)	1.59	1/32(0.031)	0.79
>8~12 (200~300)	3/32(0.093)	2.38	1/32(0.031)	0.79
>12 (300)	$\pm 1\%$ 的规定外径			

表 7 壁厚的允许偏差

NPS (DN) 标识	规定值的偏差, %	
	上偏差	下偏差
1/8~2-1/2 (6~65), 所有 t/D 比率 ^A	20.0	12.5
>2-1/2 (65), t/D ≤ 5% ^A	22.5	12.5
>2-1/2 (65), t/D > 5% ^A	15.0	12.5

^A t=规定壁厚; D=规定外径。

表 8 合格证书及标志用试验方法表示

超声波	磁泄漏	涡流	水压	标记
做	不做	不做	不做	UT
不做	做	不做	不做	FL
不做	不做	做	不做	EC
做	不做	不做	做	UT/试验压力
不做	做	不做	做	FL/试验压力
不做	不做	做	做	EC/试验压力

5.材料及制造方法

5.1 钢管可为热精整或冷拔，并经过如5.3条所要求的最终热处理。

5.2 P2和P12级钢——该级别钢应采用粗晶（粒）熔炼工艺制造。若在晶粒度或脱氧工艺上有特殊限定时，应由买方和钢厂商定。

5.3 热处理

5.3.1 所有管应重新加热热处理，然后应按表2要求进行热处理。

注3：建议回火温度应至少高于预期工作温度100°F (50°C)，因此若工作温度高于1100°F (600°C)，买方应通知钢厂。

注4：本标准适用于某些铁素体钢，如在它们的临界温度以上快速冷却将会淬透处理。某些会在空气中淬透，即从高温在空气中冷却时会硬化到不希望的程度。所以这些级别钢如在高于其临界温度进行热加工，例如焊接、卷边及热弯时，随后应进行合适的热处理。

6.化学成分

6.1 钢应符合表1中规定的化学成分要求

7.工艺、表面质量和外观

7.1 管子制造商应查出足够数量的可见表面缺陷进行测定，以保证对缺陷深度做出适当评估，不必查出所有的表面缺陷进行测定，但需保证与7.2条相符合。

7.2 当表面缺陷深度超过12.5%公称壁厚或侵占最小壁厚时应认为是有害缺陷，带有这类缺陷的管子应按下列方法之一处理：

7.2.1 如果剩余壁厚仍在规定范围以内，则该类缺陷可以用砂轮磨去。

7.2.2 按照7.6条的焊接修补规定返修。

7.2.3 在长度允许范围内，可割去管长中含有缺陷的一截管段。

7.2.4 拒收。

7.3 为提供良好的表面质量，并在符合7.2条评判条件的基础上，制管厂应打磨除去以下缺陷：

7.3.1 机械刻痕，擦伤（注5），凹坑以及其它深度大于1/16in (1.6mm) 的缺陷。

注5：刻痕及擦伤的定义为钢丝绳划痕、撞伤，导轨划痕，轨机划痕，钢球刻痕，伤痕及钢模划痕和相似的情况。

7.3.2 按7.1条测定时发现的深度大于5%公称壁厚的外观缺陷，通常指疵点、疤痕、皱皮、刮伤或银纹。

7.4 若表面缺陷虽按7.2条可以接受，但其并不分散出现，而是存在于一大块面积上，达不到良好外观的要求，则根据买方意见，该管应予拒收。这类管子的处理应由钢管厂和买方协商。

7.5 当用砂轮磨去缺陷或有害缺陷时，应保持表面平滑过渡，且不应使该处壁厚降低到小于本标准规定的允许值。打磨点外径可以由于磨削而减小。

7.5.1 壁厚应用机械卡规或用正确校定过的具有一定精度的无损检测仪测定。若有争议，应以卡规测量为准。

7.6 补焊应事先征得买方同意后方可进行，并符合 A999/A999M 标准要求。

7.6.1 所有P91级材料的补焊应采用以下某一种焊接工艺和焊接消耗性材料：SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9+天然焊剂; GTAW, A5.28/A5.28M ER90S-B9和FCAW A5.29/A5.29M

E91T1-B9。另外，P91级材料补焊使用的所有焊接消耗性材料的Ni+Mn的总含量应不超过1.0%。

7.6.2 P92、P911和P122材料的所有补焊应采用满足表1级别化学成分要求的焊接消耗性材料。

7.6.3 焊接修补后，P23, P91, P92 和 P122级钢应进行1350-1470°F [730-800°C]热处理。

7.6.4 焊接修补后，P911级钢应进行1365-1435°F [740-780°C]热处理。

7.6.5 焊接修补后，P24级钢应进行1350-1420°F [730-770°C]热处理。

7.7 成品钢管应具有良好的平直度。

8.成品分析

8.1 在买方要求时，来自每批的两个管子应由制造厂予以分析。一个批次应为由相同炉批钢制造而成，具有相同名义尺寸和壁厚（壁厚序列号）的所有管子组成。一批管子应包括如下：

NPS 标号 一个批次管子的最大根数

<2	400 根
2-5	200 根
≥6	100 根

8.2 这些分析的结果应向买方或其代表报告，并应与表 1 中规定的要求相符合。

8.3 P91钢管的成品分析含碳量可按表1规定范围内有-0.01%和+0.02%的偏差。

8.4 若按 8.1条中规定的试验中有一根管的分析结果与第6.1条中规定的要求不符合，则应自同炉同批的每一个钢坯或每根钢管进行分析，符合要求的所有钢坯或钢管应可接受。

9.拉伸性能和硬度要求

9.1 材料应符合表 3 中规定的拉伸性能要求。

9.2 表 4 列出了延伸率要求。

9.3 P91级钢管的硬度应为190-250HBW/196-265HV (91HRB-25HRC)。P24、P92、P122和P36级钢管的硬度应不得超过 250HB/265HV (25HRC)。

9.4 表5给出了壁厚每增加 1/32in(0.8mm)时算得的最小延伸率值。当壁厚在上述两值之间时，最小延伸率的值由下式确定。

试验方向

纵向，除了P23、P91、P92、P122 和P911级钢外所有级别

公式^B

$$E=48t+15.00 (E=1.87t+15.00)$$

横向，除了P23、P91、P92、P122 和P911级钢外所有级别

$$E=32t+10.00 (E=1.25t+10.00)$$

纵向，P23、P91、P92、P122 和 P911

$$E=32t+10.00 (E=1.25t+10.00)$$

纵向，P36

$$E=32t+5.0 (E=1.25t+5.0)$$

式中：E=标距为2in或50mm的延伸率，%；

t=试样的实际壁厚，in (mm)

9.5对于P91级钢，当同意按表2注D完成淬火和回火之后，应满足抗拉强度和硬度性能要求，试验验证应在半厚度位置截取的材料上进行。

10.直径允许偏差

10.1 按 NPS[DN] 或外径订购的管道，外径偏差应不超过表 6 中的规定偏差。

10.2 按内径订购的管道，内径不应超过要求内径的±1%。

11.壁厚允许偏差

11.1 除了根据A999/A999M规程的重量要求对钢管壁厚绝对值要求外，钢管任意一处的壁厚还应在表7规定的公差范围内。按 NPS[DN] 订购管道时，与本要求检验一致的最小壁厚和外径及其壁厚序列号见 ASME B36.10M所示。

12.水压试验

12.1除了P91、P92、P911和P122级别外，其它级别钢的要求见12.1.1-12.1.4所示。

12.1.1外径大于10in (250mm) 和壁厚小于等于0.75in(19mm)的每根管道应提交进行水压试验，除了12.4的例外情况外。

12.1.2所有其它规格的管道应按章节13提交进行无损电测试验，除了12.1.3和12.1.4的例外情况外。

12.1.3当买方规定时，所有其它规格的管道供应时应可不进行水压试验和无损电测试验。

12.1.4当买方规定时，管道供应时应进行水压试验和无损电测试验。

12.2 P91、P92、P911和P122级别钢的要求见12.2.1-12.2.3所示。

12.2.1 外径大于10in (250mm) 和壁厚小于等于0.75in(19mm)的每根管道应按章节13提交进行水压试验和无损电测试验。

12.2.2所有其它规格的管道应按章节13提交进行无损电测试验，除了12.2.3的例外情况外。

12.2.3当买方规定时，所有其它规格的管道供应时应进行水压试验和无损电测试验。

13.无损检测

13.1 当以上 12.1.2 或 12.2 要求时，当买方订单规定时(除了水压试验之外 (12.2.3))，每根钢管均应按照 E213、E309 或 E570 检验方法要求进行无损检测。对于 P91、P92、P911 和 P122 级别钢，应按规程 E213

中的某一检查方法进行检查。当订单规定时，P91、P92、P911 和 P122 级别钢应可按规程 E309 或 E570 中的某一检查方法进行检查，除了规程 E213 规定的某一检查方法之外。每种检测方法所能检测的管道尺寸范围应以各方法的限制范围为条件。

13.2 当替代或增加规范 A999/A999M 的要求时，以下条件适用。

13.2.1 缺口的宽度应不超过深度。

13.2.2 在任何标定中，若发现参考信号波幅减幅达 25% (2db)，则该试验装置应认为标定已失效。可改变试验系统设定，或调整换器，线圈或探头，并对整个系统重新标定；但是自上一次合格标定以来测试过的所有管子必须重新试验。

13.2.3 产生出大于等于参考标准试块所产生信号的钢管应经过进一步鉴别，这些挑出的钢管可以受下列四种处理之一：

13.2.3.1 钢管厂可以自行决定，对这些钢管不再作进一步的检验，作为拒收处理；

13.2.3.2 对于缺陷产生的试验无法辨认的管或由裂纹及类似裂纹缺陷产生的信号的钢管应予拒收。

13.2.3.3 这些钢管可以进行打磨修理（按 7.2.1 条），焊补（按 7.6 条）或分割（按 7.2.3 条）。修补过的管子必须能通过原先被拒收时相同的无损检测检验，且剩余壁厚必须符合本标准的要求，方可验收。

13.2.3.4 若是由下列所示外观缺陷产生的试验信号，则这些管可以根据第 7 节的规定进行评估：

- (a) 擦伤；
- (b) 表面粗糙；
- (c) 撞伤；
- (d) 矫直机划痕；
- (e) 切屑；
- (f) 钢模划痕；
- (g) 刹车痕；
- (h) 减径管皱纹。

14.要求的机械性能试验

14.1 批次—对于机械性能试验，一个批次是指自同炉生产的钢制造的和在连续炉里经相同热处理的相同公称尺寸和壁厚（或壁厚系列号）的所有管子。如果最后热处理在分批炉进行，则批仅是同炉装料热处理的这些管子。

14.2 横向或纵向拉伸试验及压扁试验，硬度试验或弯曲试验——对于在分批处理式炉内热处理的材料，应在每一处理批中的 5% 钢管上进行试验。对批量小的应至少试验 1 根钢管。对于用连续工艺进行热处理的材料，试验应该在足够数量的管上进行达到每一批的 5%，但任何情况下不少于 2 根钢管。

14.3 硬度试验

14.3.1 维氏硬度试验应按试验方法 E92 执行。

14.3.2 壁厚 $\geq 0.200\text{in}$ (5.1mm) 的管道，应可以进行布氏硬度试验或洛氏硬度试验。当进行布氏硬度试验时，制造商应可选择采用 10mm 球施加 3000、1500 或 500kg 载荷进行试验。

14.3.3 壁厚 $\geq 0.065\text{in}$ (1.7mm)，但是 $< 0.200\text{in}$ (5.1mm) 的管道，应进行洛氏硬度试验。

14.3.4 壁厚 $< 0.065\text{in}$ (1.7mm) 的管道，硬度试验应不作要求。

14.3.5 制造商可选择在管道接近末端的外侧、切自管道上的某一样本的外侧或切自管道的某一样本管壁横截面上进行布氏硬度试验。本试验进行时，样本边缘的压痕中心应至少为 2.5 倍的压痕直径。

14.3.6 制造商应可选择在内表面、管壁横截面或外表面平坦位置进行洛氏硬度试验。

14.3.1 对于 P24、P91、P92、P122、P911 和 P36 级钢的管子应从每批抽取一个样本进行布氏硬度、维氏硬度或洛氏硬度试验。

14.4 弯曲试验

14.3.1 对于直径大于 NPS 25 及直径和壁厚比小于等于 7.0 的钢管应进行弯曲试验代替压扁试验。当得到买方的批准时，其他的直径大于等于 NPS 10 的钢管可以用弯曲试验代替压扁试验。

14.4.2 弯曲试样应在室温下弯曲到 180°，而变弯部分的外侧不发生开裂。弯曲内径应为 1in(25mm)。

14.4.3 除非另有规定，对于 14.4 条规定的弯曲试验的试样应从管子的一端切取，且沿横向取下。一个试样

应尽量靠近外表面切取，而另一个则尽量靠近内表面。试样的截面尺寸应 $1/2\text{in} \times 1/2\text{in}$ ($12.5\text{mm} \times 12.5\text{mm}$)或 $1\text{in.} \times 1/2\text{in}$ ($25\text{mm} \times 12.5\text{mm}$)，截面上的四个角应倒成圆角，圆角半径不大于 $1/16\text{in}$ (1.6mm)，长度上不超过 6in (150mm)。在弯曲试验试样贴近管子内、外表面的侧面应分别位于受拉位置。

15.合格证书

15.1 要求按A999/A999M标准中章节25所述准备合格证书和试验报告。

15.2 除A999/A999M标准所要求的信息以外，合格证书上应说明材料是否作过水压试验。如果材料进行过无损电测试验，则在合格证书应注明，并示出所遵照的操作规程及所用的参考标定不连续。此外，在合格证书所示出的标准号及级别处应加上如表8中列出的试验方法信息。

16.产品标志

16.1 除 A999/A999M 标准中规定的标志外，还应包括：长度；如果管子符合 S1至S6的任一补充要求时，还应附加符号“S”；按壁厚系列定购时的壁厚系列号，以及炉号或能鉴别炉号的钢管厂的编号。此外，标记还应包括表8中设定的标志以表示试验方法。钢管上标记可以是字模喷刷，打印或滚印。按 7.6 条焊补过的钢管应标上“WR”。

17.政府采购

17.1 不带氧化皮的钢管

17.1.1 当在合同或订单中有规定，美国的政府机构要求提供不带氧化皮的钢管，则在咨询合同或订货单中应考虑这些要求。当这些要求和产品标准有冲突时，应优先满足这些要求。

17.1.2 当钢管按本标准订货时，A999/A999M 标准的要求适用于该钢管。

17.1.3 钢管应是下列规定的级别中的一种：

级别	UNS标号
P11	K11597
P22	K21590
P5	K41545

17.1.4 材料编号

17.1.4.1 钢管应按ASME B36.10M 标准中规定的钢管公称尺寸及管壁厚度标号订货。

举例：A335/A335M 钢管P-11 NPS 12 Sch 40

标准号	ASTM A335/A335M
管子	P
级别	P-11
NPS	12
壁厚	0.375

17.1.4.2

标准号	ASTM A335/A335M
管道	T
级别	P-11
外径	0.250
壁厚	0.035

17.1.5 订货须知——按本标准订购材料的订货单上除了第3节的要求外，还应包括以下内容：

17.1.5.1 管子或管道。

17.1.5.2 材料编号。

17.1.5.3 如有需要，超声波检验。

17.1.5.4 如果在环向的相对两侧进行剪力波试验。

17.1.5.5 要求的防护及包装水平。

18.关键词

18.1 合金钢管；高温用途；无缝钢管；钢管；高温使用场合。

补充要求

下列补充要求的某一条或若干条仅当订货单中有规定时方应采用。买方可以规定超过补充要求中所提出的不同的试验或分析次数。经买方与厂方同意，本补充要求中复试和重新热处理的条文规定也可以修订。

S1. 成品分析

S1.1 应对每根钢管作成品分析，其中化学成分不符合要求的钢管应予拒收。

S2. 横向拉伸试验

S2.1 对于大于等于 NPS 8 的每根钢管，应从一端或其两端切取试样作横向拉伸试验。若规定了补充要求，则也应规定每根钢管的试验次数。若自任一根钢管切取的试样与规定的拉伸性能（抗拉、屈服强度及延伸率）不符合，则该管应按 A999/A999M 标准重新热处理并满足复试要求，否则应予拒收。

S3. 压扁试验

S3.1 A530/A530M 标准规定的压扁试验应从每根钢管的一端或其两端取样，料头可以使用。若规定了补充要求，则也应规定每根钢管的试验次数。若自任何一根钢管切取的试样在第一阶段的压扁试验满足要求前，因延展性不足而失效，则该钢管应按 A999/A999M 标准重新热处理并满足复试要求，否则应予拒收。若自任何一根钢管切取的试样由于有缺陷而失效，则该根钢管应予拒收，除非以后的复试表明剩下那段钢管是完好无缺陷的。对于直径超过 NPS 2.5 及直径和壁厚比小于等于 7.0 的钢管，13.2 的弯曲试验应代替压扁试验。

S4. 金属组织与浸蚀试验

S4.1 钢材应根据 E381 方法的适当章节进行浸蚀试验以证明其均匀性。浸蚀试验应在每根钢管的一端或其两端截面上作出，并应证明是完好无缺陷的，且材质均匀并无有害的夹层、裂纹及类似的有害缺陷。若规定了本补充要求，还应规定每根钢管要求的试验次数。若自任何一根钢管切取的试样显示出有害缺陷，但割去有缺陷的一端后进行的复试表明余下管段完好且材质均匀，则不应拒收。

注 S4.1：在开发适合于本标准所包括的产品的浸渍方法期间，推荐使用美国金属学会 1948 年版“金属手册”P389 页及随后中所述的钢和铁常规检查用标准宏观浸蚀试验推荐规程。

S5. 金相照片

S5.1 当买方有要求并在订货单中注明时，对于 NPS 3 及以上的管子的每一个炉批号的每一种尺寸及壁厚，钢管厂应提供一张从交货状态钢管试样上拍得的 100 倍的金相照片。这种金相照片应按管子尺寸、壁厚及炉批适当地做出标志。除非补充要求 S6 规定了方法，需提供所订购的单根钢管的金相照片。这些金相照片仅用作为显示成品管的实际金属结构、作为资料使用。

S6. 单根钢管的金相照片

S6.1 除了根据补充要求 S5 要求提供的金相照片外，买方可以规定对 NPS 3 及以上钢管应提供从每一炉批中的一根或更多根钢管的一端上取得的交货状态下的金相照片。买方应在订货单中规定一炉批所要试验的钢管根数。当要求在每根钢管上取金相照片时，按补充要求 S5 要求的每一炉批钢管交货状态下的金相照片可以省略。所有要求提供的金相照片应按切取截面管子的炉批号，尺寸及壁厚适当地作出标志。金相照片还应进一步加以标志以便于每张金相照片能和其代表的单根钢管相对应。

S7. 可替代的热处理—P91 级别

S7.1 P91 级别钢管应按表 2 进行正火，并在买方规定的温度下进行回火，该温度应低于 1350°F (730°C)。在最低为 1350°F (730°C) 的温度下进行随后的回火处理应是买方的责任。在按表 2 进行热处理过的材料上应做所有的力学性能试验，合格证书上应引证本补充要求注明所采用的回火温度。标志“S7”应被包括在该管子所要求的标记以内。

更改摘要

委员会 A01 已标记了本文件相对于前一版本 (A335/A335M-10b) 所做的修改位置, 这些修改可能影响本标准的使用。 (2011 年 10 月 1 日批准)

- (1) 引用文件增加了新的 2.3 节, 即增加了 AWS 规范, 并对随后章节进行了重新编号。
- (2) 插入了新的 7.6.1 和 7.6.2, 即增加了 P91 焊补的工艺和消耗性材料的化学成分要求, P92、9122 和 P911 焊补所有焊接消耗性材料的化学成分要求, 并对随后章节进行了重新编号。

委员会 A01 已标记了本文件相对于前一版本 (A335/A335M-10a) 所做的修改位置, 这些修改可能影响本标准的使用。 (2010 年 11 月 1 日批准)

- (1) 重写了章节 12 水压试验和章节 13 无损检查, 即无损试验为强制性试验, 水压试验为可选择试验。修订了表 8 以确保与这些更改一致。
- (2) 修订了表 1 中 P23 级别材料的化学成分要求。

委员会 A01 已标记了本文件相对于前一版本 (A335/A335M-10) 所做的修改位置, 这些修改可能影响本标准的使用。 (2010 年 5 月 1 日批准)

- (1) 增加了新的 9.5 节, 规定在 P91 级别淬火和回火材料的中间厚度位置处进行抗拉和硬度性能试验。
- (2) 对于 P92 级别材料, 表 2 增加了脚注 E 作为引述。
- (3) 7.6.5、9.3、14.3.7 和表 1-5 增加了新级别 P24。

委员会 A01 已标记了本文件相对于前一版本 (A335/A335M-09a) 所做的修改位置, 这些修改可能影响本标准的使用。 (2010 年 4 月 1 日批准)

- (1) 增加了新的 15.1 节, 规定在所有场合合格证书和试验报告为强制性要求, 并对随后章节进行了重新编号。
- (2) 修订了 14.3, 以允许进行硬度试验。
- (3) 将注 6 和注 7 变为正文, 作为本标准的主要部分。



Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service¹

This standard is issued under the fixed designation A335/A335M; 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 specification² covers nominal wall and minimum wall seamless ferritic alloy-steel pipe intended for high-temperature service. Pipe ordered to this specification shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of ferritic steels (see **Note 1**) are covered. Their compositions are given in **Table 1**.

NOTE 1—Ferritic steels in this specification are defined as low- and intermediate-alloy steels containing up to and including 10 % chromium.

1.3 Supplementary requirements (S1 to S7) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired, shall be so stated in the order together with the number of such tests required.

1.4 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

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 Oct. 1, 2011. Published November 2011. Originally approved in 1951. Last previous edition approved in 2010 as A335/A335M-10b. DOI: 10.1520/A0335_A0335M-11.

² For ASME Boiler and Pressure Vessel Code applications see related Specification SA-335 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.

- [A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe](#)
- [E92 Test Method for Vickers Hardness of Metallic Materials⁴](#)
- [E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing](#)
- [E309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation](#)
- [E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings](#)
- [E527 Practice for Numbering Metals and Alloys in the Unified Numbering System \(UNS\)](#)
- [E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products](#)
- 2.2 ASME Standard:**
 - [B36.10M Welded and Seamless Wrought Steel Pipe](#)
- 2.3 AWS Specifications⁵**
 - [A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding](#)
 - [A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding](#)
 - [A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding](#)
 - [A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding](#)
- 2.4 Other Documents:**
 - [SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification⁶](#)
 - [SAE J 1086 Practice for Numbering Metals and Alloys \(UNS\)⁷](#)

⁴ Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

⁵ Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

⁶ Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

⁷ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

TABLE 1 Chemical Requirements

Grade	UNS Designation ^A	Composition, %						
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum
P1	K11522	0.10–0.20	0.30–0.80	0.025	0.025	0.10–0.50	...	0.44–0.65
P2	K11547	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65
P5	K41545	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65
P5b	K51545	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65
P5c	K41245	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65
P9	S50400	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10
P11	K11597	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65
P12	K11562	0.05–0.15	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65
P15	K11578	0.05–0.15	0.30–0.60	0.025	0.025	1.15–1.65	...	0.44–0.65
P21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06
P22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13
P23	K41650	0.04–0.10	0.10–0.60	0.030 max	0.010 max	0.50 max	1.90–2.60	0.05–0.30
								V 0.20–0.30 Cb 0.02–0.08 B 0.0010–0.006 N 0.015 max Al 0.030 max W 1.45–1.75 Ni 0.40 max Ti 0.005–0.060 Ti/N ≥ 3.5 ^C
P24	K30736	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	2.20–2.60	0.90–1.10
								V 0.20–0.30 Ti 0.06–0.10 N 0.012 max Al 0.02 max
P36	K21001	0.10–0.17	0.80–1.20	0.030 max	0.025 max	0.25–0.50	0.30 max	0.25–0.50
								B 0.0015–0.007 Ni 1.00–1.30 Cu 0.50–0.80 Cb 0.015–0.045 V 0.02 max N 0.02 max Al 0.050 max
P91	K91560	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05
								V 0.18–0.25 N 0.030–0.070 Ni 0.40 max Al 0.02 max Cb 0.06–0.10 Ti 0.01 max Zr 0.01 max
P92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60
								V 0.15–0.25 N 0.03–0.07 Ni 0.40 max Al 0.02 max Cb 0.04–0.09 W 1.5–2.00 B 0.001–0.006 Ti 0.01 max Zr 0.01 max
P122	K92930	0.07–0.14	0.70 max	0.020	0.010	0.50 max	10.00–11.50	0.25–0.60
								V 0.15–0.30 W 1.50–2.50 Cu 0.30–1.70 Cb 0.04–0.10 B 0.0005–0.005 N 0.040–0.100 Ni 0.50 max Al 0.020 max Ti 0.01 max Zr 0.01 max
P911	K91061	0.09–0.13	0.30–0.60	0.020 max	0.010 max	0.10–0.50	8.5–9.5	0.90–1.10
								V 0.18–0.25 Ni 0.40 max Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.02 max W 0.90–1.10 Ti 0.01 max Zr 0.01 max

^A New designation established in accordance with Practice [E527](#) and [SAE J 1086](#), Practice for Numbering Metals and Alloys (UNS).

^B Grade P 5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70 %; or a columbium content of 8 to 10 times the carbon content.

^C Alternatively, in lieu of this ratio minimum, the material shall have a minimum hardness of 275 HV in the hardened condition, defined as after austenitizing and cooling to room temperature but prior to tempering. Hardness testing shall be performed at mid-thickness of the product. Hardness test frequency shall be two samples of product per heat treatment lot and the hardness testing results shall be reported on the material test report.

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 3.1.1 Quantity (feet, metres, or number of lengths),
- 3.1.2 Name of material (seamless alloy steel pipe),
- 3.1.3 Grade (Table 1),
- 3.1.4 Manufacture (hot-finished or cold-drawn),
- 3.1.5 Size using one of the following:
 - 3.1.5.1 NPS and schedule number,
 - 3.1.5.2 Outside diameter and nominal wall thickness,
 - 3.1.5.3 Outside diameter and minimum wall thickness,
 - 3.1.5.4 Inside diameter and nominal wall thickness, and
 - 3.1.5.5 Inside diameter and minimum wall thickness.
- 3.1.6 Length (specific or random),
- 3.1.7 End finish (Ends Section of Specification A999/A999M),
- 3.1.8 Optional requirements (Section 8, 12 and 13 of this specification. See the Sections on Hydrostatic Test Requirements).

ments and Permissible Variation in Weight for Seamless Pipe in Specification A999/A999M),

- 3.1.9 Specification designation, and
- 3.1.10 Special requirements or any supplementary requirements selected, or both.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.3.

5.2 *Grade P2 and P12*—The steel shall be made by coarse-grain melting practice. Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

5.3 Heat Treatment:

TABLE 2 Heat Treatment Requirements^A

Grade	Heat Treat Type	Normalizing Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]
P1	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1200 [650]
	subcritical anneal	...	...	1200-1300 [650-705]
P2	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P5	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P5b	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P5c	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1325-1375 [715-745]
	subcritical anneal	...	...	1250 [675]
P9	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P11	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1200 [650]
	subcritical anneal	...	...	1200-1300 [650-705]
P12	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P15	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1200 [650]
	subcritical anneal	...	...	1200-1300 [650-705]
P21	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P22	full or isothermal anneal	...	...	...
	normalize and temper	...	...	1250 [675]
	subcritical anneal	...	...	1200-1300 [650-705]
P23	normalize and temper	1900-1975 [1040-1080]	air or accelerated cooling	1250 [675]
	subcritical anneal	...	air or accelerated cooling	1350-1470 [730-800]
	normalize and temper	1900-1975 [1040-1080]	air or accelerated cooling	1350-1470 [730-800]
P24	normalize and temper	1800-1870 [980-1020]	air or accelerated cooling	1350-1420 [730-770]
	subcritical anneal	...	air or accelerated cooling	1350-1470 [730-800]
	normalize and temper	1800-1870 [980-1020]	air or accelerated cooling	1350-1470 [730-800]
P36	normalize and temper ^B	1650 [900]	...	1100 [595]
	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800] ^C
	quench and temper ^D	1900-1975 [1040-1080]	...	1350-1470 [730-800]
P91	normalize and temper	1900-1975 [1040-1080]	E	1350-1470 [730-800]
	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]
	subcritical anneal	...	...	1350-1470 [730-800]
P92	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]
	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]
	subcritical anneal	...	...	1350-1470 [730-800]
P122	normalize and temper	1900-1975 [1040-1080]	...	1365-1435 [740-780]
	normalize and temper	1900-1975 [1040-1080]	...	1365-1435 [740-780]
	subcritical anneal	...	...	1365-1435 [740-780]

^AWhere ellipses (...) appear in this table there is no requirement.

^BAlternatively, Grade P36, Class 2 shall be cooled from the austenitizing temperature by accelerated cooling in air or by liquid quenching.

^CExcept when Supplementary Requirement S7 is specified by the purchaser.

^DWhen mutually agreed upon between the manufacturer and the purchaser, quenching and tempering shall be permitted for thicknesses greater than 3 in. [75 mm].

^EAccelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

5.3.1 All pipe shall be reheated for heat treatment and heat treated in accordance with the requirements of [Table 2](#).

NOTE 3—It is recommended that the temperature for tempering should be at least 100 °F [50 °C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100 °F [600 °C].

NOTE 4—Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in [Table 1](#).

7. Workmanship, Finish, and Appearance

7.1 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 may be necessary to ensure compliance with [7.2](#).

7.2 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:

7.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

7.2.2 Repaired in accordance with the repair welding provisions of [7.6](#).

7.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

7.2.4 Rejected.

7.3 To provide a workmanlike finish and basis for evaluating conformance with [7.2](#), the pipe manufacturer shall remove by grinding the following:

7.3.1 Mechanical marks, abrasions (see [Note 5](#)) and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm].

NOTE 5—Marks and abrasions are defined as cable marks, dings, guide marks, roll marks, ball scratches, scores, die marks, and the like.

7.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with [7.1](#) to be deeper than 5 % of the nominal wall thickness.

7.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under [7.2](#) 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.

7.5 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 may be reduced by the amount so removed.

7.5.1 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.

7.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification [A999/A999M](#).

7.6.1 All repair welds in P91 shall be made with one of the following welding processes and consumables: SMAW, [A5.5/A5.5M](#) E90XX-B9; SAW, [A5.23/A5.23M](#) EB9 + neutral flux; GTAW, [A5.28/A5.28M](#) ER90S-B9; and FCAW [A5.29/A5.29M](#) E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair P91 shall not exceed 1.0 %.

7.6.2 All repair welds in P92, P911, and P122, shall be made using welding consumables meeting the chemical requirements for the grade in [Table 1](#).

7.6.3 After weld repair, Grades P23, P91, P92, and P122 shall be heat treated at 1350-1470 °F [730-800 °C].

7.6.4 After weld repair, Grade P911 shall be heat treated at 1365-1435 °F [740-780 °C].

7.6.5 After weld repair, Grade P24 shall be heat treated at 1350-1420 °F [730-770 °C].

7.7 The finished pipe shall be reasonably straight.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of two pipes from each lot as defined hereafter shall be made by the manufacturer. A lot is all pipe of the same nominal size and wall thickness (schedule) which is produced from the same heat of steel and shall be limited as follows:

NPS Designator	Maximum Number of Lengths in a Lot
Under 2	400
2 to 5	200
6 and over	100

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 [Table 1](#).

8.3 For grade P 91 the carbon content may vary for the product analysis by -0.01 % and +0.02 % from the specified range as per [Table 1](#).

8.4 If the analysis of one of the tests specified in [8.1](#) does not conform to the requirements specified in [6.1](#), 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. Tensile and Hardness Requirements

9.1 The tensile properties of the material shall conform to the requirements prescribed in [Table 3](#).

9.2 [Table 4](#) lists elongation requirements.

9.3 Pipe of Grade P91 shall have a hardness inclusively in the range 190 to 250 HBW/196 to 265 HV [91 HRB to 25 HRC]. Pipe of Grades P24, P92, P122, and P36 shall have a hardness not exceeding 250 HBW/265 HV30 [25 HRC].

9.4 [Table 5](#) gives the computed minimum elongation values for each $\frac{1}{32}$ -in. [0.8-mm] decrease in wall thickness. Where the



TABLE 3 Tensile Requirements

Grade								
P1, P2		P12		P23		P24		P91
Tensile strength, min:								
ksi	55	60		74		85		85
MPa	380	415		510		585		585
Yield strength, min:								
ksi	30	32		58		60		60
MPa	205	220		400		415		415
P92, P911 P36 Class 1								
90						620		620
60						440		440
P122							90	95.5
P36 Class 2							660	660
All Others							400	400

TABLE 4 Elongation Requirements

Elongation Requirements					
	All grades except P23, P36 P91, P92, P122, and P911		P23, P24, P91, P92, P122, and P 911		P36
	Longi- tudi- nal	Trans- verse	Longi- tudi- nal	Trans- verse	Longi- tudi- nal
Elongation in 2 in. or 50 mm, (or 4D), min, %:					
Basic minimum elongation for wall $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	30	20	20	...	15
When standard round 2-in. or 50-mm gage length or proportionally smaller size specimen with the gage length equal to 4D (4 times the diameter) is used	22	14	20	13	...
For strip tests a deduction for each $\frac{1}{32}$ -in. [0.8 mm] decrease in wall thickness below in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.50 ^A	1.00 ^A	1.00 ^A	...	1.00 ^A

^A Table 5 gives the calculated minimum values.

wall thickness lies between two values above, the minimum elongation value is determined by the following formula:

Direction of Test

Longitudinal, all grades except P23, P91,
P92, P122, and P911

Equation^B

$$E = 48t + 15.00$$

$$[E = 1.87t + 15.00]$$

Transverse, all grades except P23, P91,
P92, P122, and P911

$$E = 32t + 10.00$$

$$[E = 1.25t + 10.00]$$

Longitudinal, P23, P24, P91, P92, P122,
and P911

$$E = 32t + 10.00$$

$$[E = 1.25t + 10.00]$$

Longitudinal, P36

$$E = 32t + 5.0$$

$$[E = 1.25t + 5.0]$$

where:

E = elongation in 2 in. or 50 mm, %, and

t = actual thickness of specimens, in. [mm].

9.5 For Grade P91, when quenching and tempering has been agreed upon in accordance with Note D in Table 2, the tensile

and hardness properties shall be met and verified on material taken from the half-thickness location.

10. Permissible Variations in Diameter

10.1 For pipe ordered to NPS [DN] or outside diameter, variations in outside diameter shall not exceed those specified in Table 6.

10.2 For pipe ordered to inside diameter, the inside diameter shall not vary more than $\pm 1\%$ from the specified inside diameter.

11. Permissible Variations in Wall Thickness

11.1 In addition to the implicit limitation of wall thickness for pipe imposed by the limitation on weight in Specification A999/A999M, the wall thickness for pipe at any point shall be within the tolerances specified in Table 7. The minimum wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS [DN] and schedule number is shown in ASME B36.10M.

12. Hydrostatic Test

12.1 The requirements for grades other than P91, P92, P911, and P122 are shown in 12.1.1-12.1.4.

12.1.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to the hydrostatic test, except as provided for in 12.1.4.

12.1.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.1.3 and 12.1.4.

12.1.3 When specified by the purchaser, pipe of all other sizes shall be furnished without the hydrostatic test and without nondestructive examination.

12.1.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

12.2 The requirements for grades P91, P92, P911, and P122 are shown in 12.2.1-12.2.3.

12.2.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to both the hydrostatic test and the ultrasonic test as shown in Section 13.



TABLE 5 Calculated Minimum Elongation Values

Wall Thickness	in.	mm	Elongation in 2 in. or 50 mm, min, %		
			All grades except P23, P36, P91, P92, P122, and P911		P23, P24, P91, P92, P122, and P911
			Longi-tudinal	Transverse	Longi-tudinal
5/16 (0.312)	8	30	20	20	15
9/32 (0.281)	7.2	28	19	19	14
1/4 (0.250)	6.4	27	18	18	13
7/32 (0.219)	5.6	26	...	17	12
3/16 (0.188)	4.8	24	...	16	11
5/32 (0.156)	4	22	...	15	10
1/8 (0.125)	3.2	21	...	14	9
3/32 (0.094)	2.4	20	...	13	8
1/16 (0.062)	1.6	18	...	12	7

TABLE 6 Permissible Variations in Outside Diameter

NPS [DN] Designator	Over		Under	
	in.	mm	in.	mm
1/8 to 1 1/2 [6 to 40], incl.	1/64 (0.015)	0.40	1/64 (0.015)	0.40
Over 1 1/2 to 4 [40 to 100], incl.	1/32 (0.031)	0.79	1/32 (0.031)	0.79
Over 4 to 8 [100 to 200], incl.	1/16 (0.062)	1.59	1/32 (0.031)	0.79
Over 8 to 12 [200 to 300], incl.	3/32 (0.093)	2.38	1/32 (0.031)	0.79
Over 12 [300]	$\pm 1\%$ of the specified outside diameter			

TABLE 7 Permitted Variations in Wall Thickness

NPS [DN] Designator	Tolerance, % from Specified	
	Over	Under
1/8 to 2 1/2 [6 to 65] incl., all t/D ratios ⁴	20.0	12.5
Above 2 1/2 [65], t/D $\leq 5\%$ ⁴	22.5	12.5
Above 2 1/2 [65], t/D $> 5\%$ ⁴	15.0	12.5

⁴t = Specified Wall Thickness; D = Specified Outside Diameter.

12.2.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.2.3.

12.2.3 When specified by the purchaser, pipe of all other sizes shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

13. Nondestructive Examination

13.1 When required by 12.1.2 or 12.2 above, or when specified in the purchase order in addition to the hydrostatic test (12.2.3), each pipe shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309, or Practice E570. Except for Grades P91, P92, P911, and P122, the type of nondestructive examination shall be at the option of the manufacturer, unless otherwise specified in the order. Grades P91, P92, P911, and P122 shall be examined by an examination method in accordance with Practice E213. When specified in the order, pipe of Grades P91, P92, P911, and P122 shall be examined by an examination method in accordance with Practices E309 or E570, in addition to the examination method in accordance with Practice E213. 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.

13.2 Following conditions apply in lieu or in addition to those in Specification A999/A999M:

13.2.1 The width of the notch shall not exceed the depth.

13.2.2 If upon any standardization, the reference signal amplitude has decreased by more than 25 % (2 db), the test apparatus shall be considered out of standardization. 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 shall be retested.

13.2.3 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be subject to one of the following four dispositions:

13.2.3.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

13.2.3.2 The pipes shall be rejected if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections.

13.2.3.3 The pipes may be repaired by grinding (in accordance with 7.2.1), welding (in accordance with 7.6) or sectioning (in accordance with 7.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

13.2.3.4 If the test signals were produced by visual imperfections such as those listed below, the pipes may be evaluated in accordance with the provisions of Section 7:

- (a) Scratches,
- (b) Surface roughness,
- (c) Dings,
- (d) Straightener marks,
- (e) Cutting chips,
- (f) Steel die stamps,
- (g) Stop marks, or
- (h) Pipe reducer ripple.

14. Mechanical Tests Required

14.1 *Lot*—For mechanical testing, a lot is all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same



finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

14.2 Transverse or Longitudinal Tension Test and Flattening Test, Hardness Test, or Bend Test—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each treated lot. For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 pipe.

14.3 Hardness Test:

14.3.1 The Vickers hardness testing shall be made in accordance with Test Method **E92**.

14.3.2 For pipes with wall thickness 0.200 in [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load shall be used at the option of the manufacturer.

14.3.3 For pipes with wall thickness 0.065 in [1.7 mm] or over, but less than 0.200 in [5.1 mm], the Rockwell hardness test shall be used.

14.3.4 For pipes with wall thickness less than 0.065 in [1.7 mm], the hardness test shall not be required.

14.3.5 The Brinell test shall be made, at the option of the manufacturer, on the outside of the pipe near the end, on the outside of a specimen cut from the pipe, or on the wall cross section of a specimen cut from the pipe. This test shall be made so that the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

14.3.6 The Rockwell hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat of the outside surface.

14.3.7 For pipe of Grades P24, P91, P92, P122, P911, and P36, Brinell, Vickers, or Rockwell hardness tests shall be made on a specimen from each lot.

14.4 Bend Test:

14.4.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

14.4.2 The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

14.4.3 Test specimens for the bend test specified in **14.4** 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 1/2 by 1/2 in. [12.5 by 12.5 mm] in section or 1 by 1/2 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.

15. Certification

15.1 Certification and test reports, as described in Section 25 of Specification **A999/A999M**, are required.

15.2 In addition to the information required by Specification **A999/A999M**, the certification shall state whether or not the pipe was hydrostatically tested. If the pipe was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in **Table 8** shall be appended to the specification number and grade shown on the certification.

16. Product Marking

16.1 In addition to the marking prescribed in Specification **A999/A999M**, the marking shall include the length, an additional symbol "S", if the pipe conforms to any of the Supplementary Requirements S1 to S6, the schedule number, if the pipe is ordered to a schedule number, and the heat number or manufacturer's number by which the heat can be identified. Furthermore, the marking designated in **Table 8** to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with **7.6** shall be marked "WR."

17. Government Procurement

17.1 Scale Free Pipe:

17.1.1 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 is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

17.1.2 The requirements of Specification **A999/A999M** for pipe shall be applicable when pipe is ordered to this specification.

17.1.3 Pipe shall be one of the following grades as specified herein:

Grade	UNS Designation
P11	K11597
P22	K21590
P5	K41545

17.1.4 Part Number:

TABLE 8 Test Method Information for Certification and Marking

Ultrasonic	Flux Leakage	Eddy Current	Hydrostatic	Marking
YES	NO	NO	NO	UT
NO	YES	NO	NO	FL
NO	NO	YES	NO	EC
YES	NO	NO	YES	UT/TEST PRESSURE
NO	YES	NO	YES	FL/TEST PRESSURE
NO	NO	YES	YES	EC/TEST PRESSURE



17.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ASME **B36.10M**

Example: A335/A335M Pipe P-11 NPS 12 Sch 40

Specification Number	ASTM A335/A335M
Pipe	P
Grade	P-11
NPS	12
Wall	0.375

17.1.4.2

Specification Number	ASTM A335/A 335 M
Tube	T
Grade	P-11
Outside Diameter	0.250
Wall	0.035

17.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 3:

- 17.1.5.1 Pipe or tube,
- 17.1.5.2 Part number,
- 17.1.5.3 Ultrasonic inspection, if required,
- 17.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and
- 17.1.5.5 Level of preservation and packing required.

18. Keywords

18.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications

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 Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 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 **A999/A999M** and satisfactory retest.

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. The bend test of **13.2** shall be substituted for the flattening test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

S4. Metal Structure and 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 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.

NOTE S4.1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook*, Am. Soc. for Metals, 1948 edition, p. 389, be followed.

S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5

may be omitted. All photo-micrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Alternative Heat Treatment—Grade P91

S7.1 Grade P91 shall be normalized in accordance with **Table 2** and tempered at a temperature, to be specified by the

purchaser, less than 1350 °F [730 °C]. It shall be purchaser's responsibility to subsequently temper at 1350-1470 °F [730-800 °C] minimum. All mechanical tests shall be made on material heat treated in accordance with **Table 2**. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M-10b, that may impact the use of this specification. (Approved October 1, 2011)

(1) Added new **2.3** to Referenced Documents to add AWS specifications and renumbered subsequent paragraphs.

(2) Inserted new **7.6.1** and **7.6.2** to add process and consumable chemistry restrictions for P91 weld repairs and weld consumable chemistry restrictions for P92, P122, and P911, and renumbered subsequent paragraphs.

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M-10a, that may impact the use of this specification. (Approved November 1, 2010)

(1) Rewrote Section **12** Hydrostatic Test and Section **13** Nondestructive Examination, thus making the nondestructive test mandatory and the hydrotest optional. Revised **Table 8** to ensure coherence with these changes.

(2) Modified the chemical composition of grade P23 in **Table 1**.

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M-10, that may impact the use of this specification. (Approved May 1, 2010)

(1) Added new **9.5** dealing with compliance of the tensile and hardness properties at mid-thickness for Grade P91 quenched and tempered.

(2) Added a citation for Footnote E to Grade P92 in **Table 2**.
(3) Added new Grade P24 to **7.6.5**, **9.3**, **14.3.7**, and **Tables 1-5**.

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M-09a, that may impact the use of this specification. (Approved April 1, 2010)

(1) Added new **15.1** to make the certification and test reports mandatory in all cases and renumbered subsequent paragraphs.

(3) Moved the text of Notes 6 and 7 into the main body of the standard.

(2) Revised **14.3** to permit performance of the hardness testing.

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