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认证焊接检验师 (CWI)
部分实际操作

规程手册
(BOS)
2017

请勿在本手册上书写

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前言

这本*B 部分规程手册*拟用作参加实际操作考试的参考手册，实际操作考试是 CWI 认证考试的一部分。这项考试将模拟认证焊接检验师 (CWI) 进行的实际动手检验和文件审查。您应当运用标准量具、目检以及展示册中的文件，针对工艺、焊工评定和生产焊接评估试样和文件的合格性。合格性基于本*规程手册*中所含的信息。实际操作考试将测试您执行这些功能的能力。

尽管本*规程手册*的格式看似真正的规范手册，但其实并非真正的规范手册，并且也不应当用作规范手册。本*规程手册*中的某些条款类似于您所熟悉的规范手册，请格外仔细地阅读本*规程手册*，在回答本场考试中的问题时不要靠记忆来做出决定。

查看*B 部分规程手册*的编排。其中包含与结构、管路和压力管道这三种应用中的工艺和目检标准相关的具体条款。另外也包含适用于这三种应用的检验、工艺和资格评定通用条款。由于本*规程手册*适用于这三种应用，因此术语和定义不限于 AWS A3.0 – *标准焊接术语和定义*。

除本规程的正文以外，还有对您考试中的决定十分重要的附录、表格和图形。为避免混淆，这些项目被赋予了唯一编号。务必在回答问题前找到所有必备的附录、表格和图形。

考试中会用到展示册，其中包含各种文件和图片示例，包括但不限于 WPS、PQR、WQTR 的文件和图片、热处理图表以及 NDE 方法。考试前既不会提供试样，也不会提供展示册。

对于某些问题，会以叙述的形式提供信息，接着会问您具体的问题。问题可能涉及您的测验包中包含的特定试样上的位置，或涉及展示册中的文件。除了展示册外，所有测验包还提供了完成考试必备的标准量具。

重要事项

1. 仔细阅读完每道问题，包括提供的每个选项。正确答案只有一个。小心地将答案选项填写到答题纸上的正确位置。

2. 所分配的测验包中的焊件仿制品用塑料制成，目的是确保所有考生收到完全相同的试样。由于复制过程的缘故，实际焊缝金属的颜色可能会有变化，塑料组装过程中可能会出现明显的接缝。请在确定正确答案时忽略任何小孔、接缝、胶水挤出或颜色变化。

3. 您应当知晓如何使用和运用测验包中的各种测量和检验仪器，包括知晓如何在适当情况下将仪器清零。

4. 请在考试册中的页边或空白页上进行必要的计算。请勿在本手册上书写。

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表格列表

表格 **页码**

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图形 **页码**

1.0 通用要求

1.1 范围

1.1.1 本规程适用于美国焊接学会的认证焊接检验师 (CWI) 考试，不得另作他用。CWI 实际操作考试中使用的是实际焊缝试样的模制塑料仿制品，由于金属的部分视觉特性无法足够逼真地在塑料中再现，因此对这些特性的验收标准的排除不应视为认可在任何实际制造中也排除这些标准。

1.1.2 本规程涵盖结构钢、管路和压力管道应用的典型要求。它们拟用于检验师考试时的焊缝仿制品，不用于实际的工业设施、设备或结构。

1.1.3 本*规程手册*中的条款1.0、5.0和6.0所含的要求被视为适用于全部三种应用的通用要求，除非另有说明。

1.1.4 本规程中的规范性附录意在提供要求，参考性附录意在提供信息。二者均视为本规程的一部分。不能根据规范性附录与参考性附录的分配而得出关于附录在考试中使用的推论。

1.1.5 CWI 考试中使用的计算、公式、定义和材料性质基于本规程附录中公布的数据。由于本*规程手册*适用于这三种应用，因此术语和定义不限于 AWS A3.0 – *标准焊接术语和定义*。

1.1.6 本规程中使用的“必须”、“应当”和“可以”具有如下意义：

1.1.6.1 必须。使用“必须”的规程条款具有强制性。

1.1.6.2 应当。使用“应当”的规程条款表示非强制性但被视为有益的作法。

1.1.6.3 可以。使用“可以”的规程条款表示必须选择可选的过程或作法，来用作规程要求的替代或补充。

1.2 目检

1.2.1 可以借助手电筒、放大镜和镜子目检焊缝和母材金属中的裂纹以及其他不连续性，此类物品可能会有所帮助或有必要。

1.2.2 焊缝的焊接尺寸、长度和位置应符合本规程的要求。

1.2.3 接头制备、组装和焊接技术必须加以验证。

1.2.4 必要时必须使用合适的量具和量规。

1.3 尺寸公差

使用本规程时必须应用以下标准尺寸公差，另有规定的除外。这些尺寸公差不适用于试样、附录 IV 或不连续性验收限制中的尺寸。

1.3.1 小数公差取决于尺寸中使用的小数位数（精确度），如下所示：

X.X	± 0.3	（例如1.0 mm 可能是0.7至1.3mm）
X.XX	± 0.13	（例如1.00 mm 可能是0.87至1.13 mm）

1.3.2 整数公差取决于尺寸中使用的总体尺寸长度，如下所示：

>150 mm 的整数	± 3 mm
25至150 mm（包括150 mm）之间的整数	± 1.5 mm
1至<25 mm 的整数	± 0.8 mm

2.0 工艺要求和目检验收标准 - 结构钢

2.1 母材金属制备

2.1.1 打磨引起的不连续性。不连续长度为材料切割表面上的明显长边，深度为不连续点从切割表面延伸至材料的距离。可接受的极限以及对明显切割表面不连续性的修补必须遵循如下要求：

(a) 任何长度为25 mm 或以下的不连续性无需修补，且深度无需探明。

(b) 任何长度超过25 mm 且最大深度为3 mm 的不连续性无需修补，但应当探明深度。

(c) 任何长度超过25 mm、深度超过3 mm 但不大于6 mm 的不连续性必须彻底清除并进行补焊。

(d) 任何长度超过25 mm、深度超过6 mm 的不连续性必须交由工程师处置。

2.2 工艺要求

2.2.1 粗糙度要求。焊缝边缘制备及其他边缘表面必须根据表面粗糙度指南 AWS C4.1-77进行评估。验收标准必须符合如下要求：

2.2.1.1 对于手工和半自动焊接过程的焊缝边缘制备表面，其粗糙度严禁超过样本3，并且严禁出现深度超过1.5 mm 的刨槽。

2.2.1.2对于机械化和自动焊接过程（SAW 除外）的焊缝边缘制备表面，其粗糙度严禁超过样本4，并且严禁出现刨槽。

2.2.1.3 对于 SAW 的焊缝边缘制备表面，其粗糙度严禁超过样本3，并且严禁出现刨槽。

2.2.1.4 对于不受所计算的应力约束的工件边缘，其粗糙度严禁超过样本2，且严禁出现深度超过3 mm 的刨槽。

2.2.1.5 所有其他边缘的粗糙度严禁超过样本3，且严禁出现深度超过1.5 mm 的刨槽。

2.2.2 电弧击伤。母材金属不得出现电弧击伤。

2.2.3 完工焊缝的清理。所有完工焊缝上的熔渣必须清除。飞溅是可以接受的，除非是执行 NDT（而不是目检）或另有规定。

2.2.4 角焊缝的起止端。角焊缝严禁在搭接接头角端终止。起止端必须符合如下要求：

2.2.4.1 静载荷连接。起止端必须按以下方式形成：抑制焊缝止于离角端部不小于指定角焊缝尺寸的距离处，或围绕边角对焊缝进行不小于指定角焊缝尺寸两倍且不大于其四倍的缠绕。

2.2.4.2 周期载荷连接。起止端必须按以下方式形成：围绕边角对焊缝进行不小于指定角焊缝尺寸两倍且不大于其四倍的缠绕。

2.2.5 修补。焊缝金属或母材金属部分可以通过机械加工、打磨、凿平或刨槽清除。操作时必须保证相邻焊缝金属或母材金属不会出现刻痕或刨槽。焊缝上不合格的部分必须清除，且不得大量清除母材金属。表面必须彻底清理后方可焊接。焊缝金属必须熔敷，以补偿焊缝金属中的任何尺寸的不足。

2.3 目检验收标准。所有焊缝必须目检，且应符合表 1 中的验收标准。

2.3.1 焊缝外形。焊缝外形必须符合表1、表2、表3、图 A、图 B 的要求，2.3.1.1、2.3.1.2和2.3.1.3中另外允许的情况除外。

2.3.1.1 角焊缝。如图 B 中所示，角焊缝表面可能略微凸、平直或略凹，除非另有规定。

2.3.1.2 间断角焊缝除外。除本规程中允许的咬边外，图 B 的外形要求不适用于超出其有效长度的间断角焊缝端部。

2.3.1.3 坡口焊缝坡口焊缝余高应符合表2和表3的要求。焊缝应逐渐过渡到母材金属表面的平面。

2.3.1.4 焊瘤。所有焊缝均不得有焊瘤。

2.4 角焊缝尺寸公差

2.4.1 焊缝长度和间距。所指示的焊缝长度为最小焊缝长度，且没有最大焊缝长度，除非另有规定。角焊缝长度为全尺寸填角的总长，其中包含沿有效焊喉的中心线测量的绕角焊（包角焊），不包含起止端尺寸不足的部分。必须根据子条款1.3.2的公差来确定最小长度是否合格，例如74.2 mm 的焊缝长度符合75 mm 焊缝的要求。

焊缝间距（节距）为相邻焊缝中心之间的最大间距，且不存在最小间距，除非另有规定。必须根据子条款1.3.2的公差来确定实际测量的最大间距是否合格，例如75.8 mm 的间距符合75 mm 间距要求。

2.4.2 角焊缝尺寸。角焊缝尺寸为最小焊缝尺寸，且无最大焊缝尺寸，除非目检验收标准中另有规定。子条款1.3.2的公差不适用。

表1
目检验收标准 - 结构钢

不连续性类别和检验标准	静载荷 非管材连接	周期载荷 非管材连接	管材连接 （所有载荷）
1) 禁止裂纹 所有裂纹都不合格，不论其尺寸或部位如何。	X	X	X
(2) 焊缝/母材金属熔合 焊缝金属相邻焊层之间以及焊缝金属与母材金属之间必须完全熔合。	X	X	X
(3) 弧坑横截面 除了超出其有效长度的间断角焊缝的端部外，所有弧坑必须填焊至规定的焊缝尺寸。	X	X	X
(4) 焊缝外形 焊缝外形必须符合2.3.1的要求。	X	X	X
(5) 检验时机 所有钢焊缝的目检可在完工的焊缝冷却至环境温度后立即开始。ASTM A 514、A 517钢和 A 709100级及100 W 级钢焊缝的验收必须以焊缝完工后至少48小时后所作的目检为依据。	X	X	X
(6) 焊缝尺寸不足 在未进行下述数值 (U) 校正的情况下，任何连续焊缝中的角焊缝尺寸可能小于规定的公称尺寸 (L)： L, U, 规定的公称焊缝尺寸，mm 在 L 的基础上允许的减少量，mm ≤ 5 ≤ 2 6 ≤ 2.5 ≥ 8 ≤ 3	X	X	X
(7) 咬边 (A) 厚度小于25 mm 的材料上的咬边严禁超过0.8 mm。厚度等于或大于25 mm 的材料，任何长度焊缝的咬边严禁超过2 mm。	X		
(B) 在主要工件中，在任何设计载荷情况下，焊缝与拉伸应力成横向关系时，咬边深度严禁大于0.25 mm。对于所有其他情况，咬边深度严禁大于0.8 mm。		X	X
(8) 气孔 (A) 与计算拉伸应力成横向关系的对接接头完全焊透 (CJP) 坡口焊缝，严禁有可见气孔。对于所有其他坡口焊缝和角焊缝，直径等于或大于0.8 mm 的可见气孔直径的总和，在任何25 mm 长焊缝范围内严禁超过10 mm。	X		
(B) 角焊缝中气孔出现频度为每100 mm 焊缝长度严禁超过1个，且最大直径严禁超过2.5 mm。下述情况例外：对于连接加劲材于腹板的角焊缝，在任何25 mm 长焊缝范围内气孔直径总和严禁超过10 mm。		X	X
(C) 与计算拉伸应力成横向关系的对接接头完全焊透 (CJP) 坡口焊缝，严禁有气孔。对于所有其他坡口焊缝，气孔出现频度为每100 mm 焊缝长度严禁超过1个，且最大直径严禁超过2.5 mm。		X	X

注：“X”意指所适合的连接类型；阴影区域表示此栏不适用。

表2
焊缝外形（参见2.3.1）

焊缝类型	接头类型			
	对接	T 形接头	搭接	内角
坡口焊缝（CJP 或 PJP）	图 A	不适用	不适用	不适用
	等级 A	不适用	不适用	不适用
角焊缝	不适用	图 B	图 B	图 B
	不适用	等级 B	等级 B	等级 B

表3
焊缝外形等级（参见2.3.1）

等级 A

（t = CJP 连接的较厚板的厚度；t = PJP 焊喉尺寸）

t	R min.	R max.
≤ 25 mm	0	2 mm
>25 mm ≤ 50 mm	0	3 mm
>50 mm	0	5 mm

等级 B

（W = 个别表面焊道的焊缝表面宽度；C = 允许的凸度）

W	C min.	C max.
≤ 8 mm	0	2 mm
>8 mm <25 mm	0	3 mm
≥ 25 mm	0	5 mm

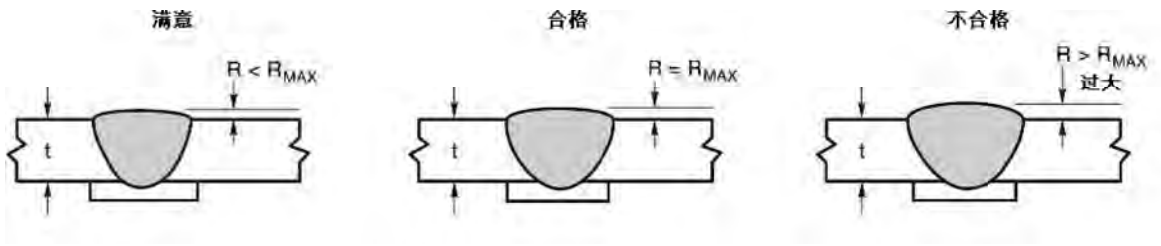

图 A - 对接接头的焊缝外形要求（参见表2和表3）

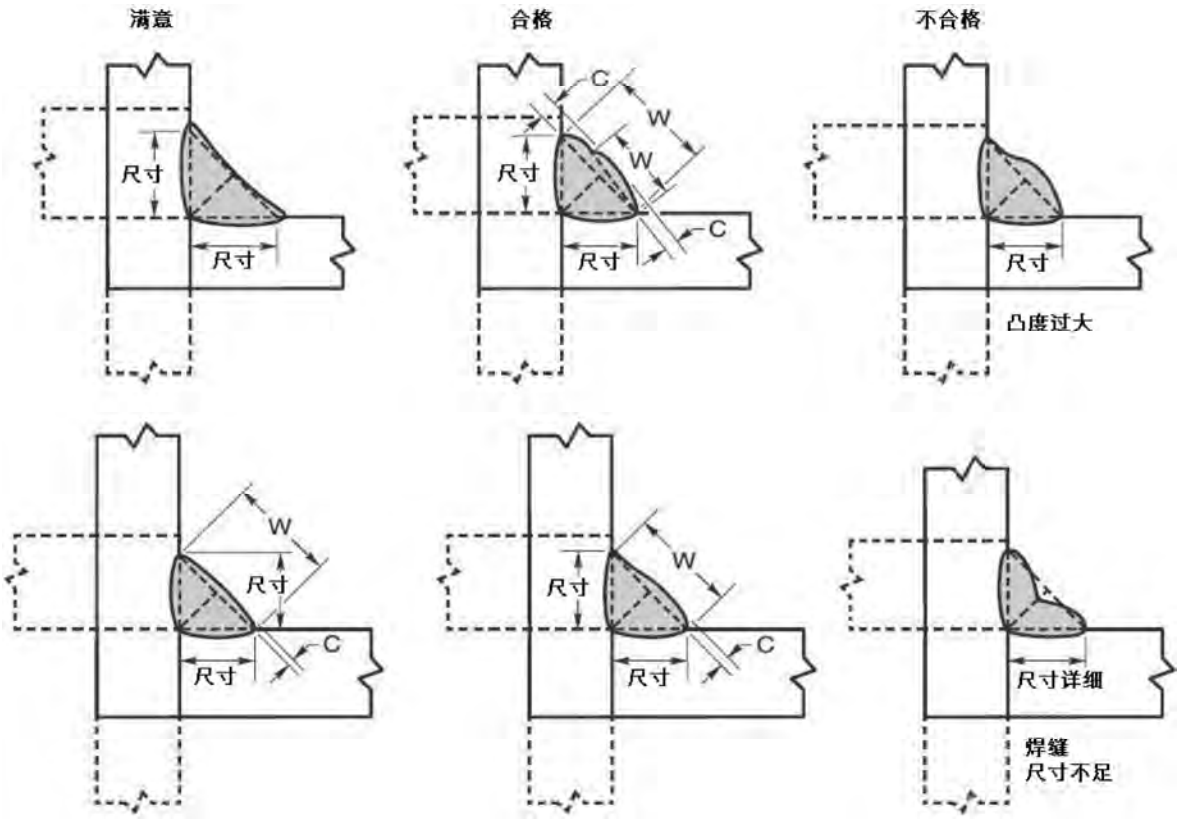

图 B - 内角接头、搭接接头和 T 形接头的角焊缝外形要求（参见表 2 和表 3）

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3.0 工艺要求和目检验收标准 - 管线

3.1 工艺要求

3.1.1 边缘制备细则和组对尺寸必须符合 WPS 中的规定。

3.1.2 斜边端必须光滑、一致。

3.1.3 对接端对齐时必须保证最大限度减小表面之间的偏移。对于相同公称厚度的管道端部，禁止偏移超出3 mm。

3.1.4 填充物和完工焊道的数目必须确保完工焊缝在管子周围提供非常一致的横截面。任何时候焊冠表面都不得位于管子外表面下方，也不得高出母材金属超过2 mm。

3.1.5 相邻焊道不得在同一部位起止。

3.1.6 完工焊缝的表面宽度不得超出原始坡口宽度3 mm。

3.1.7 完工焊缝（包括母材金属）必须彻底刷洗清洁。所有飞溅必须清除。

3.1.8 母材金属表面的电弧烧伤被视为不合格。

3.1.9 修补和清除缺陷

3.1.9.1 授权。裂纹修补、背面焊缝修补和再次修补必须取得公司授权。对于任何不涉及加热或焊缝金属的修补，例如打磨、锉削等等，则无需取得公司授权。返工不算是修补，因此无需取得公司授权。

3.1.9.2 裂纹修补。开裂的焊缝必须切除，除非公司授权进行补焊。在授权修补裂纹的情况下：

(1) 只要单条裂纹的长度或单个修补区域中多条裂纹的总长不到焊缝长度的8%，则可使用合格的修补工艺通过清除部分或全部焊缝来予以补焊；

(2) 如果一条焊缝中有多个修补区域出现裂纹，则不得进行补焊，除非总修补长度不到焊缝长度的8% 并采用合格的修补工艺；

(3) 禁止对裂纹进行再次修补。在修补后，任何焊缝中再出现裂纹必须切除。

(4) 对于完全处在内部或外部焊缝余高中的浅弧坑裂纹或星形裂纹，可以在不采用合格修补工艺的情况下通过打磨（例如磨蚀法）进行修补。如果打磨超出内部或外部余高，必须采用合格的焊接工艺代替余高。

3.1.9.3 修补裂纹之外的缺陷。根部、填充物和完工焊道中除裂纹之外的缺陷可以在事先取得公司授权的情况下进行修补。在以下情况下，任何时候通过焊接进行修补时，必须采用合格的修补工艺：

(1) 运用焊接工艺、焊接工艺组合或不同于原始焊缝的应用方法或填充金属时；或

(2) 对以前焊接过的修补区域进行修补时；或

(3) 根据公司要求进行修补时。

3.1.9.4 打磨修补。如满足以下前提，则可采用打磨修补来清除根部焊道余高和盖面焊道中的

缺陷：

(1) 打磨区域和原始焊缝之间平滑过渡，不存在咬边及其他缺陷，以及

(2) 不违背管子表面轮廓和最小壁厚及焊缝厚度要求。

如果最小壁厚/焊缝厚度未知，则打磨深度限制为超出根部焊道熔深或外部余高。打磨修补长度和打磨修补区域数量无限制。打磨修补无需采用评定的修补工艺。

3.1.9.5 背面焊缝修补。如公司允许实施背面焊缝修补，必须评定修补工艺。

3.1.9.6 再次补焊。再次补焊必须事先取得公司授权。禁止对再次补焊的焊缝进行后续修补。

3.1.9.7 焊缝修补和检验工艺。通过打磨、凿平、刨槽或综合这些方法来清除缺陷，然后进行补焊。焊接前必须目检修补坡口，并通过 PT 或 MT 来确认完全清除此缺陷。预热和道间热处理必须遵循原始焊缝的要求。必须对完工后的补焊进行目检，并且必须对整条焊缝进行射线检测。

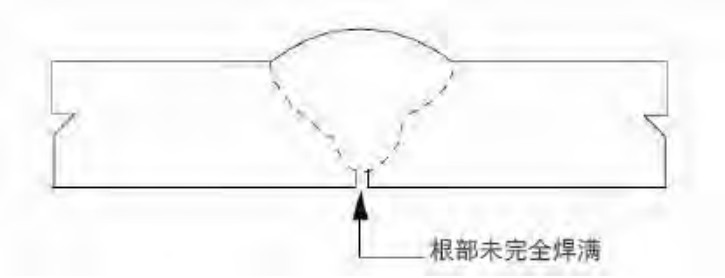
3.2 目检验收标准

3.2.1 没有高低错边的熔深不足 (IP)。没有高低错边的熔深不足定义为焊根未完全填充。图 C 中显示了这种状况。如果存在以下任何情况，必须将 IP 视为缺陷：

3.2.1.1 有一处 IP 显示的长度超过25 mm。

3.2.1.2 在长度为300 mm 的任何连续焊缝中显示的 IP 总长超过25 mm。

3.2.1.3 在长度小于300 mm 的任何焊缝中显示的 IP 总长超出焊缝长度的8%。



注：内部表面的一个或两个钝边可能填充不足。

图 C - 没有高低错边的焊透不足 (IP)

3.2.2 由于高低错边导致熔深不足 (IPD)。由于高低错边导致熔深不足定义为由于相邻管子或装配接头未对齐，导致根部的一条边暴露（未接合）。图 D 中显示了这种状况。如果存在以下任何情况，必须将 IPD 视为缺陷：

3.2.2.1 有一处 IPD 显示的长度超过50 mm。

3.2.2.2 在长度为300 mm 的任何连续焊缝中显示的 IP 总长超过75 mm。

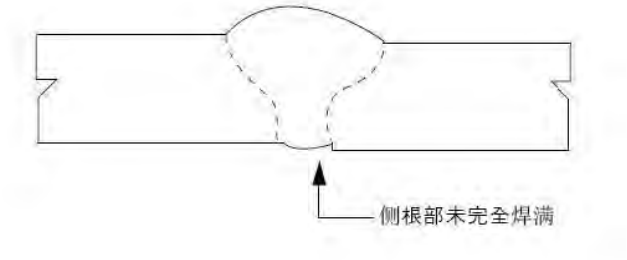


图 D - 由于高低错边导致熔深不足 (IPD)

3.2.3 未熔合 (IF)。未熔合定义为焊缝金属与外露到表面的母材金属之间的表面缺陷。图 E 中显示了这种状况。如果存在以下任何情况，必须将其视为缺陷：

3.2.3.1 有一处 IF 显示的长度超过25 mm。

3.2.3.2 在长度为300 mm 的任何连续焊缝中显示的 IF 总长超过25 mm。

3.2.3.3 在长度小于300 mm 的任何焊缝中显示的 IF 总长超出焊缝长度的8%。

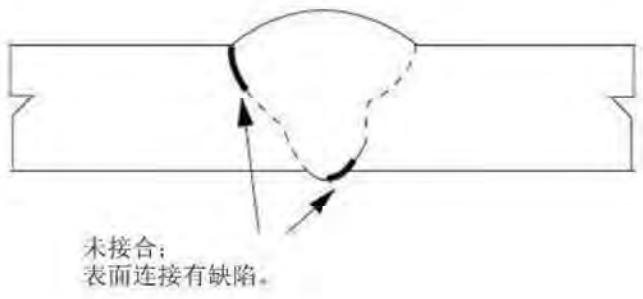


图 E - 焊道根部或接头顶部未熔合 (IF)

3.2.4 焊穿 (BT)。焊穿定义为一部分根部焊道中发生过度焊透，使得焊缝熔池吹入管子，导致一个

坡口焊缝的根部焊道形成一个孔或凹陷。如果存在以下任何情况，必须将 BT 视为缺陷：

3.2.4.1 最大尺寸超过6 mm。

3.2.4.2 在长度为300 mm 的任何连续焊道中或焊道总长中（取二者中的较小值），单个 BT 的尺寸之和超过13 mm。

3.2.5 气孔 (P)。气孔定义为气体有机会升到熔池表面而逸出前因焊缝金属固化而困住的气体。气孔通常为球状，但可能呈现出拉长或不规则的形状，例如管状（蠕虫状气孔）气孔。如果存在以下任何情况，必须将气孔视为缺陷：

3.2.5.1 单个孔的尺寸超过3 mm。

3.2.5.2 单个孔的尺寸超过连接的较薄公称壁厚的25%。

3.2.5.3 如果存在以下任何情况，必须将完工焊径中出现的簇状气孔 (CP) 视为缺陷：

3.2.5.3.1 簇的直径超过13 mm。

3.2.5.3.2 在长度为300 mm 的任何连续焊缝中的 CP 总长超过13 mm。

3.2.6 裂纹 (C)。裂纹必须视为一种缺陷。

3.2.7 外部咬边 (EU) 或内部咬边 (IU)。咬边定义为坡口融化或焊趾或焊缝根部相邻的母材减少而未得到焊缝金属填充。如果超过表4中的最大尺寸，与盖面焊道 (EU) 或根部焊道 (IU) 相邻的咬边必须视为缺陷。

表4 - 最大咬边尺寸（EU 或 IU）

深度	长度
>0.8 mm 或>管子壁厚的12.5%（取较小者）	不合格
>0.4 mm 且 ≤ 0.8 mm 或>6% 且 ≤ 管子壁厚的12.5%（取较小者）	长度为300 mm 的连续焊缝中的50 mm，或焊缝长度的六分之一（取较小者）
≤ 0.4 mm 或 ≤ 管子壁厚的6%（取较小者）	合格（无论长度如何）

3.2.8 缺陷累计 (AI)。如存在以下任何情况，除 IPD、EU 和 IU 外，P、CP、IF、IP 和 BT 等其他可以接受的缺陷的任何累积必须视为缺陷：

3.2.8.1 在长度为300 mm 的任何连续焊缝中的 AI 总长超过50 mm。

3.2.8.2 AI 总长超过焊缝长度的8%。

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4.0 工艺要求和目检验收标准 - 压力管道

4.1 工艺要求

4.1.1 要连接的端部内部焊偏不得大于2 mm。内部焊偏超过容许值时，最好对管壁在内部伸展的部件进行内部修整。但是，修整必须保证管道组件厚度不小于最低容许厚度，并且轮廓变化不得超过30度。

4.1.2 接头的边缘制备细则和根部间隙必须符合 WPS 中的规定。

4.1.3 焊接表面必须清洁，不能有油漆、油、锈、鳞片或其他不利于焊接的物质。

4.1.4 定位焊缝的起止端必须通过打磨或其他机械途径制备，确保可以充分整合到完工焊缝中。有裂纹的定位焊缝不合格，必须清除并补焊。

4.1.5 开始焊接后，应当保持最低预热温度直至接头完工。但是，只要熔敷了厚度至少10 mm 的焊缝或填充了25% 的坡口（取二者中的较小值），则可以中断焊接并让接头慢慢冷却。

4.1.6 目标焊缝区域外部的电弧击伤被视为不合格。

4.1.7 焊态表面（包括接合处）必须平滑、一致，且不得有焊瘤。

4.1.8 母材金属表面不得有飞溅。

4.1.9 补焊。任何不连续性超过4.2中允许的最大值时，必须将其清除，并且可以在对该区域进行磁粉检验或着色渗透检验后通过焊接来修补，确保完全清除不连续性。

4.1.9.1 清除缺陷。焊缝或母材中所有需要修补的缺陷必须通过火焰或电弧刨槽、打磨、凿平或机械加工的方式清除。在某些淬硬型合金材料上采用火焰或电弧刨槽时可能需要预热，以防止火焰或电弧刨槽表面相邻的部位出现表面龟裂或裂纹。如果清除了缺陷但不必进行补焊，必须确保表面轮廓无锐利的槽口或角。必须按照与最初定位缺陷时使用的相同途径来重新检验表面轮廓。

4.1.9.2 修补焊缝。必须由合格焊工根据 WPS 的要求进行焊缝修补，并且要认识到，要补焊的空腔可能不同于正常接头制备的轮廓和尺寸，而且可能存在不同的限制条件。所有补焊必须遵循4.2的目检验收标准。

4.1.9.3 检验。所有对深度超过25 mm 或截面厚度20%（取二者中的较小值并从管子表面测量）的焊缝进行的修补，必须通过射线检验和磁粉或着色渗透检验来检验完工焊缝表面。所有对深度小于截面厚度20% 或25 mm（取二者中的较小值）的焊缝进行的修补，必须通过磁粉或着色渗透检验来检验熔敷焊缝金属的第一层（各厚6 mm）和完工焊缝表面。对完工焊缝表面的磁粉或着色渗透探伤必须在进行焊后热处理后完成。

4.2 目检验收标准。以下任何迹象均视为不合格：

4.2.1 裂纹

4.2.2 深度超过0.8 mm 的咬边。这还包括焊趾处的母材金属出现其他任何缩减的情况。

4.2.3 焊缝余高超过表5中的规定值

表5

	设计温度的最大余高厚度		
	>400°C	175°C - 400°C	<175°C
母材金属厚度 (mm)	mm	mm	mm
<3（包括在内）	2	2.5	5
>3且<5（包括在内）	2	3	5
>5且<13（包括在内）	2	4	5
>13且<25（包括在内）	2.5	5	5
>25且<50（包括在内）	3	6	6
>50	4	备注 (a)	备注 (a)

(a) 大于6 mm 或焊缝宽度的1/8倍。

备注：

1. 对于双面焊对接接头，上表中给出的余高限制必须分别应用于此接头的内外表面。
2. 对于单面焊对接接头，上表中给出的余高限制只能应用于此接头的外表面。
3. 焊缝余高厚度必须基于所连接的较薄材料的厚度。
4. 焊缝余高厚度必须根据较高的对接表面来确定。
5. 如有需要，可以清除焊缝余高。

4.2.4 熔合不足

4.2.5 未完全焊透

4.2.6 其他任何长度超过5 mm 的线状显示

4.2.7 呈圆形显示的表面气孔，其尺寸大于5 mm，或者由任意方向的2 mm 或以下的边缘隔开的四种或以上的圆形显示。圆形显示是指显示为圆形或椭圆形且其长度小于宽度的三倍。

5.0 工艺评定要求

5.1 焊接工艺规程数据

表6针对每种焊接方法给出了 WPS 中所要包含的焊接数据。WPS 可以任何格式（书面或表格）呈现，前提是要包含表6中所需的数据。附录 VII 中显示了建议的 WPS 格式。WPS 可能会列出 PQR 上记录的评定变素允许的全范围内的变素，以及焊接机构为其他焊接数据确定的实际操作限制。

表6
WPS 数据矩阵

	FCAW		GMAW		GTAW		SMAW
5.1.1 接头设计							
(1) 接头类型和尺寸。	X		X		X		X
(2) 背面处理、刨槽/制备方法。	X		X		X		X
(3) 背衬材料（如使用）。	X		X		X		X
5.1.2 母材金属							
(1) M 编号和组编号。	X		X		X		X
(2) 评定的厚度范围。	X		X		X		X
(3) 直径（仅管状）。	X		X		X		X
(4) 涂层描述或类型（如有）。	X		X		X		X
5.1.3 填充金属							
(1) 规格、分类、F 编号和 A 编号，或者公称成分（如未分类）。	X		X		X		X
(2) 焊缝金属厚度（按焊接方法和填充金属分类）。	X		X		X		X
(3) 填充金属的尺寸或直径。	X		X		X		X
(4) 增强焊透的焊剂。					X		
(5) 附加填充金属。	X		X		X		
(6) 可熔性嵌条和类型。					X		
(7) 通电的填充金属“热丝”。					X		
5.1.4 位置							
(1) 焊接位置。	X		X		X		X
(2) 立焊方向。	X		X		X		X

表6
WPS 数据矩阵（续）

	FCAW		GMAW		GTAW		SMAW
5.1.5 预热与道间温度							
(1) 最小预热温度。	X		X		X		X
(2) 最大道间温度（如适用）	X		X		X		X
(3) 预热保持时间。	X		X		X		X
5.1.6 热处理							
(1) PWHT 温度和时间。	X		X		X		X
5.1.7 保护气							
(1) 焊炬保护气和流速范围。	X		X		X		
(2) 根部保护气和流速范围。					X		
5.1.8 电气							
(1) 电流（或送丝速度）、电流类型和极性。	X		X		X		X
(2) 电压范围（手工焊接除外）	X		X		X		
(3) 钨电极的规格、分类和直径。					X		
(4) 过渡模式。	X		X				
(5) 变到脉冲电流或从脉冲变回。	X		X		X		X
5.1.9 变素							
(1) 焊接方法以及是否手工、半自动化、机械化还是自动焊。	X		X		X		X
(2) 对于机械化或自动，单个还是多个电极及其间距。	X		X		X		
(3) 单道焊或多道焊。	X		X		X		X
(4) 导电管到工件的距离。	X		X				
(5) 清理。	X		X		X		X
(6) 锤击。	X		X		X		X
(7) 直焊道或摆动焊道。	X		X		X		X
(8) 机械化或自动焊接和手工应用的运行速度范围需要进行热输入计算。	X		X		X		

5.2 工艺评定变素。如果一个WPS的变化超出了本条款允许的范围，必须对新 WPS 或修订后的 WPS 的工艺和制备进行重新评定。此条款中未阐述的变更无需重新评定，前提是在新 WPS 或修订后的 WPS 中记录此类变更。

5.2.1 试验焊件。焊接机构必须准备足量的评定试验焊件，要涵盖此处所述的预期的焊接方法、材料、厚度等等。每个坡口试验焊件的尺寸必须大到足够提供5.3中所需的必要试样。

5.2.1.1 对于具有不同 M 编号的母材金属的焊接，必须针对每种要连接的 M 编号组合来进行工艺评定试验。但对于仅有一个 M 编号的工艺评定试验，也评定了该金属对自身的焊接以及对任一种更低M编号的金属的焊接：

(1) 母材金属 M-1、M-3、M-4和 M-5A；以及

(2) 焊接方法 SMAW、GTAW、GMAW 和 FCAW。

（*示例：*M-5A 焊接到 M-5A 评定了M-5A焊接至M-5A，同时也评定了 M-5A 至 M-4、M-5A 至 M-3以及 M-5A 至 M-1的焊接。有关母材金属 M 编号列表，请参见附录 III-A 和 III-B）

5.2.1.2 如需进行断裂韧性试验，必须针对 M 编号与要连接的组编号的各种组合进行工艺评定。即便针对焊接到自身的两种母材金属中的每一种进行了工艺评定试验，也必须针对母材金属的每个 M 编号和组号组合进行工艺评定。

(1) 如果焊接母材金属组合的焊接工艺规程 (WPS) 规定了相同的评定变素，包括电极或填充金属，由于这两种 WPS 都是针对每种母材和自身的焊接，所以唯一变化的就是母材金属，则焊接母材金属组合的 WPS 也通过评定。

(2) 当两个不同 M 编号和组编号的母材金属使用一个单独试验焊件进行了评定，则使用评定过的变素的该试验焊件，也评定了那两个 M 编号和组编号对自身的焊接以及彼此之间的焊接。

5.2.2 评定厚度限制

5.2.2.1 表7中给出了工艺评定试验所评定的厚度范围限制。

5.2.2.2 表7中的限制基于坡口焊缝的母材金属和焊缝金属厚度。

5.2.2.3 完全焊透坡口焊缝也必须评定部分焊透坡口焊缝、角焊缝和堆焊是否在表7中给出的评定限制内。

5.2.2.4 除了5.1规定的必须包含在 WPS 中的焊接数据外，当单独一个试验焊件中使用了多种焊接方法或多种类别的填充金属时，WPS 中允许使用的厚度范围必须单独应用于每种焊接方法和每种填充金属分类。评定试验中采用的每种焊接方法和每种类别的填充金属的焊缝熔敷厚度必须记录在 PQR中。

5.2.2.5 除了5.2.3规定的必须记录在 PQR 中的工艺评定变素外，评定测试中采用的每种焊接方法和每种类别的填充金属的焊缝熔敷厚度还必须记录在针对所有应用的 PQR中。

表7
坡口焊缝工艺评定的板材和管子厚度限制

	评定的母材金属厚度[b,c,d,e,f]		评定的熔敷焊缝金属厚度 (t)[b, g]
试验焊件厚度 (T), mm[a]	最小值, mm	最大值, mm	最大值, mm
<2	1/2T	2T	2t
2 - 10	2	2T	2t
>10且<19	5	2T	2t
19至<38	5	2T	2t（t <19时） 2T（t ≥ 19时）
38至<150	5	200	2t（t <19时） 200（t ≥ 19时）
150和以上	25	1.33T	2t（t <19时） 200（19 ≤ t <150） 1.33t（t ≥ 150）

(a) 采用组合焊接方法填充坡口时：
(1) 试验焊件厚度“T”适用于母材金属，必须根据“评定的母材金属厚度”栏确定。
(2) 每种焊接方法的焊缝金属的厚度“t”必须根据“熔敷焊缝金属厚度”栏确定。
(3) 以这种组合方式评定的焊接方法只能在相同的评定变素和厚度限制下单独使用。
(b) 对于 GMAW-S，评定的母材金属的最大厚度是试验焊件厚度的1.1倍（直至试验焊件的厚度为13 mm 为止），除此以外均适用表7。评定的最大焊缝金属厚度是焊件中熔敷的 GMAW- S 焊缝金属厚度的1.1倍。此外，如果厚度为10 mm 或以上，必须采用侧面弯曲试验来评定 GMAW-S WPS。
(c) 对于断裂韧性方面的应用，评定的最小母材金属厚度为 T 或16 mm（取二者中的较小值）。
(d) 如果试验焊件母材金属中的任何单个焊道的厚度超过13 mm，则评定的母材金属厚度是试验焊件厚度的1.1倍。
(e) 如果试验焊件受到超过下转变温度的焊后热处理，则评定的最大母材金属厚度是试验焊件母材金属厚度的1.1倍，评定的最大焊缝厚度是试验焊件焊缝金属的1.1倍。
(f) 对于厚度等于或小于10 mm 的母材金属，角焊缝的母材金属厚度评定与坡口焊缝的相同。对于厚度大于10 mm 的母材金属，评定的最大母材金属厚度对于角焊缝而言是无限制的。
(g) 熔敷焊缝金属厚度限制不适用于角焊缝或堆焊。
备注：
T = 试验焊件母材金属的厚度。
t = 焊缝熔敷厚度，不包括余高。

5.2.3 表8列出了在 PQR上要针对每种焊接方法记录的工艺评定变素。超出表8中所示限制的工艺评定变素的变化必须使用新的或修订的 WPS 和新 PQR。PQR 必须列出所用变素的实际值。表中条目的重点如下：

Q - 针对所有应用的评定变素

T - 针对所有断裂韧性应用的评定因素

表8
PQR 数据矩阵

	FCAW		GMAW		GTAW		SMAW
5.2.3.1 接头设计							
(1) 由角焊缝变为坡口焊缝。	Q		Q		Q		Q
(2) 背衬 M 编号的变化。	Q		Q		Q		Q
5.2.3.2 母材金属							
(1) 母材金属厚度变化超出5.2.2中允许的范围。	Q		Q		Q		Q
(2) 由一个 M 编号母材金属变为另一个 M 编号母材金属或多个 M 编号母材金属的组合，5.2.1.1中允许的情况除外。	Q		Q		Q		Q
(3) 由一个 M 编号-组编号变为其他任意 M 编号-组编号，5.2.1.2中允许的情况除外。	T		T		T		T
(4) 由一个 M-5组（A、B 等）变为其他任意一个 M-5 组。由 M-9A 变为 M-9B，但不能反过来。由一个 M-10或 M-11组（A、B 等）变为其他任意一个组。	Q		Q		Q		Q
5.2.3.3 填充金属							
(1) 由一个 F 编号变为其他任意一个 F 编号或附录 II 中未列出的任何填充金属。	Q		Q		Q		Q
(2) 对于铁质材料，由一个 A 编号变为其他任意 A 编号。	Q		Q		Q		Q

表8
PQR 数据矩阵（续）

	FCAW		GMAW		GTAW		SMAW
5.2.3.3 填充金属（续）							
(3) 填充金属拉伸强度变化超过60 MPa，或填充金属分类变化，其强度低于规定的母材金属最低拉伸强度。	Q		Q		Q		Q
(4) 填充材料的增加或消除。					Q		
(5) 焊缝金属厚度变化超出5.2.2中允许的范围。	Q		Q		Q		Q
5.2.3.4 预热和道间温度							
(1) 预热温度的减小值超过评定值55°C。	Q		Q		Q		Q
(2) 最高道间温度的增加值比 PQR 中记录的值高55°C。	T		T		T		T
5.2.3.5 焊后热处理							
(1) 对于以下 M 编号，即1、3、4、5、6、7、9、10和11，从任何一种状况变为任何其他状况必须进行重新评定： (a) 无 PWHT。 (b) PWHT 低于下转变温度。 (c) PWHT 在转变温度范围内。 (d) PWHT 高于上转变温度。 (e) PWHT 高于上转变温度，接着经过处理又低于下转变温度。	Q		Q		Q		Q
(2) 对于上述之外的所有材料，无 PWHT 和有 PWHT 时需要单独的 PQR。	Q		Q		Q		Q

表8
PQR 数据矩阵（续）

	FCAW		GMAW		GTAW		SMAW
5.2.3.6 保护气							
(1) 焊炬保护气的增加或消除。	Q		Q		Q		
(2) 规定的保护气公称成分变化。	Q		Q		Q		
5.2.3.7 电气特性							
(1) 热输入或单位焊缝长度内熔敷的焊缝金属体积的增加超过评定范围，焊接后进行晶粒细化奥氏体热处理的情况除外。通过下面的任意一种方式可以测定增加情况： (a) 热输入 (kJ/mm) = $\frac{\text{电压 x 电流 x 0.06}}{\text{运行速度 (mm/min)}}$ (b) 焊缝金属体积 - 电极单位长度内焊道尺寸（宽度 x 厚度）增大或焊道长度减小。	T		T		T		T
(2) 金属由短路到熔滴、喷射或脉冲的模式过渡变化（以及反过来的情况）。	Q		Q				
5.2.3.8 其他变素							
(1) 焊接方法变化。	Q		Q		Q		Q
(2) 对于机械化焊接或自动焊接，摆动变化超过 ± 20%。	T		T		T		
(3) 从每一边的多道焊变为每一边的单道焊。	T		T		T		T
(4) 垂直上坡焊中由直焊道变为摆动焊道。	T		T		T		T

5.3 工艺评定试验要求

5.3.1 坡口试验焊件的评估。试验焊件必须接受以下检验：

(1) 目检

(2) 导向弯曲试验

(a) 4个侧面弯曲试样，或

(b) 2个面弯试样和2个根部弯曲试样

对于金属厚度为10至19 mm（包括19 mm）的面弯和根部弯曲试样，可以用侧面弯曲试样取代。对于厚度超过19 mm 的金属，需要使用侧面弯曲试样。对于厚度为10 mm 或以上的母材金属，需要对 GMAW-S 使用侧面弯曲试样。

(3) 拉伸试验

(a) 2个横向试样

(4) CVN 断裂韧性（如需要）

(a) 3个取自焊缝金属的试样

(b) 3个取自 HAZ 的试样

5.4 工艺评定验收标准

5.4.1 目检验收标准。从完工的试验焊件清除试样坯前，必须对焊缝上所有可见的表面进行目检，并且必须满足以下标准：

5.4.1.1 不得有裂纹、未熔合或接头未完全焊透的迹象。

5.4.1.2 咬边深度不得超过母材金属厚度的10% 或0.8 mm（取二者中的较小值）。

5.4.1.3 气孔不得超过条款2.0、3.0或4.0的限制（如适用）。

5.4.2 弯曲标准。横向弯曲试样必须按附录 IV 中的规定进行制备。试样棱角半径不得超过3 mm。建议（但无硬性规定）试样打磨方向平行于弯曲方向。对于面弯试样，焊缝表面的边必须在弯曲试样的凸面。对于根部弯曲试样，焊根的边必须在弯曲试样的凸面。侧面弯曲试样可以在其中任意一个方向弯曲。所有横向弯曲试样在弯曲后，焊缝金属和热影响区必须完全位于试样的弯曲部分。

对于不连续性可拒收的试样，不论其是否符合制备或弯曲要求，都必须视为失败，除非另有规定。不符合制备或弯曲要求即使不含可拒收的不连续性的试样，必须予以舍弃，并且必须从原始焊件制备替换用试样进行试验。

弯曲试样的凸面（从试样边缘开始，包含试样棱角半径）必须进行目检，且必须符合5.4.2.1、5.4.2.2或5.4.2.3的要求（如适用）。

5.4.2.1 结构钢应用。根据如下条件，验收时焊缝或热影响区表面不得含不连续性：

(1) 在表面上从任意方向测量超过3 mm，或

(2) >10 mm - 所有不连续性的最大尺寸超过 0.8 mm，但小于或等于 3 mm之和，或

(3) 6 mm - 最大角裂纹，例外情况是可见夹渣或其它熔合型缺陷所产生的角裂纹，此种情况适用最大值3 mm。

角裂纹超过6 mm 且无可见夹渣或其他熔合型缺陷的试样必须予以舍弃，并且必须从原始焊件制备替换用试样进行试验。

5.4.2.2 管线应用。如果弯曲后焊缝或焊缝与熔合区之间在任意方向都不存在裂纹或其他超过3 mm 或规定壁厚一半（取二者中的较小值）的缺陷，则弯曲试验被视为合格。试验过程中沿试样边缘弯曲的外径上的裂纹如在任意方向测得都小于6 mm，则应不予考虑，除非发现明显缺陷。

5.4.2.3 压力管道应用。根据如下条件，验收时焊缝或热影响区表面不得含不连续性：

(1) 在表面上从任意方向测量超过3 mm。

(2) 试验过程中在试样的角上出现的外露缺陷应不予考虑，除非有确切证据表明外露缺陷导致熔合不足、夹渣或其他内部缺陷，则必须对取自原始焊件的替换用试样进行试验，。

5.4.3. 拉伸试验标准。拉伸试验的工艺和方法必须符合 AWS B4.0 - *焊缝机械试验标准方法*的要求。（备注：B4.0仅供参考，参加本门考试时无需用到。）每个拉伸试样的拉伸强度不得低于以下值：

5.4.3.1 附录 III-B 中规定的母材金属的最低拉伸强度，如果使用了两种具有不同最低拉伸强度的母材金属，则取二者中强度较弱的母材金属的最低拉伸强度；或

5.4.3.2 电极或填充金属分类（如使用了低匹配的填充金属）规定的最低拉伸强度；或

5.4.3.3 如果试样在焊缝外部的母材金属或焊缝交界面中破断，此试验可以接受，前提是强度不低于母材金属规定的最低拉伸强度的95%。

5.4.3.4 如果母材金属没有规定最低拉伸强度，则破断在母材金属中可以接受。

5.4.4 CVN 断裂韧性标准。对于断裂韧性试验，必须规定试验类型、试样数量和验收标准。工艺和设备必须符合 AWS B4.0 - *焊缝机械试验标准方法*的要求。（备注：B4.0仅供参考，参加本门考试时无需用到。）

5.5. 工艺评定文件。必须在焊接工艺评定报告 (PQR) 上记录制作合格试验焊件所采用的焊接变素以及评定 WPS 时对该焊件进行试验的结果。PQR可以是任意格式，书面或表格格式皆可。附录 VIII 中提供了 PQR 的建议格式。WPS 必须引用支持该 WPS 评定的所有 PQR。

此页特意留白。

6.0 资格评定要求

6.1 通用

6.1.1 本规程阐述了焊工资格评定要求。其中不含对焊接操作工或定位焊工的要求。定位焊必须由符合本规程要求的焊工来完成。

6.1.2 针对某一个 WPS 进行的焊工评定，意味着也对 6.2 中规定的资格评定变素中的其他 WPS 进行了焊接评定。

6.1.3 完成合格工艺或资格评定测试，意味着焊接试验焊件的焊工也将通过6.2中规定的资格评定变素限制范围内的评定。

6.1.4 对接头完全焊透坡口焊缝进行评定，意味着焊工也将通过接头部分焊透坡口焊缝和角焊缝的评定。对接头部分焊透的坡口焊缝进行评定，意味着焊工仅通过接头部分焊透的坡口焊缝和角焊缝的评定。

6.2 资格评定变素

如下面所列的任何变素相比焊工评定试验中所采用的变素有所变化，则需要对该焊工重新评定：

(1) 焊接方法变化。焊工通过 GMAW 喷射、脉冲喷射或熔滴过渡评定意味着也通过气体保护 FCAW 焊接评定（反之也是如此），此种情况除外。

(2) 取消背衬。

(3) 填充金属 F 编号变化，6.3.2.2中允许的情况除外。

(4) 母材金属变化，6.3.2.1中允许的情况除外。

(5) 对于 GTAW - 由交流变为直流或由直流变为交流，或极性变化。

(6) 评定位置变化，6.3.2.3中允许的情况除外。

(7) 对于任意焊道（通过背刨完全清除的根部焊道或用于处理最终焊缝表面的最终焊道除外）- 由上坡焊到下坡焊的立焊焊接方向变化（或相反）。

(8) 对于 GMAW - 由喷射过渡、熔滴过渡或脉冲喷射变为短路过渡（或相反）。

(9) 对于 GMAW 或 GTAW - 可熔性嵌条的遗漏或增加，或根部保护气的取消，双面焊接的对接接头、部分焊透坡口和角焊缝除外。

(10) 试验的厚度或直径变化，表9和表10中允许的情况除外。

表9
圆管和管子中坡口焊缝的资格评定限制

试验焊件，mm		管子和板材评定			
		最小外径，mm		最大熔敷厚度	
外径	熔敷厚度 (t)	坡口焊缝	角焊缝	坡口焊缝	角焊缝
<25		焊接尺寸	全部		
25 - 73		25	全部		
>73		73	全部		
	<19			2t	全部
	19和>19			不限	全部

t = 焊缝熔敷厚度，不包括余高。
备注：
对于 GMAW-S，在评定试验中，评定的最大焊缝金属厚度不得超过通过 GMAW-S 方法熔敷的焊缝金属厚度的1.1倍。对于厚度为 10 mm 或以上的母材金属，需要对 GMAW-S 使用侧面弯曲试样。

表10
板材坡口焊缝的资格评定限制

	板材评定[a]	
试验焊件厚度 (T)，mm	熔敷厚度 (t)，最大值[b]	角焊缝尺寸
< 19	2t	不限
≥ 19	不限	不限

[a]对板材的评定意味着也将针对直径超过600 mm 的管子中的坡口焊缝进行评定。
[b]对于 GMAW-S，在评定试验中，评定的最大焊缝金属厚度不得超过通过 GMAW-S 方法熔敷的焊缝金属厚度的1.1倍。对于厚度为10 mm 或以上的母材金属，需要对 GMAW-S 使用侧面弯曲试样。

备注：
T = 试验焊件母材金属的厚度。
t = 焊缝熔敷厚度，不包括余高。

6.3 资格评定试验要求

6.3.1 通过标准试验进行评定。在评定中，需要根据所评定的 WPS 的要求完成标准试验焊件，并根据表11中所列的方法评估试验焊件，以及按照6.4 - 检查验收标准对此焊件进行验收。表 12中显示了每个位置和产品形式所需的弯曲试验数目。

表11
资格评定的检查要求

	小于 2 mm 的管子或薄板	等于或大于 2 mm 的管子或板材
试验类型	坡口焊缝	坡口焊缝
目检	是	是
X 射线检查	否	是[a] （代替弯曲试验）
弯曲试验	否	是[a, b]

[a]在适当情况下，采用 SMAW、GTAW、GMAW（短路除外）和 FCAW 方法进行评定时，X 射线检查可以代替弯曲试验。
[b]参见表12。

表12
资格评定的弯曲试验数目

	产品形式			
	板材	圆管	管子	薄板
1G	*2*	2	2	2
2G	*2*	2	2	2
3G	*2*	—	—	2
4G	*2*	—	—	2
5G	—	4	4	—
6G	—	4	4	—

6.3.2 焊考试件

6.3.2.1 只有在金属具备相同的 M 编号时，评定才有效，表13中另外允许的情况除外。

6.3.2.2 必须使用所分配的 F 编号列示在附录 II 中的填充金属进行试验。如在评定试验中使用表14中所示的填充金属，则焊工无需其他试验，即可通过使用其他填充金属的评定。如使用的填充金属未被分配附录 II 中所示的 F 编号，则仅通过该种填充金属的评定。

6.3.2.3 对于焊接在特定试验位置的试板，意味着焊工将通过按照表15中允许的情况焊接板材或管子的评定。

6.3.2.4 可以对单独一个试验焊件进行一种或多种焊接方法的评定。可以针对一个试验的特定部分对多个焊工进行评定。此类试验焊件的任何部分失败，将构成该试验焊件中所使用的所有焊接方法和所有焊工都失败。

表13
资格评定允许使用的母材金属

试验焊件材料[a]	产品焊接材料评定
M-1 至 M-11	M-1 至 M-11

[a] 如果在评定试验中使用附录 III 中未列出的材料，则意味着该焊工只通过对试验焊件中所用材料进行焊接的评定。

表14
资格评定允许使用的填充金属

评定试验中使用的填充金属	评定焊工允许使用下列填充金属
F-编号1 - 5	试验中使用的 F 编号及以下的 F 编号
F 编号6[a]	所有 F 编号为6的填充金属

[a]AWS 规程未涵盖熔敷的实芯光焊丝，但此类焊丝符合附录 I 中的 A 编号分析，应视为 F 编号6分类。

表15
资格评定试验的位置限制

试验位置[d]		评定位置[c]		
		坡口焊缝		角焊缝
焊缝	位置	板材和外径超过 600 mm 的管子	外径≤600 mm 的管子	板材和管子
板材坡口焊缝	1G	F		F、H
	2G	F、H		F、H
	3G	F、V		F、H、V
	4G	F、O		F、H、O
	3G 和4G	F、V、O		全部
	2G、3G 和4G	全部		全部
板材角焊缝	1F	—	—	F
	2F	—	—	F、H
	3F	—	—	F、H、V
	4F	—	—	F、H、O
	3F 和4F	—	—	全部
管道坡口焊缝[a,b]	1G	F	F	F、H
	2G	F、H	F、H	F、H
	5G	F、V、O	F、V、O	全部
	6G	全部	全部	全部
	2G 和5G	全部	全部	全部
管道角焊缝	1F	—	—	F
	2F	—	—	F、H
	2FR	—	—	F、H
	4F	—	—	F、H、O
	5F	—	—	全部

[a]通过管状产品形式评定的焊工可以根据本文其他部分所含的对管径限制的规定，来对管状和板材进行焊接。
[b]参见表9。
[c] F = 平焊，H = 横焊，V = 立焊，O = 仰焊。
[d]焊接试验位置的定义见 AWS A3.0 - “标准焊接术语和定义”。

6.4 资格评定验收标准

6.4.1 目检。目检过程和验收标准必须符合下文中的规定。

6.4.1.1 目检程序。随时可以目检试验焊缝，如未表现出必要的技能，则随时终止试验。完工的试验焊缝必须进行目检。

6.4.1.2 目检验收标准。标准试验板材和管子焊件目检的验收标准必须符合以下要求：

(1) 无裂纹或未熔合。

(2) 坡口焊缝中没有接头未完全焊透的情况，规定接头部分焊透的坡口焊缝除外。

(3) 咬边深度不得超过母材金属厚度的10% 或0.8 mm（取二者中的较小值）。

(4) 表面余高或根部余高不得超过3 mm。

(5) 任何一个孔的直径均不得超过2.5 mm。

6.4.2 弯曲试验。5.3.1(2) 和5.4.2规定了弯曲试验的要求和验收标准。

6.5 资格评定文件

针对每个焊工的评定试验都必须进行记录，无论其试验合格与否。焊工资格评定测试报告 (WQTR) 的格式没有要求。任何格式的 WQTR 均可使用。有关建议的格式，请参见附录 IX。文件应当符合以下要求：

(1) 确定使用的 WPS；

(2) 阐明6.2中的各种评定变素；

(3) 确定采用的试验和检查方法及结果；以及

(4) 确定焊工评定限制范围。

附录 I（规范性）– A 编号表

铁质焊缝金属分类的工艺评定

		化学成分，重量 %					
A 编号	焊缝金属类型	C	Cr	Mo	Ni	Mn	Si
1	低碳	0.20	0.20	0.30	0.50	1.60	1.00
2	碳-钼	0.15	0.50	0.40–0.65	0.50	1.60	1.00
3	铬-钼	0.15	0.40–2.00	0.40–0.65	0.50	1.60	1.00
4	铬-钼	0.15	2.00–4.00	0.40–1.50	0.50	1.60	2.00
5	铬-钼	0.15	4.00–10.5	0.40–1.50	0.80	1.20	2.00
6	铬，马氏体	0.15	11.00–15.0	0.70	0.80	2.00	1.00
7	铬，铁素体	0.15	11.00–30.0	1.00	0.80	1.00	3.00
8	铬-镍	0.15	14.50–30.0	4.00	7.50–15.00	2.50	1.00
9	铬-镍	0.30	19.0–30.0	6.00	15.0–37.00	2.50	1.00
10	镍	0.15	0.50	0.55	0.80–4.00	1.70	1.00
11	锰-钼	0.17	0.50	0.25–0.75	0.85	1.25–2.25	1.00
12	镍-铬-钼	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

备注：
此表中单个的值表示最大值。

附录 II（规范性）– F 编号表

焊接电极和焊条分组评定

F-No.	AWS 规范	AWS 分类
		钢
1	A5.1	EXX20, EXX22, EXX24, EXX27, EXX28
1	A5.4	EXXX(X)-26
1	A5.5	EXX20-XX, EXX27-XX
2	A5.1	EXX12, EXX13, EXX14, EXX19
2	A5.5	E(X)XX13-XX
3	A5.1	EXX10, EXX11
3	A5.5	E(X)XX10-XX, E(X)XX11-XX
4	A5.1	EXX15, EXX16, EXX18, EXX18M, EXX48
4	A5.4奥氏体和双相不锈钢除外	EXXX(X)-15, EXXX(X)-16, EXXX(X)-17
4	A5.5	E(X)XX15-XX, E(X)XX16-XX, E(X)XX18-XX, E(X)XX18M, E(X)XX18M1, E(X)XX45-P2
5	A5.4奥氏体和双相不锈钢	EXXX(X)-15, EXXX(X)-16, EXXX(X)-17
6	A5.9	所有分类
6	A5.18	所有分类
6	A5.20	所有分类
6	A5.22	所有分类
6	A5.28	所有分类
6	A5.29	所有分类
6	A5.30	INMs-X, IN5XX, IN3XX(X)

附录 III-A（规范性）

母材金属规范列表 - 铁基合金

标准	母材金属规范	材料编号	组编号	类型、级别或合金牌号	UNS 编号	产品形式
			钢和钢合金			
ASTM	A 36	1	1	A 36	K02599	板材与棒材
ASTM	A 36	1	1	A 36	K02598	板材与棒材
ASTM	A 36	1	1	A 36	K02597	板材与棒材
ASTM	A 36	1	1	A 36	K02596	板材与棒材
ASTM	A 106	1	1	B 级	K03006	无缝管
ASTM	A 106	1	2	C 级	K03501	无缝管
ASTM	A 202	4	1	A 级	K11742	板材
ASTM	A 202	4	1	B 级	K12542	板材
ASTM	A 203	9A	1	A 级	K21703	板材
ASTM	A 203	9A	1	B 级	K22103	板材
ASTM	A 203	9B	1	D 级	K31718	板材
ASTM	A 203	9B	1	E 级	K32018	板材
ASTM	A 204	3	1	A 级	K11820	板材
ASTM	A 204	3	2	B 级	K12020	板材
ASTM	A 204	3	2	C 级	K12320	板材
ASTM	A 225	10A	1	C 级	K12524	板材
ASTM	A 225	10A	1	D 级	—	板材
ASTM	A 240	6	1	410型	S41000	板材
ASTM	A 240	6	2	429型	S42900	板材
ASTM	A 240	6	4	S41500级	S41500	板材
ASTM	A 240	7	1	405型	S40500	板材
ASTM	A 240	7	1	409型	S40900	板材
ASTM	A 240	7	1	410S 型	S41008	板材
ASTM	A 240	7	2	18-2型	S44400	板材
ASTM	A 240	7	2	430型	S43000	板材
ASTM	A 240	8	2	S30815	S30815	板材、薄板和条带
ASTM	A 312	8	1	TP304	S30400	无缝管与焊接管
ASTM	A 312	8	1	TP304L	S30403	无缝管与焊接管
ASTM	A 312	8	1	TP316	S31600	无缝管与焊接管
ASTM	A 312	8	1	TP316L	S31603	无缝管与焊接管
ASTM	A 312	8	3	TPXM-19	S20910	无缝管与焊接管
ASTM	A 312	8	3	TP-11	S21904	无缝管与焊接管
ASTM	A 312	8	4	317LM	S31725	无缝管与焊接管
ASTM	A 312	8	4	S31254	S31254	无缝管与焊接管
ASTM	A 333	4	2	4级	K11267	管子
ASTM	A 333	9A	1	7级	K21903	管子
ASTM	A 333	9A	1	9级	K22035	管子
ASTM	A 333	9B	1	3级	K31918	管子
ASTM	A 335	4	1	P11级	K11597	管子
ASTM	A 335	4	1	P12	K11562	管子
ASTM	A 335	5B	2	P91	K91560	无缝管
ASTM	A 353	11A	1		K81340	板材
ASTM	A 369	3	1	FP1级	K11522	锻管
ASTM	A 387	3	2	2级，2类	K12143	板材
ASTM	A 387	5A	1	21级，1类	K31545	板材

母材金属规格列表 - 铁基合金

标准	母材金属规格	材料编号	组编号	类型、级别或合金牌号	UNS 编号	产品形式
			钢和钢合金			
ASTM	A 387	5A	1	21级，2类	K31545	板材
ASTM	A 387	5B	1	5级，1类	K41545	板材
ASTM	A 387	5B	1	5级，2类	K41545	板材
ASTM	A 387	5B	2	91级，2类	S50460	板材
ASTM	A 420	11A	1	WPL8级	K81340	管道
ASTM	A 514	11B	1	A 级	K11856	板材
ASTM	A 514	11B	2	E 级	K11856	板材
ASTM	A 516	1	1	55级	K01800	板材
ASTM	A 516	1	1	65级	K02403	板材
ASTM	A 516	1	2	70级	K02700	板材
ASTM	A 517	11B	1	A 级	K11856	板材
ASTM	A 517	11B	2	E 级	K21604	板材
ASTM	A 533	3	3	A 型，1类	K12521	板材
ASTM	A 533	3	3	A 型，2类	K12521	板材
ASTM	A 533	3	3	B 型，1类	K12539	板材
ASTM	A 533	3	3	B 型，2类	K12539	板材
ASTM	A 533	11A	4	A 级，3类	K12521	板材
ASTM	A 533	11A	4	B 级，3类	K12539	板材
ASTM	A 543	11A	5	B 型，1类	K42339	板材
ASTM	A 543	11A	5	B 型，3类	K42339	板材
ASTM	A 542	5C	3	A 型，3类	K21590	板材
ASTM	A 542	5C	4	A 型，1类	K21590	板材
ASTM	A 542	5C	5	A 型，2类	K21590	板材
ASTM	A 612	10C	1	—	K02900	板材
ASTM	A 645	11A	2	—	K41583	板材
ASTM	A 709	11B	1	100级，A 型	K11856	板材与型材
ASTM	A 709	11B	1	100W 级，A 型	K11856	板材与型材
ASTM	A 709	11B	2	100级，E 型	K21604	板材与型材
ASTM	A 709	11B	2	100W 级，E 型	K21604	板材与型材
ASTM	A 832	5C	1	21V 级	K31830	
ASTM	A 871	3	2	60级	—	板材
ASTM	A 945	3	2	65级	—	板材
API	5L	1	1	X42级	—	管子
API	5L	1	2	X52级	—	管子
API	5L	1	2	X60级	—	管子
API	5L	1	4	X80级	—	管子

母材金属 M 编号列表 - 铁基合金

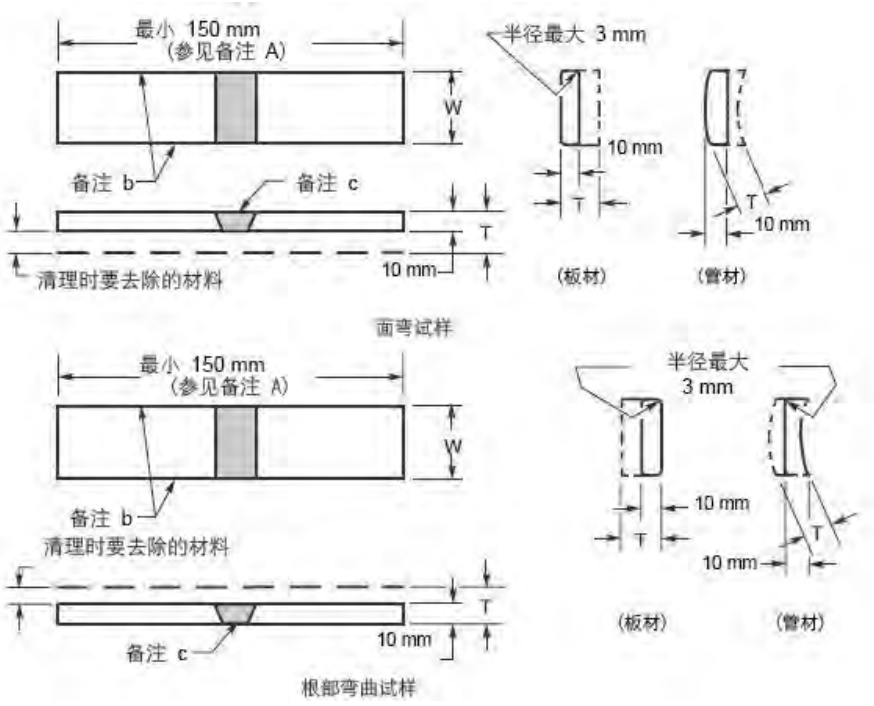
材料编号	组编号	标准	母材金属规格	类型、级别或合金牌号	UNS 编号	厚度限制 mm	最小拉伸/屈服强度，MPa	产品形式	公称成分
				钢和合金钢					
1	1	ASTM	A 36	A 36	K02595	≤20	400/250	板材与棒材	C-Mn-Si
1	1	ASTM	A 36	A 36	K02596	>20≤40	400/250	板材与棒材	C-Mn-Si
1	1	ASTM	A 36	A 36	K02597	>40≤65	400/250	板材与棒材	C-Mn-Si
1	1	ASTM	A 36	A 36	K02596	>65≤100	400/250	板材与棒材	C-Mn-Si
1	1	ASTM	A106	B 级	K03006	—	415/240	无缝管	C-Mn-Si
1	1	ASTM	A 516	55级	K01800	—	380/205	板材	C-Mn-Si
1	1	ASTM	A 516	65级	K02403	—	450/240	板材	C-Mn-Si
1	1	API	5L	X42级	—	—	415/290	管子	C-Mn
1	2	ASTM	A 106	C 级	K03501	—	485/275	无缝管	C-Mn-Si
1	2	ASTM	A 516	70级	K02700	—	485/260	板材	C-Mn-Si
1	1	API	5L	X52级	—	—	460/360	管子	C-Mn
1	2	API	5L	X60级	—	—	515/415	管子	C-Mn-Cb-V-Ti
1	4	API	5L	X80级	—	—	625/550	管子	C-Mn
3	1	ASTM	A 204	A 级	K11820	—	450/255	板材	C-0.5Mo
3	1	ASTM	A 369	FP1级	K11522	—	380/205	管子	C-0.5Mo
3	2	ASTM	A 204	B 级	K12020	—	485/275	板材	C-0.5Mo
3	2	ASTM	A 204	C 级	K12320	—	515/295	板材	C-0.5Mo
3	2	ASTM	A 387	2级，2类	K12143	—	485/310	板材	0.5Cr-0.5Mo
3	2	ASTM	A 871	60级	—	—	515/415	板材	C-Mn-Ni-Cu-Cr-V
3	2	ASTM	A 945	65级	—	—	540/450	板材	LowC-Mn
3	3	ASTM	A 533	A 型，1类	K12521	—	550/345	板材	Mn-0.5Mo
3	3	ASTM	A 533	A 型，2类	K12521	—	620/485	板材	Mn-0.5Mo
3	3	ASTM	A 533	B 型，1类	K12539	—	550/345	板材	Mn-0.5Mo-0.5Ni
3	3	ASTM	A 533	B 型，2类	K12539	—	620/485	板材	Mn-0.5Mo-0.5Ni

4	1	ASTM	A 202	A 级	K11742	—	515/310	板材	0.5Cr-1.25Mn-Si
4	1	ASTM	A 202	B 级	K12542	—	585/325	板材	0.5Cr-1.25Mn-Si
4	1	ASTM	A 335	P11	K11597	—	415/205	管子	1.25Cr-0.5Mo-Si
4	1	ASTM	A 335	P12	K11562	—	415/220	管子	1Cr-0.5Mo
4	2	ASTM	A 333	4级	K11267	—	415/240	管子	0.75Cr-0.75Ni-Cu-Al
5A	1	ASTM	A 387	21级，1类	K31545	—	415/205	板材	3Cr-1Mo
5A	1	ASTM	A 387	21级，2类	K31545	—	515/310	板材	3Cr-1Mo
5B	1	ASTM	A 387	5级，1类	K41545	—	415/205	板材	5Cr-0.5Mo
5B	1	ASTM	A 387	5级，2类	K41545	—	515/310	板材	5Cr-0.5Mo
5B	2	ASTM	A 335	P91	K91560	—	585/415	无缝管	9Cr-1Mo-V
5B	2	ASTM	A 387	91级，2类	S50460	—	585/415	板材	9Cr-1Mo-V
5C	1	ASTM	A 832	21V 级	K31830	—	585/415	板材	3Cr-1Mo-0.25V
5C	3	ASTM	A 542	A 型，3类	K21590	—	655/515	板材	2.25Cr-1Mo
5C	4	ASTM	A 542	A 型，1类	K21590	—	725/585	板材	2.25Cr-1Mo
5C	5	ASTM	A 542	A 型，2类	K21590	—	795/690	板材	2.25Cr-1Mo
6	1	ASTM	A 240	410型	S41000	—	450/205	板材	13Cr
6	2	ASTM	A 240	429型	S42900	—	450/205	板材	15Cr
6	4	ASTM	A 240	S41500	S41500	—	795/620	板材	13Cr-4.5Ni-Mo
7	1	ASTM	A 240	405型	S40500	—	415/170	板材	12Cr-1Al
7	1	ASTM	A 240	409型	S40900	—	380/170	板材	11Cr-Ti
7	1	ASTM	A 240	410S 型	S41008	—	415/205	板材	13Cr
7	2	ASTM	A 240	18-2型	S44400	—	415/275	板材	18Cr-2Mo
7	2	ASTM	A 240	430型	S43000	—	450/205	板材	17Cr
8	1	ASTM	A 312	TP304	S30400	—	515/205	无缝管与焊接管	18Cr-8Ni
8	1	ASTM	A 312	TP304L	S30403	—	485/170	无缝管与焊接管	18Cr-8Ni
8	1	ASTM	A 312	TP316	S31600	—	515/205	无缝管与焊接管	16Cr-12Ni-2Mo
8	1	ASTM	A 312	TP316L	S31603	—	485/170	无缝管与焊接管	16Cr-12Ni-2Mo
8	2	ASTM	A 240	S30815	S30815	<5	600/310	板材、薄板和条带	21Cr-11Ni-N
8	3	ASTM	A 312	TP-11	S21904	—	620/345	无缝管与焊接管	21Cr-6Ni-9Mn
8	3	ASTM	A 312	TPXM-19	S20910	—	690/380	无缝管与焊接管	22Cr-13Ni-5Mn
8	4	ASTM	A 312	S31254	S31254	—	650/305	无缝管与焊接管	20Cr-18Ni-6Mo
8	4	ASTM	A 312	317LM	S31725	—	515/205	无缝管与焊接管	19Cr-15Ni-4Mo

附录

9A	1	ASTM	A 203	A 级	K21703	—	450/255	板材	2.5Ni
9A	1	ASTM	A 203	B 级	K22103	—	485/275	板材	2.5Ni
9A	1	ASTM	A 333	7级	K21903	—	450/240	管道	2.5Ni
9A	1	ASTM	A 333	9级	K22035	—	435/315	管道	2Ni-1Cu
9B	1	ASTM	A 203	D 级	K31718	—	450/255	板材	3.5Ni
9B	1	ASTM	A 203	E 级	K32018	—	485/275	板材	3.5Ni
9B	1	ASTM	A 333	3级	K31918	—	450/240	管道	3.5Ni
10A	1	ASTM	A 225	C 级	K12524	—	725/485	板材	Mn-0.5Ni-V
10A	1	ASTM	A 225	D 级	—	≤75	550/415	板材	Mn-0.5Ni-V
10A	1	ASTM	A 225	D 级	—	>75≤150	515/380	板材	Mn-0.5Ni-V
10C	1	ASTM	A 612	—	K02900	≤13	570/345	板材	C-Mn-Si
10C	1	ASTM	A 612	—	K02900	>13	560/345	板材	C-Mn-Si
11A	1	ASTM	A 353	—	K81340	—	690/515	板材	9Ni
11A	1	ASTM	A 420	WPL8级	K81340	—	690/515	管道	9Ni
11A	2	ASTM	A 645	—	K41583	—	655/450	板材	0.5Ni-0.25Mo
11A	4	ASTM	A 533	A 级，3类	K12521	—	690/570	板材	Mn-0.5Mo
11A	4	ASTM	A 533	B 级，3类	K12539	—	690/570	板材	Mn-0.5Mo-0.5Ni
11A	5	ASTM	A 543	B 型，1类	K42339	—	725/585	板材	3Ni-1.75Cr-0.5Mo
11A	5	ASTM	A 543	B 型，3类	K42339	—	620/485	板材	3Ni-1.75Cr-0.5Mo
11B	1	ASTM	A 514	A 级	K11856	≤65	760/690	板材	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	A 级	K11856	>65≤300	760/620	板材	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	A 级	K11856	≤65	795/690	板材	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	A 级	K11856	>65≤300	725/620	板材	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 709	100级，A 型	K11856	≤65	760/690	板材与型材	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 709	100W 级，A 型	K11856	≤55	760/690	板材与型材	0.5Cr-0.25Mo-Si
11B	2	ASTM	A 514	E 级	K21604	≤65	760/690	板材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 514	E 级	K21604	>65≤300	760/620	板材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 517	E 级	K21604	≤65	795/690	板材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 517	E 级	K21604	>65≤300	725/620	板材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	100级，E 型	K21604	≤65	760/690	板材与型材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	100级，E 型	K21604	>65≤200	690/620	板材与型材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	100W 级，E 型	K21604	≤65	760/690	板材与型材	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	100W 级，E 型	K21604	>65≤200	690/620	板材与型材	1.75Cr-0.5Mo-Cu

附录 IV（规范性）
横向面弯与根部弯曲试样制备要求



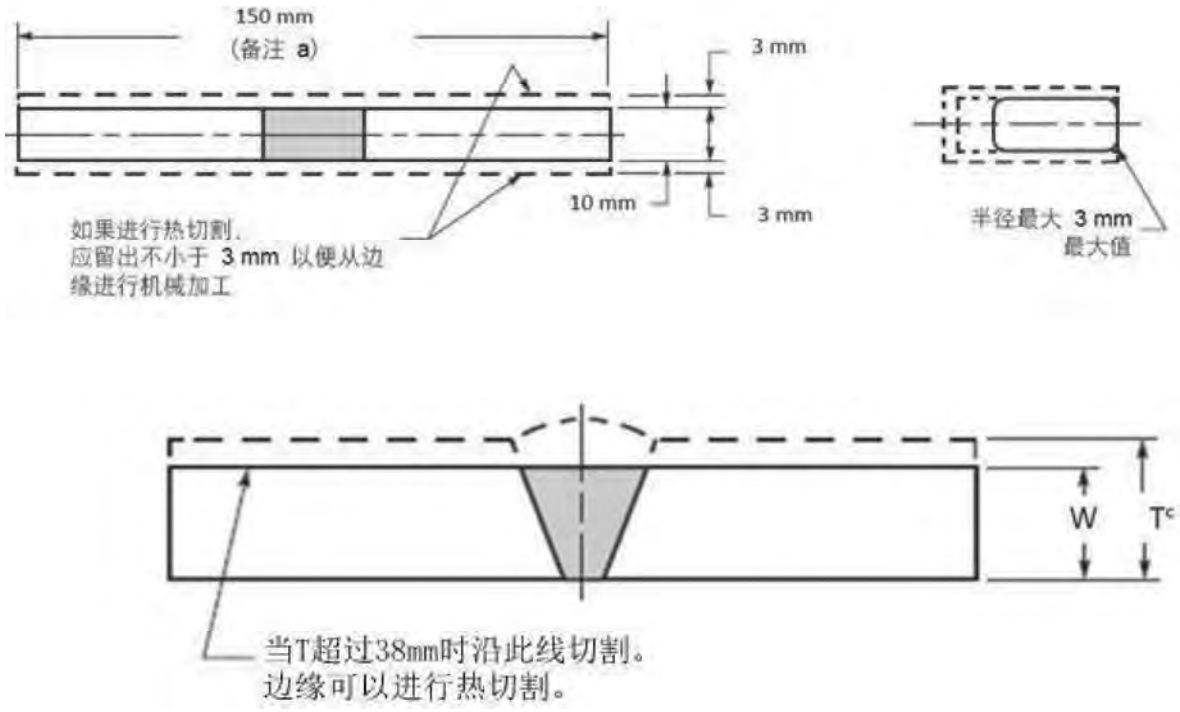
横向弯曲试样	
尺寸	
试验焊件	试样宽度，W
板材	38 mm
试验管子 <100 mm 直径 DN	备注 d
>100 mm 直径 DN	38 mm

(a) 使用包覆型弯曲夹具或测试屈服强度为620 MPa 或以上的钢时，可能需要使用更长的试样。
(b) 热切割边缘必须通过打磨来处理，M-1材料除外。
(c) 焊缝余高和背衬（如有）必须与试样表面平齐。如果使用了凹入式背衬，可将此表面加工至深度不超过要清除背衬的凹槽深度；在此种情况下，完工试样的厚度必须符合上述规定。切割的表面必须光滑且平行
(d) 对于直径为50 mm 至100 mm DN 的管子，弯曲试样的宽度不得小于19 mm。对于直径为10 mm 至50 mm DN 的管子，弯曲试样的宽度不得小于10 mm，并且可以替代性地将管子切割成四分之一部分（允许用于直径25mmDN及以下管子），在这种情况下可以清除焊缝余高，且无需对试样进行其他制备。

备注：
1. T = 板材或管子的厚度。
2. 试验板材的厚度小于10 mm 时，面弯和根部弯曲必须使用公称厚度。
3. 试样打磨方向应当平行于弯曲方向。

横向面弯与根部弯曲试样

附录 IV（规范性）
侧面弯曲试样制备要求



T	W
10至38 mm	T (mm)
>38 mm	（备注 b）

a) 使用包覆型弯曲夹具或测试屈服强度为620 MPa 或以上的钢时，可能需要使用更长的试样。
b) 对于厚度超过38 mm 的板材，必须将试样切割成大致等长的条带且 W 应介于19 mm 和38 mm 之间，并且必须对每个条带进行试验。
c) T = 板材或管道公称厚度。
备注：
1. 试样打磨方向应当平行于弯曲方向。
2. 热切割边缘必须通过打磨来处理，M-1材料除外。

侧面弯曲试样

附录 V（参考性）
实用的公式、转换、缩写和信息

本附录的目的，是为参加 AWS 考试的测试人员专门提供有关本规程手册中使用的缩写、概念和术语的一些指示。本规程手册涵盖多个行业，这些行业可能会针对相同的概念使用不同的术语。本附录解释了 AWS 考试中提出的这些差异。

缩写	说明
AI	缺陷累计
BT	焊穿
C	裂纹
CJP	接头完全焊透
CP	簇状气孔
CSA	横截面积
CVN	夏比 V 形缺口试验
EU	邻近盖面焊道处的咬边
ET	电磁检测
ID	内径
IF	未熔合
INCL	包括在内
IP	没有高低错边的焊透不足
IPD	由于高低错边导致焊透不足
m	米
mmpm	毫米/分钟
mpm	米/分钟
IU	邻近根部焊道处的咬边
J	焦耳
J/mm	焦耳/毫米
ℓ	升
LT	泄漏试验
LPH	升/小时
MT	磁粉检测
NDE	无损检查
NDT	无损检测
DN	公称直径
OD	外径
P	气孔
PJP	接头部分焊透
PQR	工艺评定报告
PT	渗透试验
PWHT	焊后热处理
RT	X 射线检验
TYP	典型
UNS	统一编号系统
UT	超声试验
UTS	极限拉伸强度
VT	目视检测
W	弯曲试样的宽度
WPS	焊接工艺规程
WQTR	焊工评定试验报告

概念	说明
AWS C4.1-77	有关氧燃料切割表面的比较测量，请参考书面标准和物理检验尺
样本1	AWS C4.1-77检验尺上的第一个粗糙度样本；最粗糙的切割
样本2	AWS C4.1-77检验尺上的第二个粗糙度样本
样本3	AWS C4.1-77检验尺上的第三个粗糙度样本
样本4	AWS C4.1-77检验尺上的第四个粗糙度样本；最光滑的切割

许多应用中采用国际单位制 (SI)。下表中所示为美制单位换算为 SI 单位时使用的转换系数以及单位倍增因数的度量 (SI) 前缀。

表16 - SI 转换系数

属性	从 SI 单位	转换为美制单位	倍增因数
力	牛顿 (N)	磅力 (lbf)	0.2248
	牛顿 (N)	千磅 (1000 lbf)	0.0002248
线性尺寸	毫米 (mm)	英寸 (in)	0.0394
拉伸强度	帕 (Pa)	磅/平方英寸 (psi)	0.000145
	千帕 (kPa)	磅/平方英寸 (psi)	0.145
	兆帕 (MPa)	磅/平方英寸 (psi)	145.14
质量	千克 (kg)	磅质量	2.205
角度，平面	弧度	度	57.296
流速	升/分钟 (l/min)	立方英尺/小时 (cfh)	2.119
热输入	焦耳/米 (J/m)	焦耳/英寸 (J/in)	0.0254
运行速度，焊丝	毫米/秒 (mm/s)	英寸/分钟 (in/min)	2.364
温度	摄氏度 (°C)	华氏度 (°F)	使用公式： °F = (°C x 1.8) + 32

表17 - SI 前缀

指数表示	倍增因数	前缀	符号
10^{9}	1000000000	千兆	G
10^{6}	1000000	兆	M
10^{3}	1000	千	k
10^{-3}	0.001	毫	m
10^{-6}	0.000001	微	**μ**
10^{-9}	0.000000001	纳	n

附录

矩形拉伸棒的横截面积 (CSA)：

CSA = w x t / CSA = w x t

其中 w = 宽度，t = 厚度

圆形拉伸棒的横截面积 (CSA)：

CSA = $\pi d^2/4$ / CSA = $\pi d^2/4$

其中 π = 数学常数3.1416，
d = 棒的初始直径

极限拉伸强度 (UTS) [Pa]：

UTS (MPa) = 最大力 (kN) / 初始横截面积 (mm^2) x 1000

帕 (Pa) 转换为兆帕 (MPa)（以及反过来）的公式：

MPa =Pa x 1,000,000 / Pa =M Pa / 1,000,000

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附录 VI（参考性）
- 管子序列表

管子尺寸 *(mm)*	外径 OD *(mm)*	标识			公称壁厚 - T - *(mm)*	最小壁厚 (mm) -12.5%	内径 - ID - *(mm)*
		钢		不锈钢管序列号			
		铁管尺寸	管子序列号				
65	73.0	-	-	5S	2.11	1.85	68.78
		-	-	10S	3.05	2.67	66.90
		STD	40	40S	5.16	4.52	62.68
		XS	80	80S	7.01	6.13	58.98
		-	160	-	9.53	8.34	53.94
		XXS	-	-	14.02	12.27	44.96
80	88.9	-	-	5S	2.11	1.85	84.68
		-	-	10S	3.05	2.67	82.80
		STD	40	40S	5.49	4.80	77.92
		XS	80	80S	7.62	6.67	73.66
		-	160	-	11.13	9.74	66.64
		XXS	-	-	15.24	13.34	58.42
90	101.6	-	-	5S	2.11	1.85	97.38
		-	-	10S	3.05	2.67	95.50
		STD	40	40S	5.74	5.02	90.12
		XS	80	80S	8.08	7.07	85.44
100	114.3	-	-	5S	2.11	1.85	110.08
		-	-	10S	3.05	2.67	108.20
		STD	40	40S	6.02	5.27	102.26
		XS	80	80S	8.56	7.49	97.18
		-	120	-	11.13	9.74	92.04
		-	160	-	13.49	11.80	87.32
		XXS	-	-	17.12	14.98	80.06
125	141.3	-	-	5S	2.77	2.42	135.76
		-	-	10S	3.40	2.98	134.50
		STD	40	40S	6.55	5.73	128.20
		XS	80	80S	9.53	8.34	122.24
		-	120	-	12.70	11.11	115.90
		-	160	-	15.88	13.90	109.54
		XXS	-	-	19.05	16.67	103.20
150	168.3	-	-	5S	2.77	2.42	162.76
		-	-	10S	3.40	2.98	161.50
		STD	40	40S	7.11	6.22	154.08
		XS	80	80S	10.97	9.60	146.36
		-	120	-	14.27	12.49	139.76
		-	160	-	18.26	15.98	131.78
		XXS	-	-	21.95	19.21	124.40
200	219.1	-	-	5S	2.77	2.42	213.56
		-	-	10S	3.76	3.29	211.58
		-	20	-	6.35	5.56	206.40
		-	30	-	7.04	6.16	205.02
		STD	40	40S	8.18	7.16	202.74
		-	60	-	10.31	9.02	198.48
		XS	80	80S	12.70	11.11	193.70
		-	100	-	15.09	13.20	188.92
		-	120	-	18.26	15.98	182.58
		-	140	-	20.62	18.04	177.86
		XXS	-	-	22.23	19.45	174.64

附录 VII（参考性）
焊接工艺规程 (WPS)

WPS 编号 [1]	日期 [2]	修订 [3]	第1页，共2页
所依据的 PQR ID			
[4]			
范围			
[5]			
焊接方法与类型			
方法： [6]			
接头设计			
接头设计 [7]			
根部间距： [8]			
背衬材料： [9]			
背面处理、刨槽/制备方法： [10]			
最大错边： [11]			
典型接头细节： [12]			
[13]			
母材金属			
M 编号 [14] **组编号** [15] **至 M 编号** [16] **组编号** [17]			
评定的厚度范围： [18]			
直径（仅管状）： [19]			
涂层说明或类型： [20]			
填充金属			
方法： [21]			
AWS 规格号： [22]			
AWS 编号（分类）： [23]			
F 编号 [24]			
焊缝金属分析 A 编号： [25]			
焊缝金属熔敷厚度： [26]			
填充金属尺寸： [27]			
焊剂-电极分类： [28]			
附加填充金属： [29]			
可熔性嵌条与类型： [30]			
可熔性嵌条： [31]			
附加脱氧剂： [32]			
通电的填充金属“热丝” [33]			

WPS 编号 [1]	日期 [2]	修订 [3]	**第2页，共2页**

位置	
焊接位置：	[34]
立焊方向：	[35]

预热与道间温度	
最低预热温度：	[36]
最高道间温度：	[37]
预热保持时间：	[38]

热处理	
PWHT 类型：	[39]
PWHT 温度：	40
PWHT 保持时间：	[41]
加热和冷却速度：	[42]

保护气	**类型和成分 %**（如适用）	**流速范围**
焊炬保护气：	[43]	[48]
根部保护气：	[44]	[49]
环境防护：	[45]	
真空压力：	[46]	
气杯尺寸：	[47]	

电气				
方法：	[50]			
填充金属直径：	[51]			
电流类型和极性：	[52]			
安培数范围：	[53]			
过渡模式：	[54]			
送丝速度 (m/min)	[55]			
电压范围：	[56]			
钨极规格号：	[57]			
钨极分类：	[58]			
钨电极直径：	[59]			
最大热输入 (kJ/mm)：	[60]			
脉冲电流：	[61]			

变素	
单电极到多电极：	[62]
电极间距 (mm)：	[63]
单道焊或多道焊：	[64]
导电管到工件的距离 (mm)：	[65]
清洁：	[66]
锤击：	[67]
传统或小孔技术：	[68]
直焊道或摆动焊道：	[69]
运行速度范围 (mm/min)：	[70]

附录 VIII（参考性）工艺评定报告 (PQR)

焊接方法与类型	
方法1：	[1]
方法2：	[2]

母材金属					
母材规格：	[3]		至	[4]	
M 编号：	[5]	组编号：		至 M 编号：	组编号：
板材或管子：	[6]		管子直径：	[7]	
厚度：	[8]				
涂层：	[9]				

填充金属		
规格号：	[10]	
AWS 编号分类：	[11]	
F 编号：	[12]	
焊缝金属分析 A 编号：	[13]	
填充金属尺寸：	[14]	
附加填充物：	[15]	
焊缝金属熔敷厚度：	[16]	

位置	
接头位置：	[17]
立焊方向：	[18]

预热	
最低预热温度：	[19]
最高层间温度：	[20]

电气		
电流与极性：	[21]	
安培数范围：	[22]	
脉冲电流：	[23]	
送丝速度 (m/min)	[24]	
电压范围：	[25]	
运行速度 (mm/min)	[26]	
过渡模式：	[27]	
最大热输入 (kJ/mm)	[28]	
钨极类型：	[29]	
钨极直径：	[30]	

接头	
焊缝类型：	[31]
坡口类型：	[32]
根部间距：	[33]
金属背衬：	[34]
热清根：	[35]
	[36]
	接头草图：

焊后热处理	
PWHT 类型：	[37]
PWHT 温度：	[38]
PWHT 时间：	[39]

气体	
保护气：	[40]
成分：	[41]
流量：	[42]
气杯尺寸：	[43]

技术	
直焊道或摆动焊道：	[44]
清理方法：	[45]
机械摆动：	[46]
导电管到工件的距离：	[47]
每一边的多道焊或单道焊：	[48]
电极数：	[49]
电极间距：	[50]
锤击：	[51]

目检：[52]

拉伸试验

试样编号	宽度 mm	厚度 mm	面积 mm²	极限总载荷(kN)	极限单位面积应力(MPa)	断裂类型与位置
[53]	[54]	[55]	[56]	[57]	[58]	[59]

导向弯曲试验

类型	结果	类型	结果
[60]	[61]	[62]	[63]

焊工姓名 [64] 钢印或时间编号 [65]

兹证明本报告所述正确无误，且试验焊缝的制备、焊接和试验符合《B 部分实际操作 CWI 考试要求》的要求。本报告仅用于 CWI B 部分考试，如未取得 AWS 的书面同意，不得用于实际生产焊接或任何其他用途。

附录 IX（参考性）
焊工评定试验报告 (WQTR)

焊工姓名 [1] **ID 编号** [2] **符号** [3]

采用的 WPS 的标识： [4]

焊接的母材金属规格： [5] **厚度：** [6]

试验变素与评定限制

焊接变素			实际数值	评定范围
焊接方法			[13]	[31]
类型（例如手工、半自动）			[14]	[32]
背衬（金属、焊缝金属）	方法1：	[7]	[15]	[33]
	方法2：	[8]	[16]	[34]
□板材□管子（如果是圆管或管子，则输入直径）			[17]	[35]
母材金属 M 编号至 M 编号焊接			[18]	[36]
AWS 填充金属或电极规格			[19]	
填充金属或电极分类			[20]	
填充金属 F 编号	方法1：	[9]	[21]	[37]
	方法2：	[10]	[22]	[38]
可熔性嵌条 (GTAW)			[23]	[39]
每种焊接方法的焊缝熔敷厚度：				
	方法1：	[11]	[24]	[40]
	方法2：	[12]	[25]	[41]
评定位置（2G、6G 等）			[26]	[42]
立焊方向（上坡焊或下坡焊）			[27]	[43]
惰性气体背衬（GTAW 或 GMAW）			[28]	[44]
过渡方式（喷射/熔滴或脉冲至短路-GMAW）			[29]	[45]
GTAW 焊接电流类型/极性（AC、DCEP、DCEN）			[30]	[46]

结果

完工焊缝目检： [47]

导向弯曲试验类型： **□横向侧面** **□横向根部与表面**

试样编号	结果	试样编号	结果
[48]	[49]	[50]	[51]

替代性的射线检测结果 [52]

角焊缝 - 断裂试验 [53] 缺陷的长度与百分比 [54] mm

宏观检查 [55] 角焊缝尺寸 (mm) [56] x [57] 凹度/凸度 (mm) [58]

其他试验 [59]

底片或试样评定人 [60] 公司 [61]

机械试验执行人 [62] 实验室试验编号 [63]

焊接监督人 [64]

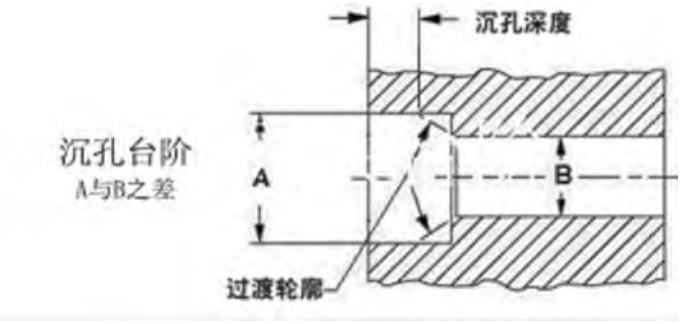
兹证明本报告所述正确无误，且试件的制备、焊接和试验符合《CWI B 部分实际操作规程手册》的要求。本报告仅用于 CWI B 部分实际操作考试，如未取得 AWS 的书面同意，不得用于实际生产焊接或任何其他用途。

机构 [65]

编制 [66] 日期 [67]

附录 X（参考性）
行业特定的非标准术语和定义

电弧烧穿。在管线应用中通常使用的术语为“电弧击伤”。
分段退焊。焊道所采用的纵向顺序与焊接方向相反。
背面补焊。在管线应用中，补焊在坡口焊缝背面进行。
公司。出于本门考试的目的，公司是指对按照此规程制造的焊件的法定所有权和公共安全负责的虚构实体。
沉孔。非圆形管子内径上的一项机械加工特征，用于确保内径进行适当的焊接对准。另请参见**沉孔深度**。
沉孔台阶面。机械加工的沉孔与未经机械加工的管道内径之间的过渡区。另请参见**沉孔**和**沉孔深度**。
沉孔深度。沉孔轴向延伸到管道中的距离。另请参见**沉孔**和**沉孔台阶面。**



沉孔

焊冠表面。在管线应用中是“焊缝表面”的替代性术语。
双重修补。在管线应用中，对完工焊缝先前修补过的区域进行二次修补；通常称作“修补修补过的区域”或“再次修补”。
高低错边。在管线应用中通常使用的术语为“内部未对准”。
缺陷。质量特征偏离于目标条件。
显示。运用无损检查得出的反应或证据。
内部未对准。接头工件未对准，例如多个具有不同内径的管道的内径未对准。*（又称“焊接头错边”和“高低错边偏差”。）*
公称尺寸。用于标识目的的“名义上”的尺寸。公称尺寸可能不对应于实际测量的尺寸，而是用于标识标准化公差范围内的尺寸范围。
母材金属表面。在管线应用中通常使用的术语为“母材金属”。
主要工件。用于传送主要拉伸应力的结构元件，此工件发生故障将导致灾难性的后果。
修补。在管线应用中，对完工焊缝进行打磨或焊接，以纠正目检或无损测试后被拒收的焊缝中的个别缺陷或累积的缺陷。
返工。对于管线应用，在焊接过程中或焊缝完工后，消除需要打磨和/或焊接的缺陷，之后再对完工焊缝进行目检或无损测试。备注：返工不是修补。
回火焊道。位于特定位置或焊缝表面的焊道，用于影响热影响区或以前熔敷的焊缝金属的冶金特性。
焊冠。在管线应用中是“焊缝余高”的替代性术语。

完

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Annex X (Informative)
Industry-Specific Non-Standard Terms and Definitions

arc burn. Preferred term for 'arc strike' in pipeline applications.

backstep sequence. A longitudinal sequence in which weld passes are made in the direction opposite to the progress of welding.

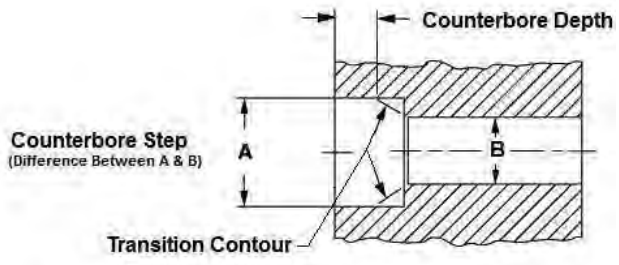
back weld repair. For pipeline applications, a repair weld made at the back side of a groove weld.

Company. For the purpose of this examination, the Company is the fictitious entity responsible for legal ownership and public safety of weldments fabricated in accordance with this specification.

counterbore. A machined feature on out-of-round pipe inside diameters to make sure inside diameters are in proper alignment for welding. See also **counterbore depth.**

counterbore step. The transition area between the machined counterbore and the unmachined pipe inside diameter. See also **counterbore** and **counterbore depth.**

counterbore depth. The distance a counterbore extends axially into a pipe. See also **counterbore** and **counterbore step.**



Counterbore

crown surface. Alternate term for Weld Face in the pipeline applications.

double repair. For Pipeline applications, second repair in a previously repaired area of a completed weld; typically referred to as a "repair of a repair" or a "re-repair."

high-low. Preferred term for 'internal misalignment' in pipeline applications.

imperfection. A departure of a quality characteristic from its intended condition.

indication. The response or evidence from the application of a nondestructive examination.

internal misalignment. Misalignment of joint members such as the inside diameter of misaligned pipes or pipes with different inside diameters. *(Also called weld joint mismatch and high-low offset.)*

nominal size. A size "in name only" used for identification purposes. The nominal size may not correspond to an actual measured size, but would represent a range of sizes falling within standardized tolerances.

parent metal surface. Preferred term for 'base metal' in pipeline applications.

primary member. A structural element which transmits the primary tensile stress and whose sole failure would be catastrophic.

repair. For Pipeline applications, any grinding or welding on a completed weld to correct an individual defect or accumulation of defects in the weld that has been rejected by visual or nondestructive testing.

rework. For Pipeline applications, during welding or after the weld has been completed, the removal of an imperfection that requires grinding and/or welding that is performed prior to visual or nondestructive testing of a completed weld. Note: rework is not a repair.

temper bead. A weld bead placed at a specific location in or at the surface of a weld for the purpose of affecting the metallurgical properties of the heat-affected zone or previously deposited weld metal.

weld crown. Alternate term in pipeline applications for weld reinforcement.

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Annex IX (Informative)
Welder Qualification Test Record (WQTR)

Welder's Name [1] **ID No.** [2] **Symbol** [3]

Identification of WPS followed: [4]

Specification of base metal(s) welded: [5] **Thickness:** [6]

Testing Variables and Qualification Limits

Welding Variables			Actual Values	Range Qualified
Welding Process(es)			[13]	[31]
Type (i.e.; manual, semi-automatic)			[14]	[32]
Backing (metal, weld metal)	Process 1:	[7]	[15]	[33]
	Process 2:	[8]	[16]	[34]
☐ Plate ☐ Pipe (enter diameter if pipe or tube)			[17]	[35]
Base Metal M-Number to M-Number			[18]	[36]
AWS Filler metal or Electrode Specification(s)			[19]	
Filler metal or electrode classification(s)			[20]	
Filler metal F-Numbers	Process 1:	[9]	[21]	[37]
	Process 2:	[10]	[22]	[38]
Consumable Insert for GTAW			[23]	[39]
Weld deposit thickness for each welding process:				
	Process 1:	[11]	[24]	[40]
	Process 2:	[12]	[25]	[41]
Position Qualified (2G, 6G, etc.)			[26]	[42]
Vertical progression (Uphill or Downhill)			[27]	[43]
Inert gas backing for GTAW or GMAW			[28]	[44]
Transfer Mode (spray/globular or pulse to short circuit-GMAW)			[29]	[45]
GTAW welding current type/polarity (AC, DCEP, DCEN)			[30]	[46]

Results

Visual Examination of Completed Weld : [47]

Guided Bend Test Type: ☐ **Transverse Side** ☐ **Transverse Root & Face**

Specimen No.	Results	Specimen No.	Results
[48]	[49]	[50]	[51]

Alternative radiographic examination results [52]

Fillet Weld – fracture test [53] Length and percent of defects [54] mm

Macro Examination [55] Fillet size (mm) [56] x [57] Concavity/convexity (mm) [58]

Other tests [59]

Film or specimens evaluated by [60] Company [61]

Mechanical tests conducted by [62] Laboratory test no. [63]

Welding supervised by [64]

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of CWI Part B Practical Book of Specifications. It is to be used for the CWI Part B Practical Exam only and is not intended to be used for actual production welding or any other use without the written consent of AWS.

Organization [65]

By [66] Date [67]

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Annex VIII (Informative)
Procedure Qualification Record (PQR)

WELDING PROCESS & Type	
Process 1:	[1]
Process 2:	[2]

BASE METALS					
Base Material Spec.:	[3]		to	[4]	
M-No.:	[5]	Group No.:		to M-No.:	Group No.:
Plate or Pipe:	[6]		Pipe Diameter:	[7]	
Thickness:	[8]				
Coating:	[9]				

FILLER METALS		
Specification No.:	[10]	
AWS No. Classification:	[11]	
F-No.:	[12]	
Weld Metal Analysis A-No.:	[13]	
Filler Metal Size:	[14]	
Supplemental Filler:	[15]	
Weld Metal Deposit Thickness:	[16]	

POSITION	
Position of Joint:	[17]
Vertical Welding Progression:	[18]

PREHEAT	
Min. Preheat Temperature:	[19]
Max. Interpass Temperature:	[20]

ELECTRICAL		
Current & Polarity:	[21]	
Amperage Range:	[22]	
Pulsed Current:	[23]	
Wire Feed Speed (m/min)	[24]	
Voltage Range:	[25]	
Travel Speed (mm/min)	[26]	
Transfer Mode:	[27]	
Maximum Heat Input (kJ/mm)	[28]	
Tungsten Type:	[29]	
Tungsten Diameter:	[30]	

JOINTS	
Weld Type:	[31]
Groove Type:	[32]
Root Spacing:	[33]
Metal Backing:	[34]
Thermal Backgouging:	[35]
	[36]
Sketch of Joint	

POSTWELD HEAT TREATMENT	
PWHT Type:	[37]
PWHT Temperature:	[38]
PWHT Time:	[39]

GAS	
Shielding Gas:	[40]
Composition:	[41]
Flow:	[42]
Gas Cup Size:	[43]

TECHNIQUE	
Stringer or Weave:	[44]
Method of Cleaning:	[45]
Oscillation:	[46]
Contact Tube to Work Distance:	[47]
Multipass or Single pass per side:	[48]
Number of Electrodes:	[49]
Electrode Spacing:	[50]
Peening:	[51]

VISUAL EXAMINATION: [52]

TENSILE TESTS

Specimen No.	Width mm	Thickness mm	Area mm^2	Ultimate Total Load (kN)	Ultimate Unit Stress (MPa)	Type of Failure & Location
[53]	[54]	[55]	[56]	[57]	[58]	[59]

GUIDED-BEND TESTS

Type	Results	Type	Results
[60]	[61]	[62]	[63]

Welder's Name [64] Stamp or Clock No. [65]

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 the Part B Practical CWI Exam Requirements. It is intended to be used for the CWI Part B Exam only and is not intended to be used for actual production welding or any other use without the written consent of AWS.

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WPS Number [1]	Date [2]	Revision [3]	Page 2 of 2

POSITION	
Welding Positions:	[34]
Progression for Vertical Welding:	[35]

PREHEAT AND INTERPASS	
Preheat Minimum:	[36]
Interpass Temperature Maximum:	[37]
Preheat Maintenance:	[38]

HEAT TREATMENT	
PWHT Type:	[39]
PWHT Temperature:	[40]
PWHT Holding Time:	[41]
Heating and Cooling Rate:	[42]

SHIELDING GAS	**Type and % Composition** (if applicable)	**Flow Rate Range**
Torch Shielding Gas:	[43]	[48]
Root Shielding Gas:	[44]	[49]
Environmental Shielding:	[45]	
Vacuum Pressure:	[46]	
Gas Cup Size:	[47]	

ELECTRICAL				
Process:	[50]			
Filler Metal Diameter:	[51]			
Current Type and Polarity:	[52]			
Amperage Range:	[53]			
Transfer Mode:	[54]			
Wire Feed Speed (m/min)	[55]			
Voltage Range:	[56]			
Tungsten Specification No.:	[57]			
Tungsten Classification:	[58]			
Tungsten Electrode Diameter:	[59]			
Maximum Heat Input (kJ/mm):	[60]			
Pulsed Current:	[61]			

VARIABLES	
Single to Multiple Electrodes:	[62]
Electrode Spacing (mm):	[63]
Single or Multipass:	[64]
Contact Tube to Work Distance (mm):	[65]
Cleaning:	[66]
Peening:	[67]
Conventional or Keyhole Technique:	[68]
Stringer or Weave Bead:	[69]
Travel-Speed Range (mm/min):	[70]

Annex VII (Informative)
Welding Procedure Specification (WPS)

WPS Number [1]	Date [2]	Revision [3]	Page 1 of 2

SUPPORTING PQR (s) ID.
[4]

SCOPE
[5]

WELDING PROCESS(ES) & TYPE	
Process(es):	[6]

JOINT DESIGN	
Joint Design:	[7]
Root Spacing:	[8]
Backing Material:	[9]
Treatment of backside, method of gouging/preparation:	[10]
Maximum Mismatch:	[11]
Typical Joint Details:	[12]
	[13]

BASE METALS					
M-No.	[14]	**Group No.** [15]	**To M-No.**	[16]	**Group No.** [17]
_____		_____	_____		_____
Thickness Range Qualified: [18]					
Diameter (Tubular Only):	[19]				
Coating Description or Type:	[20]				

FILLER METALS			
Process:	[21]		
AWS Specification No.:	[22]		
AWS No. (Classification):	[23]		
F-No.	[24]		
Weld Metal Analysis A-No.:	[25]		
Weld Metal Deposit Thickness:	[26]		
Filler Metal Size:	[27]		
Flux-Electrode Classification:	[28]		
Supplemental Filler Metal:	[29]		
Consumable Insert & Type:	[30]		
Consumable Insert:	[31]		
Supplemental Deoxidant:	[32]		
Energized Filler Metal “Hot”	[33]		

Annex VI (Informative)
Pipe Schedules

Pipe Size *(mm)*	Outside Diameter OD *(mm)*	Identification			Nominal Wall Thickness - T - *(mm)*	Minimum Wall Thickness (mm) -12.5%	Inside Diameter - ID - *(mm)*
		Steel		Stainless Steel Schedule No.			
		Iron Pipe Size	Schedule No.				
65	73.0	-	-	5S	2.11	1.85	68.78
		-	-	10S	3.05	2.67	66.90
		STD	40	40S	5.16	4.52	62068
		XS	80	80S	7.01	6.13	58.98
		-	160	-	9.53	8.34	53.94
		XXS	-	-	14.02	12.27	44.96
80	88.9	-	-	5S	2.11	1.85	84.68
		-	-	10S	3.05	2.67	82.80
		STD	40	40S	5.49	4.80	77.92
		XS	80	80S	7.62	6.67	73.66
		-	160	-	11.13	9.74	66.64
		XXS	-	-	15.24	13.34	58.42
90	101.6	-	-	5S	2.11	1.85	97.38
		-	-	10S	3.05	2.67	95.50
		STD	40	40S	5.74	5.02	90.12
		XS	80	80S	8.08	7.07	85.44
100	114.3	-	-	5S	2.11	1.85	110.08
		-	-	10S	3.05	2.67	108.20
		STD	40	40S	6.02	5.27	102.26
		XS	80	80S	8.56	7.49	97.18
		-	120	-	11.13	9.74	92.04
		-	160	-	13.49	11.80	87.32
		XXS	-	-	17.12	14.98	80.06
125	141.3	-	-	5S	2.77	2.42	135.76
		-	-	10S	3.40	2.98	134.50
		STD	40	40S	6.55	5.73	128.20
		XS	80	80S	9.53	8.34	122.24
		-	120	-	12.70	11.11	115.90
		-	160	-	15.88	13.90	109.54
		XXS	-	-	19.05	16.67	103.20
150	168.3	-	-	5S	2.77	2.42	162.76
		-	-	10S	3.40	2.98	161.50
		STD	40	40S	7.11	6.22	154.08
		XS	80	80S	10.97	9.60	146.36
		-	120	-	14.27	12.49	139.76
		-	160	-	18.26	15.98	131.78
		XXS	-	-	21.95	19.21	124.40
200	219.1	-	-	5S	2.77	2.42	213.56
		-	-	10S	3.76	3.29	211.58
		-	20	-	6.35	5.56	206.40
		-	30	-	7.04	6.16	205.02
		STD	40	40S	8.18	7.16	202.74
		-	60	-	10.31	9.02	198.48
		XS	80	80S	12.70	11.11	193.70
		-	100	-	15.09	13.20	188.92
		-	120	-	18.26	15.98	182.58
		-	140	-	20.62	18.04	177.86
		XXS	-	-	22.23	19.45	174.64

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Cross Sectional Area (CSA) for rectangular tensile bars:

CSA = w x t

Where w = width and t = thickness

Cross Sectional Area (CSA) for round tensile bars:

CSA = $\pi d^2/4$

Where π = mathematical constant 3.1416 and
d = original diameter of the bar

Ultimate Tensile Strength (UTS) [Pa]:

UTS (in MPa) = Maximum Force (in kN) / original cross sectional area (in mm^2) x 1000

Formula to convert pascals (Pa) to Megapascal (MPa) and vice versa:

Pa = MPa x 1,000,000

MPa = Pa / 1,000,000

The International System of Units (SI) is used in many applications. Shown in the tables below are the conversion factors used to convert U. S. Customary units to SI units, and the metric (SI) prefixes for the multiplication factors of units.

Table 16 – SI Conversion Factors

Property	To Convert from SI Units	To U. S. Customary Units	Multiply by
Force	Newton (N)	pound-force (lbf)	0.2248
	Newton (N)	kip (1000 lbf)	0.0002248
Linear Dimension	millimeter (mm)	inch (in)	0.0394
Tensile Strength	Pascal (Pa)	pounds per square inch (psi)	0.000145
	kiloPascal (kPa)	pounds per square inch (psi)	0.145
	megaPascal (MPa)	pounds per square inch (psi)	145.14
Mass	kilogram (kg)	pound mass	2.205
Angle, plane	radian	degree	57.296
Flow Rate	liter per minute (l/min)	cubic feet per hour (cfh)	2.119
Heat Input	Joules per meter (J/m)	Joules per inch (J/in)	0.0254
Travel Speed, wire	millimeters per second (mm/s)	inches per minute (in/min)	2.364
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	use the formula: °F = (°C x 1.8) + 32

Table 17 – SI Prefixes

Exponential Expression	Multiplication Factor	Prefix	Symbol
10^{9}	1 000 000 000	giga	G
10^{6}	1 000 000	mega	M
10^{3}	1 000	kilo	k
10^{-3}	0.001	milli	m
10^{-6}	0.000 001	micro	μ
10^{-9}	0.000 000 001	nano	n

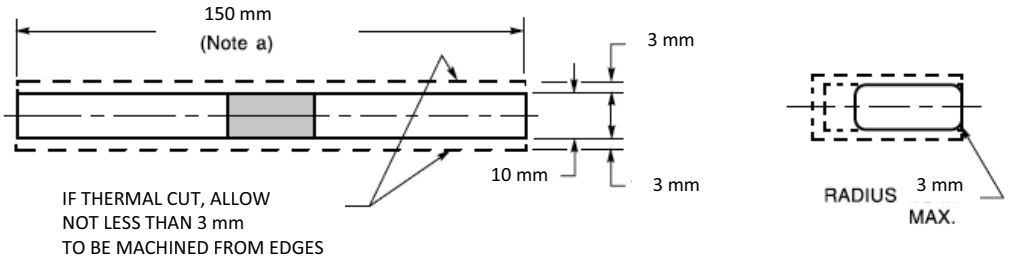
Annex V (Informative)
Useful Formulas, Conversions, Abbreviations and Information

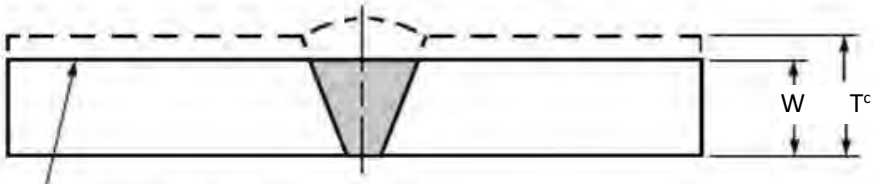
The purpose of this annex is to provide some direction to test takers regarding abbreviations, concepts, and terms used within this Book of Specifications solely for the purpose of taking an AWS examination. The scope of this Book of Specifications covers multiple industries which use different terms for the same concepts. This annex explains how these differences are addressed in this AWS exam.

Abbreviation	Description
AI	accumulation of imperfections
BT	burn-through
C	cracks
CJP	complete joint penetration
CP	cluster porosity
CSA	cross sectional area
CVN	Charpy V-notch testing
EU	undercut adjacent to the cover pass
ET	electromagnetic testing
ID	inside diameter
IF	incomplete fusion
INCL	inclusive
IP	inadequate penetration without high-low
IPD	inadequate penetration due to high-low
m	meter
mmpm	millimeters per minute
mpm	meters per minute
IU	undercut adjacent to the root pass
J	Joule
J/mm	Joules per millimeter
ℓ	liter
LT	leak testing
LPH	liters per hour
MT	magnetic particle testing
NDE	nondestructive examination
NDT	nondestructive testing
DN	diameter nominal
OD	outside diameter
P	porosity
PJP	partial joint penetration
PQR	procedure qualification record
PT	penetrant testing
PWHT	post weld heat treatment
RT	radiographic testing
TYP	typical
UNS	unified numbering system
UT	ultrasonic testing
UTS	ultimate tensile strength
VT	visual testing
W	width of bend specimen
WPS	welding procedure specification
WQTR	welder qualification test record

Concept	Description
AWS C4.1-77	refers to both the written standard and physical gauge for comparative measurement of oxyfuel cut surfaces
Sample 1	first roughness sample on the AWS C4.1-77 gauge; roughest cut
Sample 2	second roughness sample on the AWS C4.1-77 gauge
Sample 3	third roughness sample on the AWS C4.1-77 gauge
Sample 4	fourth roughness sample on the AWS C4.1-77 gauge; smoothest cut

Annex IV (Normative)
Side Bend Specimen Preparation Requirements





WHEN T EXCEEDS 38 mm CUT ALONG THIS LINE.
EDGE MAY BE THERMAL CUT.

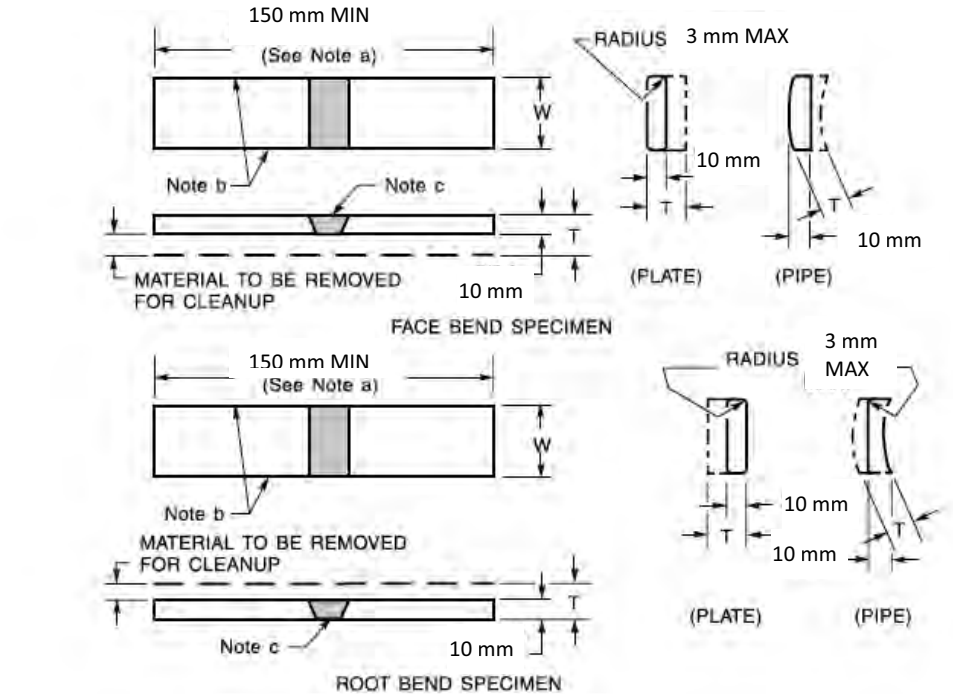
T	W
10 to 38 mm	T (mm)
> 38 mm	(Note b)

(a) A longer specimen length may be necessary when using a wraparound-type bending fixture or when testing steel with a yield strength of 620 MPa or more.
(b) For plates over 38 mm thick, the specimen shall be cut into approximately equal strips with W between 19 mm and 38 mm and each strip shall be tested.
(c) T = nominal plate or pipe thickness.

Note:
1. The specimen grinding direction should be parallel to the direction of bending.
2. Except on M-1 materials, thermal cut edges shall be dressed by grinding.

Side Bend Specimens

Annex IV (Normative)
Transverse Face and Root Bend Specimen Preparation Requirements



TRANSVERSE BEND SPECIMEN	
Dimensions	
Test Weldment	Test Specimen Width, W
Plate	38 mm
Test pipe or tube ≤ 100 mm diameter DN	Note d
> 100 mm diameter DN	38 mm

(a) A longer specimen length may be necessary when using a wraparound type bending fixture or when testing steel with a yield strength of 620 MPa or more.
(b) Except on M-1 materials, thermal cut edges shall be dressed by grinding.
(c) The weld reinforcement and backing, if any, shall be removed flush with the surface of the specimen. If a recessed backing is used, this surface may be machined to a depth not exceeding the depth of the recess to remove the backing; in such a case, the thickness of the finished specimen shall be that specified above. Cut surfaces shall be smooth and parallel
(d) For pipe diameters of 50 mm through 100 mm DN, the width of the bend specimen shall not be less than 19 mm. For pipe diameters of 10 mm to 50 mm DN, the bend specimen width shall not be less than be 10 mm with an alternative (permitted for pipe 25 mm DN and less) of cutting the pipe into quarter sections, in which case the weld reinforcement may be removed and no other preparation of the specimens is required.

Notes:
1. T = plate or pipe thickness.
2. When the thickness of the test plate is less than 10 mm, the nominal thickness shall be used for face and root bends.
3. The specimen grinding direction should be parallel to the direction of bending.

Transverse Face and Root Bend Specimens

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Annex III-B (Normative)
Base Metal Specifications & M-Number Tables

9A	1	ASTM	A 203	Grade A	K21703	—	450/255	Plate	2.5Ni
9A	1	ASTM	A 203	Grade B	K22103	—	485/275	Plate	2.5Ni
9A	1	ASTM	A 333	Grade 7	K21903	—	450/240	Pipe	2.5Ni
9A	1	ASTM	A 333	Grade 9	K22035	—	435/315	Pipe	2Ni-1Cu
9B	1	ASTM	A 203	Grade D	K31718	—	450/255	Plate	3.5Ni
9B	1	ASTM	A 203	Grade E	K32018	—	485/275	Plate	3.5Ni
9B	1	ASTM	A 333	Grade 3	K31918	—	450/240	Pipe	3.5Ni
10A	1	ASTM	A 225	Grade C	K12524	—	725/485	Plate	Mn-0.5Ni-V
10A	1	ASTM	A 225	Grade D	—	≤75	550/415	Plate	Mn-0.5Ni-V
10A	1	ASTM	A 225	Grade D	—	>75≤150	515/380	Plate	Mn-0.5Ni-V
10C	1	ASTM	A 612	—	K02900	≤13	570/345	Plate	C-Mn-Si
10C	1	ASTM	A 612	—	K02900	>13	560/345	Plate	C-Mn-Si
11A	1	ASTM	A 353	—	K81340	—	690/515	Plate	9Ni
11A	1	ASTM	A 420	Grade WPL8	K81340	—	690/515	Pipe	9Ni
11A	2	ASTM	A 645	—	K41583	—	655/450	Plate	0.5Ni-0.25Mo
11A	4	ASTM	A 533	Grade A, Class 3	K12521	—	690/570	Plate	Mn-0.5Mo
11A	4	ASTM	A 533	Grade B, Class 3	K12539	—	690/570	Plate	Mn-0.5Mo-0.5Ni
11A	5	ASTM	A 543	Type B, Class 1	K42339	—	725/585	Plate	3Ni-1.75Cr-0.5Mo
11A	5	ASTM	A 543	Type B, Class 3	K42339	—	620/485	Plate	3Ni-1.75Cr-0.5Mo
11B	1	ASTM	A 514	Grade A	K11856	≤65	760/690	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	Grade A	K11856	>65≤300	760/620	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	Grade A	K11856	≤65	795/690	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	Grade A	K11856	>65≤300	725/620	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 709	Grade 100, Type A	K11856	≤65	760/690	Plate & Shapes	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 709	Grade 100W, Type A	K11856	≤55	760/690	Plate & Shapes	0.5Cr-0.25Mo-Si
11B	2	ASTM	A 514	Grade E	K21604	≤65	760/690	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 514	Grade E	K21604	>65≤300	760/620	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 517	Grade E	K21604	≤65	795/690	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 517	Grade E	K21604	>65≤300	725/620	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100, Type E	K21604	≤65	760/690	Plate & Shapes	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100, Type E	K21604	>65≤200	690/620	Plate & Shapes	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100W, Type E	K21604	≤65	760/690	Plate & Shapes	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100W, Type E	K21604	>65≤200	690/620	Plate & Shapes	1.75Cr-0.5Mo-Cu

4	1	ASTM	A 202	Grade A	K11742	—	515/310	Plate	0.5Cr-1.25Mn-Si
4	1	ASTM	A 202	Grade B	K12542	—	585/325	Plate	0.5Cr-1.25Mn-Si
4	1	ASTM	A 335	Grade P11	K11597	—	415/205	Pipe	1.25Cr-0.5Mo-Si
4	1	ASTM	A 335	Grade P12	K11562	—	415/220	Pipe	1Cr-0.5Mo
4	2	ASTM	A 333	Grade 4	K11267	—	415/240	Pipe	0.75Cr-0.75Ni-Cu-Al
5A	1	ASTM	A 387	Grade 21, Class 1	K31545	—	415/205	Plate	3Cr-1Mo
5A	1	ASTM	A 387	Grade 21, Class 2	K31545	—	515/310	Plate	3Cr-1Mo
5B	1	ASTM	A 387	Grade 5, Class 1	K41545	—	415/205	Plate	5Cr-0.5Mo
5B	1	ASTM	A 387	Grade 5, Class 2	K41545	—	515/310	Plate	5Cr-0.5Mo
5B	2	ASTM	A 335	Grade P91	K91560	—	585/415	Seamless Pipe	9Cr-1Mo-V
5B	2	ASTM	A 387	Grade 91, Class 2	S50460	—	585/415	Plate	9Cr-1Mo-V
5C	1	ASTM	A 832	Grade 21V	K31830	—	585/415	Plate	3Cr-1Mo-0.25V
5C	3	ASTM	A 542	Type A, Class 3	K21590	—	655/515	Plate	2.25Cr-1Mo
5C	4	ASTM	A 542	Type A, Class 1	K21590	—	725/585	Plate	2.25Cr-1Mo
5C	5	ASTM	A 542	Type A, Class 2	K21590	—	795/690	Plate	2.25Cr-1Mo
6	1	ASTM	A 240	Type 410	S41000	—	450/205	Plate	13Cr
6	2	ASTM	A 240	Type 429	S42900	—	450/205	Plate	15Cr
6	4	ASTM	A 240	S41500	S41500	—	795/620	Plate	13Cr-4.5Ni-Mo
7	1	ASTM	A 240	Type 405	S40500	—	415/170	Plate	12Cr-1Al
7	1	ASTM	A 240	Type 409	S40900	—	380/170	Plate	11Cr-Ti
7	1	ASTM	A 240	Type 410S	S41008	—	415/205	Plate	13Cr
7	2	ASTM	A 240	Type 18-2	S44400	—	415/275	Plate	18Cr-2Mo
7	2	ASTM	A 240	Type 430	S43000	—	450/205	Plate	17Cr
8	1	ASTM	A 312	TP304	S30400	—	515/205	Seamless & Welded Pipe	18Cr-8Ni
8	1	ASTM	A 312	TP304L	S30403	—	485/170	Seamless & Welded Pipe	18Cr-8Ni
8	1	ASTM	A 312	TP316	S31600	—	515/205	Seamless & Welded Pipe	16Cr-12Ni-2Mo
8	1	ASTM	A 312	TP316L	S31603	—	485/170	Seamless & Welded Pipe	16Cr-12Ni-2Mo
8	2	ASTM	A 240	S30815	S30815	<5	600/310	Plate, Sheet & Strip	21Cr-11Ni-N
8	3	ASTM	A 312	TP-11	S21904	—	620/345	Seamless & Welded Pipe	21Cr-6Ni-9Mn
8	3	ASTM	A 312	TPXM-19	S20910	—	690/380	Seamless & Welded Pipe	22Cr-13Ni-5Mn
8	4	ASTM	A 312	S31254	S31254	—	650/305	Seamless & Welded Pipe	20Cr-18Ni-6Mo
8	4	ASTM	A 312	317LM	S31725	—	515/205	Seamless & Welded Pipe	19Cr-15Ni-4Mo

M-Number Listing of Base Metals—Ferrous Alloys

Material Number	Group Number	Standard	Base Metal Specification	Type, Grade, or Alloy Designation	UNS Number	Thickness Limitations mm	Minimum Tensile/Yield Strength, MPa	Product Form	Nominal Composition
Steel and Steel Alloys									
1	1	ASTM	A 36	A 36	K02595	≤20	400/250	Plate & Bars	C-Mn-Si
1	1	ASTM	A 36	A 36	K02596	>20≤40	400/250	Plate & Bars	C-Mn-Si
1	1	ASTM	A 36	A 36	K02597	>40≤65	400/250	Plate & Bars	C-Mn-Si
1	1	ASTM	A 36	A 36	K02596	>65≤100	400/250	Plate & Bars	C-Mn-Si
1	1	ASTM	A106	Grade B	K03006	—	415/240	Seamless Pipe	C-Mn-Si
1	1	ASTM	A 516	Grade 55	K01800	—	380/205	Plate	C-Mn-Si
1	1	ASTM	A 516	Grade 65	K02403	—	450/240	Plate	C-Mn-Si
1	1	API	5L	Grade X42	—	—	415/290	Pipe	C-Mn
1	2	ASTM	A 106	Grade C	K03501	—	485/275	Seamless Pipe	C-Mn-Si
1	2	ASTM	A 516	Grade 70	K02700	—	485/260	Plate	C-Mn-Si
1	1	API	5L	Grade X52	—	—	460/360	Pipe	C-Mn
1	2	API	5L	Grade X60	—	—	515/415	Pipe	C-Mn-Cb-V-Ti
1	4	API	5L	Grade X80	—	—	625/550	Pipe	C-Mn
3	1	ASTM	A 204	Grade A	K11820	—	450/255	Plate	C-0.5Mo
3	1	ASTM	A 369	Grade FP1	K11522	—	380/205	Pipe	C-0.5Mo
3	2	ASTM	A 204	Grade B	K12020	—	485/275	Plate	C-0.5Mo
3	2	ASTM	A 204	Grade C	K12320	—	515/295	Plate	C-0.5Mo
3	2	ASTM	A 387	Grade 2, Class 2	K12143	—	485/310	Plate	0.5Cr-0.5Mo
3	2	ASTM	A 871	Grade 60	—	—	515/415	Plate	C-Mn-Ni-Cu-Cr-V
3	2	ASTM	A 945	Grade 65	—	—	540/450	Plate	LowC-Mn
3	3	ASTM	A 533	Type A, Class 1	K12521	—	550/345	Plate	Mn-0.5Mo
3	3	ASTM	A 533	Type A, Class 2	K12521	—	620/485	Plate	Mn-0.5Mo
3	3	ASTM	A 533	Type B, Class 1	K12539	—	550/345	Plate	Mn-0.5Mo-0.5Ni
3	3	ASTM	A 533	Type B, Class 2	K12539	—	620/485	Plate	Mn-0.5Mo-0.5Ni

List of Base Metal Specifications—Ferrous Alloys

Standard	Base Metal Specification	Material Number	Group Number	Type, Grade, or Alloy Designation	UNS Number	Product Form
Steel and Steel Alloys						
ASTM	A 387	5A	1	Grade 21, Class 2	K31545	Plate
ASTM	A 387	5B	1	Grade 5, Class 1	K41545	Plate
ASTM	A 387	5B	1	Grade 5, Class 2	K41545	Plate
ASTM	A 387	5B	2	Grade 91, Class 2	S50460	Plate
ASTM	A 420	11A	1	Grade WPL8	K81340	Pipe
ASTM	A 514	11B	1	Grade A	K11856	Plate
ASTM	A 514	11B	2	Grade E	K11856	Plate
ASTM	A 516	1	1	Grade 55	K01800	Plate
ASTM	A 516	1	1	Grade 65	K02403	Plate
ASTM	A 516	1	2	Grade 70	K02700	Plate
ASTM	A 517	11B	1	Grade A	K11856	Plate
ASTM	A 517	11B	2	Grade E	K21604	Plate
ASTM	A 533	3	3	Type A, Class 1	K12521	Plate
ASTM	A 533	3	3	Type A, Class 2	K12521	Plate
ASTM	A 533	3	3	Type B, Class 1	K12539	Plate
ASTM	A 533	3	3	Type B, Class 2	K12539	Plate
ASTM	A 533	11A	4	Grade A, Class 3	K12521	Plate
ASTM	A 533	11A	4	Grade B, Class 3	K12539	Plate
ASTM	A 543	11A	5	Type B, Class 1	K42339	Plate
ASTM	A 543	11A	5	Type B, Class 3	K42339	Plate
ASTM	A 542	5C	3	Type A, Class 3	K21590	Plate
ASTM	A 542	5C	4	Type A, Class 1	K21590	Plate
ASTM	A 542	5C	5	Type A, Class 2	K21590	Plate
ASTM	A 612	10C	1	—	K02900	Plate
ASTM	A 645	11A	2	—	K41583	Plate
ASTM	A 709	11B	1	Grade 100, Type A	K11856	Plate & Shapes
ASTM	A 709	11B	1	Grade 100W, Type A	K11856	Plate & Shapes
ASTM	A 709	11B	2	Grade 100, Type E	K21604	Plate & Shapes
ASTM	A 709	11B	2	Grade 100W, Type E	K21604	Plate & Shapes
ASTM	A 832	5C	1	Grade 21V	K31830	
ASTM	A 871	3	2	Grade 60	—	Plate
ASTM	A 945	3	2	Grade 65	—	Plate
API	5L	1	1	Grade X42	—	Pipe
API	5L	1	2	Grade X52	—	Pipe
API	5L	1	2	Grade X60	—	Pipe
API	5L	1	4	Grade X80	—	Pipe

Annex III-A (Normative)

List of Base Metal Specifications—Ferrous Alloys

Standard	Base Metal Specification	Material Number	Group Number	Type, Grade, or Alloy Designation	UNS Number	Product Form
			Steel and Steel Alloys			
ASTM	A 36	1	1	A 36	K02599	Plate & Bars
ASTM	A 36	1	1	A 36	K02598	Plate & Bars
ASTM	A 36	1	1	A 36	K02597	Plate & Bars
ASTM	A 36	1	1	A 36	K02596	Plate & Bars
ASTM	A 106	1	1	Grade B	K03006	Seamless Pipe
ASTM	A 106	1	2	Grade C	K03501	Seamless Pipe
ASTM	A 202	4	1	Grade A	K11742	Plate
ASTM	A 202	4	1	Grade B	K12542	Plate
ASTM	A 203	9A	1	Grade A	K21703	Plate
ASTM	A 203	9A	1	Grade B	K22103	Plate
ASTM	A 203	9B	1	Grade D	K31718	Plate
ASTM	A 203	9B	1	Grade E	K32018	Plate
ASTM	A 204	3	1	Grade A	K11820	Plate
ASTM	A 204	3	2	Grade B	K12020	Plate
ASTM	A 204	3	2	Grade C	K12320	Plate
ASTM	A 225	10A	1	Grade C	K12524	Plate
ASTM	A 225	10A	1	Grade D	—	Plate
ASTM	A 240	6	1	Type 410	S41000	Plate
ASTM	A 240	6	2	Type 429	S42900	Plate
ASTM	A 240	6	4	Grade S41500	S41500	Plate
ASTM	A 240	7	1	Type 405	S40500	Plate
ASTM	A 240	7	1	Type 409	S40900	Plate
ASTM	A 240	7	1	Type 410S	S41008	Plate
ASTM	A 240	7	2	Type 18-2	S44400	Plate
ASTM	A 240	7	2	Type 430	S43000	Plate
ASTM	A 240	8	2	S30815	S30815	Plate, Sheet & Strip
ASTM	A 312	8	1	TP304	S30400	Seamless & Welded Pipe
ASTM	A 312	8	1	TP304L	S30403	Seamless & Welded Pipe
ASTM	A 312	8	1	TP316	S31600	Seamless & Welded Pipe
ASTM	A 312	8	1	TP316L	S31603	Seamless & Welded Pipe
ASTM	A 312	8	3	TPXM-19	S20910	Seamless & Welded Pipe
ASTM	A 312	8	3	TP-11	S21904	Seamless & Welded Pipe
ASTM	A 312	8	4	317LM	S31725	Seamless & Welded Pipe
ASTM	A 312	8	4	S31254	S31254	Seamless & Welded Pipe
ASTM	A 333	4	2	Grade 4	K11267	Pipe
ASTM	A 333	9A	1	Grade 7	K21903	Pipe
ASTM	A 333	9A	1	Grade 9	K22035	Pipe
ASTM	A 333	9B	1	Grade 3	K31918	Pipe
ASTM	A 335	4	1	Grade P11	K11597	Pipe
ASTM	A 335	4	1	Grade P12	K11562	Pipe
ASTM	A 335	5B	2	Grade P91	K91560	Seamless Pipe
ASTM	A 353	11A	1		K81340	Plate
ASTM	A 369	3	1	Grade FP1	K11522	Forged Pipe
ASTM	A 387	3	2	Grade 2, Class 2	K12143	Plate
ASTM	A 387	5A	1	Grade 21, Class 1	K31545	Plate

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Annex II (Normative) – F Number Table

Grouping of Welding Electrodes and Rods for Qualification

F-No.	AWS Specification	AWS Classification
		Steel
1	A5.1	EXX20, EXX22, EXX24, EXX27, EXX28
1	A5.4	EXXX(X)-26
1	A5.5	EXX20-XX, EXX27-XX
2	A5.1	EXX12, EXX13, EXX14, EXX19
2	A5.5	E(X)XX13-XX
3	A5.1	EXX10, EXX11
3	A5.5	E(X)XX10-XX, E(X)XX11-XX
4	A5.1	EXX15, EXX16, EXX18, EXX18M, EXX48
4	A5.4 other than austenitic and duplex	EXXX(X)-15, EXXX(X)-16, EXXX(X)-17
4	A5.5	E(X)XX15-XX, E(X)XX16-XX, E(X)XX18-XX, E(X)XX18M, E(X)XX18M1, E(X)XX45-P2
5	A5.4 austenitic and duplex	EXXX(X)-15, EXXX(X)-16, EXXX(X)-17
6	A5.9	All Classifications
6	A5.18	All Classifications
6	A5.20	All Classifications
6	A5.22	All Classifications
6	A5.28	All Classifications
6	A5.29	All Classifications
6	A5.30	INMs-X, IN5XX, IN3XX(X)

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Annex I (Normative) – A Number Table

Classification of Ferrous Weld Metal for Procedure Qualification

A-No.	Type of Weld Metal	Chemical Composition, wt %					
		C	Cr	Mo	Ni	Mn	Si
1	Low-carbon	0.20	0.20	0.30	0.50	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	0.50	1.60	1.00
3	Chromium-Molybdenum	0.15	0.40–2.00	0.40–0.65	0.50	1.60	1.00
4	Chromium-Molybdenum	0.15	2.00–4.00	0.40–1.50	0.50	1.60	2.00
5	Chromium-Molybdenum	0.15	4.00–10.5	0.40–1.50	0.80	1.20	2.00
6	Chromium, martensitic	0.15	11.00–15.0	0.70	0.80	2.00	1.00
7	Chromium, ferritic	0.15	11.00–30.0	1.00	0.80	1.00	3.00
8	Chromium-Nickel	0.15	14.50–30.0	4.00	7.50–15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.0–30.0	6.00	15.0–37.00	2.50	1.00
10	Nickel	0.15	0.50	0.55	0.80–4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	0.50	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

Note:
Single values in this table are maximum values.

6.4.1.2 Visual Examination Acceptance Criteria. Acceptance criteria for visual examination of standard test plate and pipe weldments shall be as follows:

(1) No cracks or incomplete fusion.

(2) No incomplete joint penetration in groove welds, except where partial joint penetration groove welds are specified.

(3) Undercut depth shall not exceed the lesser of 10% of the base metal thickness or 0.8 mm.

(4) Face reinforcement or root reinforcement shall not exceed 3 mm.

(5) No single pore shall exceed 2.5 mm diameter.

6.4.2 Bend Tests. Bend testing requirements and acceptance criteria are as specified in 5.3.1(2) and 5.4.2.

6.5 Performance Qualification Documentation

The qualification test for each welder shall be documented for both acceptable and unacceptable tests. There is no required format for Welder Performance Qualification Test Records (WQTR). Any WQTR form may be used. See Annex IX for a suggested format. The documentation shall:

(1) Identify the WPS used;

(2) Address each of the qualification variables in 6.2;

(3) Identify test and examination methods used and results; and

(4) Identify the limits of qualification for the welder.

Table 15
Position Limitation for Performance Tests

Test Positions[d]		Qualified Position[c]		
		Groove		Fillet
Weld	Position	Plate and Pipe Over 600 mm O.D.	Pipe ≤ 600 mm O.D.	Plate and Pipe
Plate Groove	1G	F		F, H
	2G	F, H		F, H
	3G	F, V		F, H, V
	4G	F, O		F, H, O
	3G and 4G	F, V, O		All
	2G, 3G, and 4G	All		All
Plate Fillet	1F	—	—	F
	2F	—	—	F, H
	3F	—	—	F, H, V
	4F	—	—	F, H, O
	3F and 4F	—	—	All
Pipe Groove[a,b]	1G	F	F	F, H
	2G	F, H	F, H	F, H
	5G	F, V, O	F, V, O	All
	6G	All	All	All
	2G and 5G	All	All	All
Pipe Fillet	1F	—	—	F
	2F	—	—	F, H
	2FR	—	—	F, H
	4F	—	—	F, H, O
	5F	—	—	All

[a] Welders qualified on tubular product forms may weld on both tubular and plate in accordance with any restrictions on diameter contained in other portions of this document.
[b] See Table 9.
[c] F = Flat, H = Horizontal, V = Vertical, O = Overhead.
[d] Welding test position definitions are as defined in AWS A3.0 , “Standard Welding Terms and Definitions”.

6.4 Performance Qualification Acceptance Criteria

6.4.1 Visual. Examination procedures and acceptance criteria shall be as specified in the following paragraphs.

6.4.1.1 Visual Examination Procedure. The test weld may be examined visually at any time, and the test terminated at any stage if the necessary skills are not exhibited. The completed test weld shall be visually examined.

Table 13
Allowable Base Metals for Performance Qualification

Test Weldment Material[a]	Qualifies for Production Welding Materials
M-1 through M-11	M-1 through M-11

[a] If materials not listed in Annex III are used for qualification tests, the welder shall be qualified to weld only on the material used in the test weldment.

Table 14
Allowable Filler Metals for Performance Qualification

Filler Metal Used In Qualification Test	Qualifies a Welder to Use the Filler Metals Listed Below
F-Number 1 through 5	The F-Number used in the test and any lower F-Number
F-Number 6[a]	All F-Number 6 filler metals

[a] Deposited solid bare wire, which is not covered by an AWS specification but which conforms to an A-Number analysis in Annex I may be considered classified as F-Number 6.

Table 11
Examination Requirements for Performance Qualification

	Tube or Sheet Less than 2 mm	Pipe or Plate Equal to or Greater than 2 mm
Type of Test	Groove	Groove
Visual Examination	Yes	Yes
Radiography	No	Yes[a] (in lieu of bends)
Bend Test	No	Yes[a, b]

[a] Radiography may be substituted for bend testing for the SMAW, GTAW, GMAW (except short-circuiting), and FCAW processes, as applicable, for qualifications.
[b] See Table 12.

Table 12
Number of Bend Tests for Performance Qualification

	Product Form			
	Plate	Pipe	Tube	Sheet
1G	*2*	2	2	2
2G	*2*	2	2	2
3G	*2*	—	—	2
4G	*2*	—	—	2
5G	—	4	4	—
6G	—	4	4	—

6.3.2 Test Weldments

6.3.2.1 Qualification is valid only for metals having the same M-Numbers, except as otherwise permitted in Table 13.

6.3.2.2 Tests shall be performed using a filler metal which has an assigned F-Number listed in Annex II. Table 14 provides a matrix showing filler metals which, if used in qualification testing, will qualify that welder to use other filler metals without further testing. A test using a filler metal not assigned an F-Number in Annex II shall qualify only for that filler metal.

6.3.2.3 Test coupons welded in the specific test positions qualify the welder to weld plate or pipe as permitted in Table 15.

6.3.2.4 One or more welding process may be qualified on a single test weldment. Multiple welders may be qualified for specific portions of one test. Failure of any portion of such test weldments constitutes failure for all processes and welders used in that test weldment.

Table 9
Limitations for Performance Qualification on Groove Welds in Pipe and Tube

Test Weldment, mm		Qualifies for Pipe and Plate			
		Minimum Outside Diameter, mm		Maximum Deposit Thickness	
Outside Diameter	Deposit Thickness (t)	Grooves	Fillets	Grooves	Fillets
Less than 25		Size welded	All		
25 through 73		25	All		
Over 73		73	All		
	Less than 19			2t	All
	19 and over			Unlimited	All

t = The thickness of the Weld Deposit, excluding reinforcement.
Note:
For GMAW-S, the maximum weld metal thickness qualified shall not exceed 1.1 times the thickness of weld metal deposited by the GMAW-S process in the qualification test. For base metals 10 mm thick and greater, side bends are required for GMAW-S.

Table 10
Limitations for Performance Qualification in Plate Groove Welds

Test Weldment Thickness (T), mm	Qualifies for Plate[a]	
	Deposit Thickness (t), Maximum[b]	Fillet Weld Size
< 19	2t	Unlimited
≥ 19	Unlimited	Unlimited

[a] Qualification on plate will also qualify for groove welds in pipe over 600 mm in diameter.
[b] For GMAW-S, the maximum weld metal thickness qualified shall not exceed 1.1 times the thickness of weld metal deposited by the GMAW-S process in the qualification test. For base metals 10 mm thick and greater, side bends are required for GMAW-S.

NOTES:
T = The thickness of the Test Weldment Base Metal.
t = The thickness of the Weld Deposit, excluding reinforcement.

6.3 Performance Qualification Test Requirements

6.3.1 Qualification by Standard Test. Qualification requires completion of a standard test weldment in accordance with a qualified WPS, evaluation of the test weldment by the methods listed in Table 11, and acceptance of the weldment in accordance with the criteria of 6.4, Examination Acceptance Criteria. The number of bend tests required for each position and product form is shown in Table 12.

6.0 Performance Qualification Requirements

6.1 General

6.1.1 This specification addresses the requirements for welder performance qualifications. It does not contain requirements for welding operators or tack welders. Tack welds shall be made by welders qualified in accordance with this specification.

6.1.2 Welder qualification on one WPS will also qualify for welding with any other WPS within the performance qualification variables specified in 6.2.

6.1.3 Completion of an acceptable procedure or performance qualification test shall qualify the welder who welded the test weldment within the limits of performance qualification variables specified in 6.2.

6.1.4 Qualification on a complete joint penetration groove weld also qualifies the welder for partial joint penetration groove welds and fillet welds. Qualification on a partial joint penetration groove weld qualifies only for partial joint penetration groove welds and fillet welds.

6.2 Performance Qualification Variables

A change in any variable listed below from that which was used in a welder's qualification test will require requalification of that welder:

(1) A change in welding process except that welders qualified with GMAW spray, pulsed spray, or globular transfer are also qualified to weld with gas shielded FCAW and vice versa.

(2) The deletion of backing.

(3) A change in filler metal F-Number except as allowed in 6.3.2.2.

(4) A change in base metal except as permitted in 6.3.2.1.

(5) For GTAW, a change from alternating to direct current or vice versa, or a change in polarity.

(6) A change in position from that qualified, except as permitted in 6.3.2.3.

(7) A change in vertical weld progression from uphill to downhill, or vice versa for any pass except root passes that are completely removed by back gouging or final passes used to dress the final weld surface.

(8) For GMAW, a change from spray transfer, globular transfer, or pulsed spray welding to short-circuiting transfer; or vice versa.

(9) For GMAW or GTAW, omission or addition of consumable inserts, or deletion of root shielding gas except for double welded butt joints, partial penetration groove, and fillet welds.

(10) A change in thickness or diameter from that tested except as permitted in Tables 9 and 10.

Record (PQR). The PQR may be presented in any format, written or tabular. A suggested format for the PQR is included in Annex VIII. The WPS shall reference all PQR's which support the qualification of that WPS.

5.4.2.1 Structural Steel Applications. For acceptance, the surface shall contain no discontinuities in the weld or heat-affected zone per the following:

(1) >3 mm measured in any direction on the surface, or

(2) >10 mm —the sum of the greatest dimensions of all discontinuities exceeding 0.8 mm, but less than or equal to 3 mm, or

(3) 6 mm —the maximum corner crack, except when that corner crack results from visible slag inclusion or other fusion type discontinuity, then the 3 mm maximum shall apply.

Specimens with corner cracks exceeding 6 mm with no evidence of slag inclusions or other fusion type discontinuity shall be disregarded, and a replacement test specimen from the original weldment shall be tested.

5.4.2.2 Pipeline Applications. The bend test shall be considered acceptable if no crack or other imperfection exceeding 3 mm or one-half the specified wall thickness, whichever is smaller, in any direction is present in the weld or between the weld and the fusion zone after bending. Cracks that originate on the outer radius of the bend along the edges of the specimen during testing and that are less than 6 mm, measured in any direction, shall not be considered unless obvious imperfections are observed.

5.4.2.3 Pressure Piping Applications. For acceptance, the surface shall contain no discontinuities in the weld or heat-affected zone per the following:

(1) >3 mm measured in any direction on the surface.

(2) Open discontinuities occurring on the corners of the specimen during testing shall not be considered and a replacement test specimen from the original weldment shall be tested unless there is definite evidence that the open discontinuities result from lack of fusion, slag inclusions, or other internal discontinuities.

5.4.3 Tension Test Criteria. The procedures and method for tension testing shall conform to AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. (Note: B4.0 is referenced, but not needed when taking this examination.) Each tensile test specimen shall have a tensile strength not less than the following:

5.4.3.1 The minimum tensile strength of the base metal as specified in Annex III-B, or of the weaker of the two base metals if metals of different minimum tensile strength are used; or

5.4.3.2 The specified minimum tensile strength of the electrode or filler metal classification when undermatching filler metal is used; or

5.4.3.3 If the specimen breaks in the base metal outside of the weld or weld interface, the test shall be accepted, provided the strength is not more than 5% below the specified minimum tensile strength of the base metal; or

5.4.3.4 If the base metal has no specified minimum tensile strength then failure in the base metal shall be acceptable.

5.4.4 CVN Fracture Toughness Criteria. For fracture toughness testing, the type of test, number of specimens, and acceptance criteria shall be as specified. The procedures and apparatus shall conform to the requirements of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. (Note: B4.0 is referenced, but not needed when taking this examination.)

5.5 Procedure Qualification Documentation. Welding variables used to produce an acceptable test weldment and the results of tests conducted on that weldment to qualify a WPS shall be recorded on a Welding Procedure Qualification

5.3 Procedure Qualification Test Requirements

5.3.1 Evaluation of Groove Test Weldments. Test weldments shall be subjected to the following:

(1) Visual Examination

(2) Guided Bend Test

(a) 4 side bend specimens, or

(b) 2 face bend and 2 root bend specimens

Side bend specimens may be substituted for face and root bend specimens for metal thicknesses from 10 to 19 mm inclusive. For metal over 19 mm thick, side bend specimens are required. For base metals 10 mm thick and greater, side bends are required for GMAW-S.

(3) Tension Test

(a) 2 transverse specimens

(4) CVN Fracture Toughness (if required)

(a) 3 specimens from weld metal

(b) 3 specimens from HAZ

5.4 Procedure Qualification Acceptance Criteria

5.4.1 Visual Examination Acceptance Criteria. Prior to removing specimen blanks from the completed test weldment, the weld shall be visually examined on all accessible surfaces and shall meet the following criteria:

5.4.1.1 There shall be no evidence of cracks, incomplete fusion, or incomplete joint penetration.

5.4.1.2 The depth of undercut shall not exceed the lesser of 10% of the base metal thickness or 0.8 mm.

5.4.1.3 Porosity shall not exceed the limitations of clause 2.0, 3.0, or 4.0, as applicable.

5.4.2 Bend Criteria. Transverse bend specimens shall be prepared as specified in Annex IV. The specimen edge radius shall not exceed 3 mm. It is recommended, but not a requirement, that the specimen grinding direction be parallel to the direction of bending. For face bend specimens, the weld face side shall be on the convex side of the bend specimen. For root bend specimens, the weld root side shall be on the convex side of the bend specimen. Side bend specimens may be bent in either direction. For all transverse bend specimens, the weld metal and heat-affected zone shall be completely within the bent portion of the specimen after bending.

Unless otherwise specified, specimens containing a rejectable discontinuity shall be considered as failed, regardless of their conformance to preparation or bending requirements. Specimens not meeting preparation or bending requirements that do not contain a rejectable discontinuity shall be disregarded and a replacement specimen prepared from the original weldment shall be tested.

The convex surface of the bend test specimen (beginning at the edge of the specimen and including the specimen edge radius) shall be visually examined and meet the requirements of 5.4.2.1, 5.4.2.2 or 5.4.2.3, as applicable.

Table 8
PQR Data Matrix (Cont'd)

	FCAW		GMAW		GTAW		SMAW
5.2.3.6 Shielding Gas							
(1) Addition or deletion of torch shielding gas.	Q		Q		Q		
(2) A change in the specified nominal composition of shielding gas.	Q		Q		Q		
5.2.3.7 Electrical Characteristics							
(1) An increase in heat input or volume of weld metal deposited per unit length of weld, over that qualified, except when a grain refining austenitizing heat treatment is applied after welding. The increase may be measured by either of the following: (a) Heat Input (kJ/mm) = $\frac{\text{Volts x Amps x 0.06}}{\text{Travel Speed (mm/min)}}$ (b) Weld Metal Volume–An increase in bead size, (width x thickness) or a decrease in the length of weld bead per unit length of electrode.	T		T		T		T
(2) A change in the mode of metal transfer from short circuiting to globular, spray, or pulsed and vice versa.	Q		Q				
5.2.3.8 Other Variables							
(1) A change in welding process.	Q		Q		Q		Q
(2) A change exceeding ± 20% in the oscillation variables for mechanized or automatic welding.	T		T		T		
(3) A change from multipass per side to single pass per side.	T		T		T		T
(4) A change from a stringer bead to a weave bead in vertical uphill welding.	T		T		T		T

Table 8
PQR Data Matrix (Cont'd)

	FCAW	GMAW	GTAW	SMAW
5.2.3.3 Filler Metals (Cont'd)				
(3) A change in filler metal tensile strength exceeding 60 MPa, or a change in filler metal classified to a strength lower than the specified minimum tensile strength designator of the base metal.	Q	Q	Q	Q
(4) The addition or deletion of filler material.			Q	
(5) A change in the weld metal thickness beyond that permitted in 5.2.2.	Q	Q	Q	Q
5.2.3.4 Preheat and Interpass Temperature				
(1) A decrease in preheat of more than 55°C from that qualified.	Q	Q	Q	Q
(2) An increase of more than 55°C in the maximum interpass temperature from that recorded on the PQR.	T	T	T	T
5.2.3.5 Postweld Heat Treatment				
(1) For the following M-Numbers 1, 3, 4, 5, 6, 7, 9, 10, and 11 a change from any one condition to any other requires requalification: (a) No PWHT. (b) PWHT below the lower transformation temperature. (c) PWHT within the transformation temperature range. (d) PWHT above the upper transformation temperature. (e) PWHT above the upper transformation temperature, followed by treatment below the lower transformation temperature.	Q	Q	Q	Q
(2) For all materials not covered above, a separate PQR is required for no PWHT and PWHT.	Q	Q	Q	Q

5.2.3 Table 8 lists the procedure qualification variables to be recorded on the PQR for each welding process. A change in a procedure qualification variable beyond the limits shown in Table 8 shall require a new or revised WPS and a new PQR. The PQR shall list the actual values of the variables used. The key to the entries in the body of the table is as follows:

Q—Qualification variable for all applications

T— Qualification variable for all fracture toughness applications

Table 8
PQR Data Matrix

	FCAW	GMAW	GTAW	SMAW
5.2.3.1 Joint Design				
(1) A change from a fillet to a groove weld.	Q	Q	Q	Q
(2) A change in the M-Number of backing.	Q	Q	Q	Q
5.2.3.2 Base Metal				
(1) A change in base metal thickness beyond the range permitted in 5.2.2.	Q	Q	Q	Q
(2) A change from one M-Number base metal to another M-Number base metal or to a combination of M-Number base metals, except as permitted in 5.2.1.1.	Q	Q	Q	Q
(3) A change from one M-Number Group Number to any other M-Number Group Number, except as permitted in 5.2.1.2.	T	T	T	T
(4) A change from one M-5 group (A, B, etc.) to any other. A change from M-9A to M-9B, but not vice versa. A change from one M-10 or M-11 group (A, B, etc.) to any other group.	Q	Q	Q	Q
5.2.3.3 Filler Metals				
(1) A change from one F-Number to any other F-Number or to any filler metal not listed in Annex II.	Q	Q	Q	Q
(2) For ferrous materials, a change from one A-Number to any other A-Number.	Q	Q	Q	Q

Table 7
Thickness Limitation of Plate and Pipe for Groove Welds for Procedure Qualification

Test Weldment Thickness (T), mm[a]	Base Metal Thickness Qualified [b,c,d,e,f]		Deposit Weld Metals Thickness Qualified (t) [b, g]
	Minimum, mm	Maximum, mm	Maximum, mm
Less than 2	1/2T	2T	2t
2 to 10	2	2T	2t
Over 10, but less than 19	5	2T	2t
19 to less than 38	5	2T	2t when t < 19 2T when t ≥ 19
38 to less than 150	5	200	2t when t < 19 200 when t ≥ 19
150 and over	25	1.33T	2t when t < 19 200 when 19 ≤ t < 150 1.33t when t ≥ 150

(a) When the groove is filled using a combination of welding processes:

(1) The test weldment thickness "T" is applicable for the base metal and shall be determined from the Base Metal Thickness Qualified column.

(2) The thickness "t" of the weld metal for each welding process shall be determined from the Deposited Weld Metal thickness column.

(3) Each welding process qualified in this combination manner may be used separately only within the same qualification variables and the thickness limits.

(b) For GMAW-S, the maximum thickness of base metal qualified is 1.1 times the thickness of the test weldment until the test weldment thickness is 13 mm, beyond which Table 7 applies. The maximum weld metal thickness qualified is 1.1 times the GMAW-S weld metal thickness deposited in the weldment. In addition, for thickness 10 mm thick and greater, side bend tests shall be used to qualify GMAW-S WPSs.

(c) For fracture toughness applications, minimum base metal thickness qualified is T or 16 mm, whichever is less.

(d) If any single pass in the test weldment base metal is greater in thickness than 13 mm, the qualified base metal thickness is 1.1 times the test weldment thickness.

(e) If a test weldment receives a postweld heat treatment exceeding the lower transformation temperature, the maximum base metal thickness qualified is 1.1 times the base metal thickness of the test weldment, and the maximum weld thickness qualified is 1.1 times the weld metal of the test weldment.

(f) For base metals equal to or less than 10 mm, fillet welds have the same base metal thickness qualifications as groove welds. For base metals thickness greater than 10 mm, the maximum base metal thickness qualified for fillet welds is unlimited.

(g) Deposited weld metal thickness limitations do not apply to fillet welds or weld buildups.

NOTES:
T = The thickness of the Test Weldment Base Metal.
t = The thickness of the Weld Deposit, excluding reinforcement.

5.2 Procedure Qualification Variables. A change in a WPS beyond that allowed in this clause shall require requalification of the procedure and preparation of a new or revised WPS. Changes not addressed in this clause shall not require requalification, provided such changes are documented in a new or revised WPS.

5.2.1 Test Weldments. The welding organization shall prepare a sufficient number of qualification test weldments to cover the anticipated processes, materials, thicknesses, etc. as described herein. Each groove test weldment shall be large enough to provide the necessary test specimens required in 5.3.

5.2.1.1 For the welding of base metals with different M-Numbers, a procedure qualification test shall be made for each combination of M-Numbers to be joined. However, a procedure qualification test with one M-Number shall also qualify for that metal welded to itself and to each of the lower M-Number metals for:

(1) Base metals M-1, M-3, M-4, and M-5A; and

(2) Welding processes SMAW, GTAW, GMAW, and FCAW.

(*Example:* M-5A to M-5A would qualify for M-5A to M-5A, as well as M-5A to M-4, M-5A to M-3, and M-5A to M-1. Refer to Annexes III-A and III-B for listings of base metal M-Numbers)

5.2.1.2 If fracture toughness testing is required, then procedure qualification shall be made for each combination M-Number and Group Number to be joined. A procedure qualification shall be made for each M-Number and Group Number combination of base metals, even though procedure qualification tests have been made for each of the two base metals welded to itself.

(1) If the Welding Procedure Specification (WPS) for welding the combination of base metals specifies the same qualification variables, including electrode or filler metal, as both WPSs for welding each base metal to itself, such as that the base metal is the only change, then the WPS for welding the combination of base metals is also qualified.

(2) When base metals of two different M-Numbers and Group Numbers are qualified using a single test weldment, that test weldment qualifies the welding of those two M-Numbers and Group Numbers to themselves as well as to each other using the variables qualified.

5.2.2 Qualification Thickness Limitations

5.2.2.1 Limitations on the thickness ranges qualified by procedure qualification tests are given in Table 7.

5.2.2.2 The limitations in Table 7 are based upon the base metal and weld metal thickness for groove welds.

5.2.2.3 Complete penetration groove welds shall also qualify partial penetration groove welds, fillet welds, and weld buildups within the qualification limits given in Table 7.

5.2.2.4 In addition to the welding data required to be included in the WPS by 5.1, when multiple process or multiple filler metal classifications are used in a single test weldment, the thickness ranges permitted for use in the WPS shall apply separately to each welding process and filler metal classification. The weld deposit thickness for each welding process and each filler metal classification used in the qualification test shall be recorded on the PQR.

5.2.2.5 In addition to the procedure qualification variables required to be recorded on the PQR by 5.2.3, the weld deposit thickness for each welding process and each filler metal classification used in the qualification test shall be recorded on the PQR for all applications.

Table 6
WPS Data Matrix (Cont'd)

	FCAW	GMAW	GTAW	SMAW
5.1.5 Preheat and Interpass				
(1) Preheat minimum.	X	X	X	X
(2) Interpass temperature maximum (if applicable).	X	X	X	X
(3) Preheat maintenance.	X	X	X	X
5.1.6 Heat Treatment				
(1) PWHT temperature and time.	X	X	X	X
5.1.7 Shielding Gas				
(1) Torch shielding gas and flow rate range.	X	X	X	
(2) Root shielding gas and flow rate range.			X	
5.1.8 Electrical				
(1) Current (or wire feed speed), current type, and polarity.	X	X	X	X
(2) Voltage range (except for manual welding).	X	X	X	
(3) Specification, classification, and diameter of tungsten electrode.			X	
(4) Transfer mode.	X	X		
(5) A change to or from pulsed current.	X	X	X	X
5.1.9 Variables				
(1) Welding process and whether manual, semiautomatic, mechanized, or automatic.	X	X	X	X
(2) For mechanized or automatic, single or multiple electrode and spacing.	X	X	X	
(3) Single or multipass.	X	X	X	X
(4) Contact tube to work distance.	X	X		
(5) Cleaning.	X	X	X	X
(6) Peening.	X	X	X	X
(7) Stringer or weave bead.	X	X	X	X
(8) Travel-speed range for mechanized or automatic welding and manual applications requiring heat input calculations.	X	X	X	

5.0 Procedure Qualification Requirements

5.1 Welding Procedure Specification Data.

Table 6 indicates the welding data to be included in a WPS for each welding process. A WPS may be presented in any format, written or tabular, provided the data required in Table 6 are included. A suggested WPS format appears in Annex VII. The WPS may list variables recorded on the PQR within the full range permitted for qualification variables and for practical limits determined by the welding organization for other welding data.

Table 6
WPS Data Matrix

	FCAW	GMAW	GTAW	SMAW
5.1.1 Joint Design				
(1) Joint type and dimensions.	X	X	X	X
(2) Treatment of backside, method of gouging/preparation.	X	X	X	X
(3) Backing material, if used.	X	X	X	X
5.1.2 Base Metal				
(1) M-Number and Group Number.	X	X	X	X
(2) Thickness range qualified.	X	X	X	X
(3) Diameter (tubular only).	X	X	X	X
(4) The coating description or type, if present.	X	X	X	X
5.1.3 Filler Metals				
(1) Specification, classification, F- and A-Number, or if not classified the nominal composition.	X	X	X	X
(2) Weld metal thickness by process and filler metal classification.	X	X	X	X
(3) Filler metal size or diameter.	X	X	X	X
(4) Penetration enhancing flux.			X	
(5) Supplemental filler metal.	X	X	X	
(6) Consumable insert and type.			X	
(7) Energized filler metal “hot.”			X	
5.1.4 Position				
(1) Welding position(s).	X	X	X	X
(2) Progression for vertical welding.	X	X	X	X

4.1.9.3 Inspection. All weld repairs of depth exceeding 25 mm or 20% of the section thickness, whichever is the lesser (as measured from the pipe surface), shall be inspected by radiography and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 25 mm, whichever is the lesser shall be examined by magnetic particle or dye penetrant inspection of the first layer of each 6 mm thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

4.2 Visual Inspection Acceptance Criteria. Any of the following indications are unacceptable:

4.2.1 Cracks

4.2.2 Undercut that is greater than 0.8 mm deep. This also includes any other reduction of base metal at the weld toes.

4.2.3 Weld reinforcement greater than specified in Table 5

Table 5

	Maximum Thickness of Reinforcement for Design Temperature		
	>400°C	175°C - 400°C	<175°C
Thickness of Base Metal (mm)	mm	mm	mm
Up to 3, incl.	2	2.5	5
Over 3 to 5, incl.	2	3	5
Over 5 to 13, incl.	2	4	5
Over 13 to 25, incl.	2.5	5	5
Over 25 to 50, incl.	3	6	6
Over 50	4	note (a)	note (a)

(a) The greater of 6 mm or 1/8 times the width of the weld.

NOTES:

1. For double welded butt joints, this limitation on reinforcement given above shall apply separately to both inside and outside surfaces of the joint.
2. For single welded butt joints, the reinforcement limits given above shall apply to the outside surface of the joint only.
3. The thickness of weld reinforcement shall be based on the thickness of the thinner of the materials being joined.
4. The weld reinforcement thicknesses shall be determined from the higher of the abutting surfaces involved.
5. Weld reinforcement may be removed if so desired.

4.2.4 Lack of fusion

4.2.5 Incomplete penetration

4.2.6 Any other linear indications greater than 5 mm long

4.2.7 Surface porosity with rounded indications having dimensions greater than 5 mm or four or more rounded indications separated by 2 mm or less edge to edge in any direction. Rounded indications are indications that are circular or elliptical with their length less than three times their width.

4.0 Workmanship Requirements and Visual Inspection
Acceptance Criteria – Pressure Piping

4.1 Workmanship Requirements

4.1.1 The internal misalignment of the ends to be joined shall not be greater than 2 mm. When the internal misalignment exceeds the allowable, it is preferred that the component with the wall extending internally be internally trimmed. However, trimming shall result in a piping component thickness not less than the minimum allowable thickness, and the change in contour shall not exceed 30 degrees.

4.1.2 Edge preparation details and the root opening of the joint shall be as specified in the WPS.

4.1.3 Surfaces for welding shall be clean and free from paint, oil, rust, scale, or other material that is detrimental to welding.

4.1.4 The stopping and starting ends of tack welds shall be prepared by grinding or other mechanical means so that they can be satisfactorily incorporated into the final weld. Tack welds that have cracked are unacceptable and shall be removed and rewelded.

4.1.5 After welding commences, the minimum preheat temperature should be maintained until the joint is completed. However, welding may be interrupted and the joint allowed to cool slowly provided a minimum 10 mm thickness of weld is deposited or 25% of the groove is filled, whichever is less.

4.1.6 Arc strikes outside the area of the intended weld are unacceptable.

4.1.7 As-welded surfaces, including tie-ins, shall be smooth, uniform, and free from overlap.

4.1.8 Base metal surfaces shall be free of spatter.

4.1.9 Repair Welding. Any discontinuities in excess of the maximum permitted in 4.2 shall be removed and may be repaired by welding after the area has been magnetic particle or dye penetrant inspected to assure complete removal of discontinuities.

4.1.9.1 Defect Removal. All defects in welds or base materials requiring repair shall be removed by flame or arc gouging, grinding, chipping, or machining. Preheating may be required for flame or arc gouging on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface. When a defect is removed but welding repair is unnecessary, the surface shall be contoured to eliminate any sharp notches or corners. The contoured surface shall be reinspected by the same means originally used for locating the defect.

4.1.9.2 Repair Welds. Repair welds shall be made in accordance with a WPS using qualified welders, recognizing that the cavity to be repair welded may differ in contour and dimension from a normal joint preparation and may present different restraint conditions. All repair welds shall meet the visual acceptance criteria of 4.2.

3.2.4 Burn-through (BT). A burn-through is defined as a portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe resulting in a hole or depression in the root bead of a single groove weld. BT shall be considered a defect should any of the following conditions exist:

3.2.4.1 The maximum dimension exceeds 6 mm.

3.2.4.2 The sum of the dimensions of separate BTs exceeds 13 mm in any continuous 300 mm length of weld or the total weld length, whichever is less.

3.2.5 Porosity (P). Porosity is defined as gas trapped by solidifying weld metal before the gas has a chance to rise to the surface of the molten puddle and escape. Porosity is generally spherical but may be elongated or irregular in shape, such as piping (wormhole) porosity. Porosity shall be considered a defect should any of the following conditions exist:

3.2.5.1 The size of an individual pore exceeds 3 mm.

3.2.5.2 The size of an individual pore exceeds 25% of the thinner of the nominal wall thicknesses joined.

3.2.5.3 Cluster porosity (CP) that occurs in the finish pass shall be considered a defect should any of the following conditions exist:

3.2.5.3.1 The diameter of the cluster exceeds 13 mm.

3.2.5.3.2 The aggregate length of CP in any continuous 300 mm length of weld exceeds 13 mm.

3.2.6 Cracks (C). Cracks shall be considered a defect.

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3.2.7 External Undercutting (EU) or Internal Undercutting (IU). Undercutting is defined as a groove melted or any reduction of the parent material adjacent to the toe or root of the weld and left unfilled by weld metal. Undercutting adjacent to the cover pass (EU) or root pass (IU) shall be considered a defect should the maximum dimensions of Table 4 be exceeded.

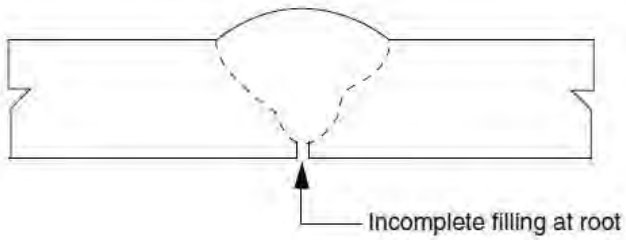
Table 4 – Maximum Dimensions of Undercutting (EU or IU)

Depth	Length
> 0.8 mm or > 12.5% of pipe wall thickness, whichever is smaller	Not acceptable
> 0.4 mm but ≤ 0.8 mm or > 6% but ≤ 12.5% of pipe wall thickness, whichever is smaller	50 mm in a continuous 300 mm weld length or one-sixth the weld length, whichever is smaller
≤ 0.4 mm or ≤ 6% of pipe wall thickness, whichever is smaller	Acceptable, regardless of length

3.2.8 Accumulation of Imperfections (AI). Excluding IPD, EU, and IU, any accumulation of otherwise acceptable imperfections such as P, CP, IF, IP, and BT, shall be considered a defect should any of the following conditions exist:

3.2.8.1 The aggregate length of AI in any continuous 300 mm length of weld exceeds 50 mm.

3.2.8.2 The aggregate length of AI exceeds 8% of the weld length.



Note: One or both root faces may be inadequately filled at the inside surface.

FIGURE C – Inadequate Penetration Without High-Low (IP)

3.2.2. Inadequate Penetration Due to High-low (IPD). Inadequate penetration due to high-low is defined as the condition that exists when one edge of the root is exposed (or unbonded) because adjacent pipe or fitting joints are misaligned. This condition is shown schematically in Figure D. IPD shall be considered a defect should any of the following conditions exist:

3.2.2.1 The length of an individual indication of IPD exceeds 50 mm.

3.2.2.2 The aggregate length of indications of IPD in any continuous 300 mm length of weld exceeds 75 mm.

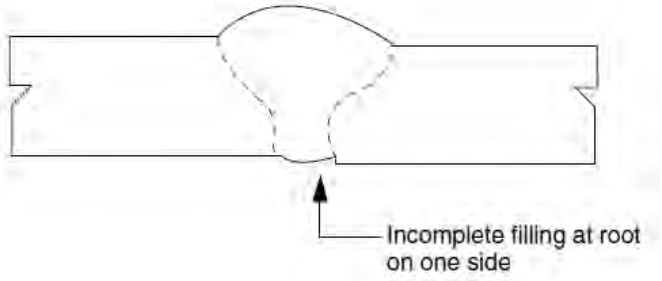


FIGURE D – Inadequate Penetration Due to High-Low (IPD)

3.2.3 Incomplete Fusion (IF). Incomplete fusion is defined as a surface imperfection between the weld metal and the base material that is open to the surface. This condition is shown schematically in Figure E. It shall be considered a defect should any of the following conditions exist:

3.2.3.1 The length of an individual indication of IF exceeds 25 mm.

3.2.3.2 The aggregate length of indications of IF in any continuous 300 mm length of weld exceeds 25 mm.

3.2.3.3 The aggregate length of indications of IF exceeds 8% of the weld length in any weld less than 300 mm in length.

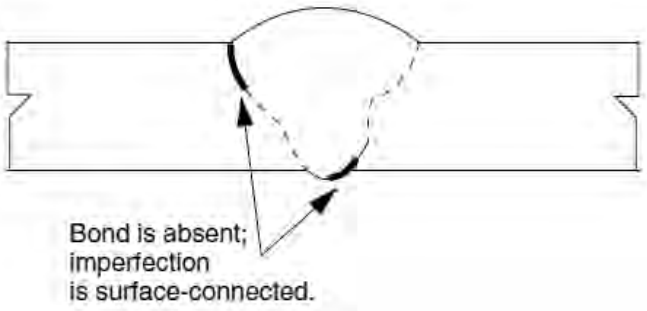


FIGURE E – Incomplete Fusion at Root of Bead or Top of Joint (IF)

3.1.9.3 Repairs of Defects Other Than Cracks. Defects other than cracks in the root, filler, and finish beads may be repaired with prior Company authorization. A qualified repair procedure shall be required whenever a repair is made by welding when:

(1) using a welding process, combination of welding processes, or method of application or filler metals different from that used to make the original weld; or

(2) repairs are made in a previously welded repair area; or

(3) required by the Company.

3.1.9.4 Grinding Repairs. Grinding repairs may be used to remove defects in the reinforcement of root beads and cover passes provided:

(1) there is a smooth transition free of undercutting and other imperfections between the ground area and the original weld, and

(2) pipe surface contour and the minimum wall and weld thickness requirements are not violated.

If the minimum wall/weld thickness is not known, the grinding depth is limited to the excess root bead penetration or external reinforcement. The grinding repair length and number of grinding repair areas is not limited. Grinding repairs do not require the use of a qualified repair procedure.

3.1.9.5 Back Weld Repairs. When back weld repairs are permitted by the Company, a repair procedure shall be qualified.

3.1.9.6 Welded Double Repairs. A double repair requires prior Company authorization. Subsequent repair of a double repair weld is not permitted.

3.1.9.7 Weld Repair and Inspection Procedure. Defects may be removed by grinding, chipping, or gouging or a combination of these methods followed by a weld repair. Prior to welding, the repair groove shall be examined visually and by either PT or MT to verify complete removal of the defect. Preheat and interpass heat treatment shall be the same as required for the original weld. The completed repair shall be visually examined and the entire weld shall be radiographed.

3.2 Visual Inspection Acceptance Criteria

3.2.1 Inadequate Penetration Without High-low (IP). Inadequate penetration without high-low is defined as the incomplete filling of the weld root. This condition is shown schematically in Figure C. IP shall be considered a defect should any of the following conditions exist:

3.2.1.1 The length of an individual indication of IP exceeds 25 mm.

3.2.1.2 The aggregate length of indications of IP in any continuous 300 mm length of weld exceeds 25 mm.

3.2.1.3 The aggregate length of indications of IP exceeds 8% of the weld length in any weld less than 300 mm in length.

3.0 Workmanship Requirements and Visual Inspection Acceptance Criteria – Pipeline

3.1 Workmanship Requirements

3.1.1 Edge preparation details and fit-up dimensions shall be as specified in the WPS.

3.1.2 The beveled ends shall be smooth and uniform.

3.1.3 The alignment of abutting ends shall minimize the offset between surfaces. For pipe ends of the same nominal thickness, the offset shall not exceed 3 mm.

3.1.4 The number of filler and finish beads shall allow the completed weld a substantially uniform cross section around the circumference of the pipe. At no point shall the crown surface fall below the outside surface of the pipe, nor shall it be raised above the parent metal by more than 2 mm.

3.1.5 Adjacent beads shall neither be started nor terminated at the same location.

3.1.6 The face of the completed weld shall be no more than 3 mm wider than the width of the original groove.

3.1.7 The completed weld (including parent metal) shall be thoroughly brushed and cleaned. All spatter shall be removed.

3.1.8 Arc burns on the parent metal surface are unacceptable.

3.1.9 Repair and Removal of Defects

3.1.9.1 Authorization. Company authorization is required for crack repairs, back weld repairs and double repairs. Company authorization is not required for any repairs that do not involve the application of heat or weld metal, such as grinding, filing, etc. Rework is not a repair and does not require Company authorization.

3.1.9.2 Crack Repairs. Cracked welds shall be cut out unless the repair is authorized by the Company. When a crack repair is authorized:

(1) a cracked weld may be repaired by complete or partial removal of the weld provided the length of a single crack or aggregate length of more than one crack in a single repair area is less than 8% of the weld length using a qualified repair procedure;

(2) a weld that contains multiple repair areas with cracks shall not be repaired unless the total accumulated repair length is less than 8% of the weld length and a qualified repair procedure is used;

(3) a double repair of a crack is not permitted. Additional cracking in any weld after repair shall require a cut out;

(4) shallow crater cracks or star cracks found and contained completely in internal or external weld reinforcement may be repaired by grinding (i.e., abrasive methods) without a qualified repair procedure. If the grinding exceeds the internal or external reinforcement, the reinforcement shall be replaced using a qualified weld procedure.

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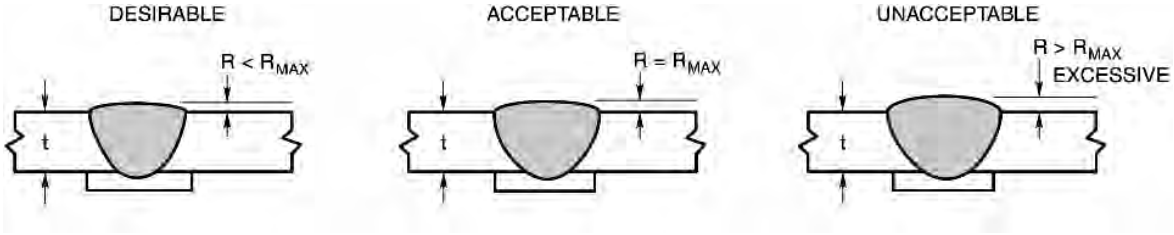

FIGURE A – WELD PROFILES FOR BUTT JOINT REQUIREMENTS (see Tables 2 and 3)

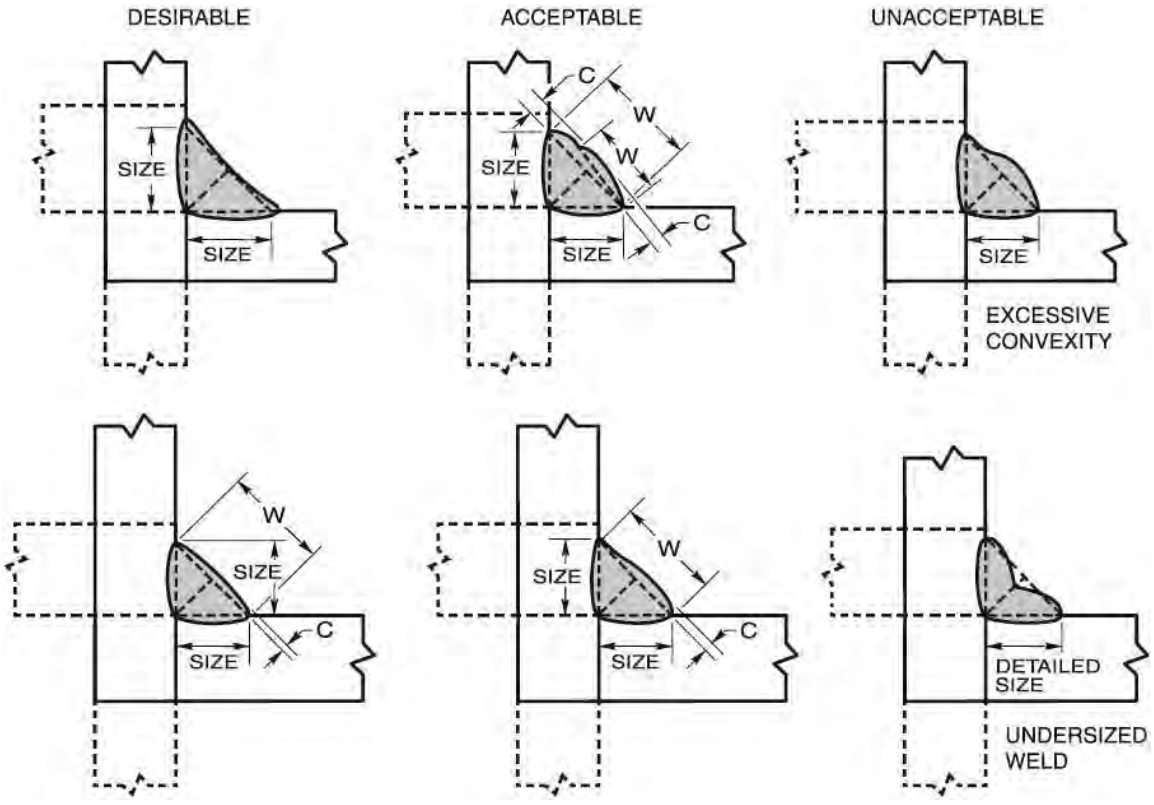

FIGURE B – FILLET WELD PROFILE REQUIREMENTS FOR INSIDE CORNER JOINTS, LAP JOINTS, AND T-JOINTS (see Tables 2 and 3)

Table 2
Weld Profiles (see 2.3.1)

Weld Type	Joint Type			
	Butt	T-Joint	Lap	Corner-Inside
Groove (CJP or PJP)	Figure A	N/A	N/A	N/A
	Schedule A	N/A	N/A	N/A
Fillet	N/A	Figure B	Figure B	Figure B
	N/A	Schedule B	Schedule B	Schedule B

Table 3
Weld Profile Schedules (see 2.3.1)

Schedule A (t = thickness of thicker plate joined for CJP; t = throat size for PJP)

t	R min.	R max.
≤ 25 mm	0	2 mm
> 25 mm ≤ 50 mm	0	3 mm
> 50 mm	0	5 mm

Schedule B (W = width of weld face or individual surface bead; C = allowable convexity)

W	C min.	C max.
≤ 8 mm	0	2 mm
> 8 mm < 25 mm	0	3 mm
≥ 25 mm	0	5 mm

Table 1
Visual Inspection Acceptance Criteria – Structural Steel

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
1) Crack Prohibition Any crack shall be unacceptable, regardless of size or location.	X	X	X
(2) Weld/Base-Metal Fusion Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
(3) Crater Cross Section All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 2.3.1.	X	X	X
(5) Time of Inspection Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A 514, A 517, and A 709 Grade 100 and 100 W steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X
(6) Undersized Welds The size of a fillet weld in any continuous weld may be less than the specified nominal size (L) without correction by the following amounts (U): L, specified nominal weld size, mm / U, allowable decrease from L, mm ≤ 5 / ≤ 2 6 / ≤ 2.5 ≥ 8 / ≤ 3	X	X	X
(7) Undercut (A) For material less than 25 mm thick, undercut shall not exceed 0.8 mm. For material equal to or greater than 25 mm thick, undercut shall not exceed 2 mm for any length of weld.	X		
(B) In primary members, undercut shall be no more than 0.25 mm deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 0.8 mm deep for all other cases.		X	X
(8) Porosity (A) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible porosity. For all other groove welds and for fillet welds, the sum of the visible porosity 0.8 mm or greater in diameter shall not exceed 10 mm in any linear 25 mm of weld.	X		
(B) The frequency of porosity in fillet welds shall not exceed one in each 100 mm of weld length and the maximum diameter shall not exceed 2.5 mm. Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of porosity shall not exceed 10 mm in any linear 25 mm of weld.		X	X
(C) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no porosity. For all other groove welds, the frequency of porosity shall not exceed one in 100 mm of length and the maximum diameter shall not exceed 2.5 mm.		X	X

Note: An “X” indicates applicability for the connection type; a shaded area indicates non-applicability.

2.2.4.1 Statically Loaded Connections. Terminations and starts shall be made by either holding the weld back from the corner for a distance not less than the specified fillet weld size or by wrapping the weld around the corner not less than two times nor more than four times the specified fillet weld size.

2.2.4.2 Cyclically Loaded Connections. Terminations and starts shall be made by wrapping the weld around the corner for a distance not less than two times nor more than four times the specified fillet weld size.

2.2.5 Repairs. The removal of weld metal or portions of the base metal may be done by machining, grinding, chipping, or gouging. It shall be done in such a manner that the adjacent weld metal or base metal is not nicked or gouged. Unacceptable portions of the weld shall be removed without substantial removal of the base metal. The surfaces shall be cleaned thoroughly before welding. Weld metal shall be deposited to compensate for any deficiency in size in the weld metal.

2.3 Visual Inspection Acceptance Criteria. All welds shall be visually inspected and meet the acceptance criteria of Table 1.

2.3.1 Weld Profiles. Weld profiles shall be in accordance with Table 1, Table 2, and Table 3, Figure A, Figure B, except as otherwise allowed in 2.3.1.1, 2.3.1.2 and 2.3.1.3.

2.3.1.1 Fillet Welds. Unless otherwise specified, the faces of fillet welds may be slightly convex, flat, or slightly concave as shown in Figure B.

2.3.1.2 Exception for Intermittent Fillet Welds. Except for undercut, as allowed by this specification, the profile requirements of Figure B shall not apply to the ends of intermittent fillet welds outside their effective length.

2.3.1.3 Groove Welds. Groove weld reinforcement shall comply with Table 2 and Table 3. Welds shall have a gradual transition to the plane of the base-metal surfaces.

2.3.1.4 Overlap. All welds shall be free of overlap.

2.4 Fillet Weld Dimensional Tolerances

2.4.1 Weld length and spacing. Unless otherwise specified, the weld length indicated is the minimum weld length and there is no maximum. The length of a fillet weld is the overall length of the full size fillet, including end returns (boxing) as measured along the center line of the effective throat and excluding the undersize portions of starts and stops. The tolerances of subclause 1.3.2 shall be applied to determine if the minimum length is acceptable, e.g., a 74.2 mm weld length satisfies the requirement for a 75 mm weld.

Unless otherwise specified, the weld spacing (pitch) is the maximum spacing between the centers of adjacent welds and there is no minimum. The tolerances of subclause 1.3.2 shall be applied to determine if the actual measured maximum spacing is acceptable, e.g., a 75.8 mm spacing satisfies the requirement for a 75 mm spacing.

2.4.2 Fillet Weld Size. Unless otherwise specified in the visual inspection acceptance criteria, the fillet weld size is the minimum weld size and there is no maximum. The tolerances of subclause 1.3.2 do not apply.

2.0 Workmanship Requirements and Visual Acceptance Criteria – Structural Steel

2.1 Base Metal Preparation

2.1.1 Mill-Induced Discontinuities. The length of these discontinuities is the visible long dimension on the cut surface of material and the depth is the distance that the discontinuity extends into the material from the cut surface. The limits of acceptability and the repair of visually observed cut surface discontinuities shall be as follows:

(a) Any discontinuity 25 mm in length or less need not be repaired and the depth need not be explored.

(b) Any discontinuity over 25 mm in length with maximum depth of 3 mm need not be repaired, but the depth should be explored.

(c) Any discontinuity over 25 mm in length with depth over 3 mm but not greater than 6 mm shall be completely removed and repair welded.

(d) Any discontinuity over 25 mm in length with depth over 6 mm shall be referred to the Engineer for disposition.

2.2 Workmanship Requirements

2.2.1 Roughness Requirements. Weld edge prep and other edge surfaces shall be evaluated with the surface roughness guide AWS C4.1-77. Acceptance criteria shall be as follows:

2.2.1.1 Weld edge prep surfaces for manual and semiautomatic welding processes shall not be rougher than Sample 3 and shall have no gouges deeper than 1.5 mm.

2.2.1.2 Weld edge prep surfaces for mechanized and automatic welding processes (except SAW) shall not be rougher than Sample 4 and shall have no gouges.

2.2.1.3 Weld edge prep surfaces for SAW shall not be rougher than Sample 3 and shall have no gouges.

2.2.1.4 Edges of members not subject to calculated stresses shall not be rougher than Sample 2 and shall have no gouges deeper than 3 mm.

2.2.1.5 All other edges shall not be rougher than Sample 3 and shall have no gouges deeper than 1.5 mm.

2.2.2 Arc Strikes. Base metal shall be free of arc strikes.

2.2.3 Cleaning of Completed Welds. Slag shall be removed from all completed welds. Spatter is acceptable unless NDT other than visual inspection is to be performed or otherwise specified.

2.2.4 Fillet Weld Terminations and Starts. Fillet welds shall not be terminated on corners of lap joints. Terminations and starts shall be as follows:

1.3 Dimensional Tolerances

Unless otherwise specified, the following standard dimensional tolerances shall apply when using this specification. They do not apply to the dimensions in test specimens, Annex IV, or to discontinuity acceptance limits.

1.3.1 Decimal tolerances are determined by the number of decimal places (precision) used in the dimension as follows:

X.X	± 0.3	(e.g,, 1.0 mm could be 0.7 to 1.3 mm)
X.XX	± 0.13	(e.g., 1.00 mm could be 0.87 to 1.13 mm)

1.3.2 Whole number tolerances are determined by the overall dimensional length used in the dimension as follows:

Whole numbers > 150 mm	± 3 mm
Whole numbers from 25 to 150 mm inclusive	± 1.5 mm
Whole numbers from 1 to < 25 mm	± 0.8 mm

1.0 General Requirements

1.1 Scope

1.1.1 This specification applies to the American Welding Society Certified Welding Inspector (CWI) examination and shall not be used for any other purpose. The CWI Practical Exam relies on the use of molded plastic replicas of actual weld specimens and as there are some visual characteristics of metal that do not reproduce in plastic with sufficient fidelity, the exclusion of acceptance criteria for these characteristics should not be construed as an endorsement for the exclusion of these criteria for any actual fabrication.

1.1.2 This specification includes representative requirements for Structural Steel, Pipeline, and Pressure Piping applications. They are intended to be applied to inspector examination weld replicas and not to actual industrial facilities, equipment, or structures.

1.1.3 Unless otherwise noted, requirements contained in this *Book of Specifications*, in Clauses 1.0, 5.0, and 6.0, are to be considered general requirements applicable to all three applications.

1.1.4 Normative Annexes in this specification are provided for requirements and Informative Annexes are provided for information. Both are considered as part of this specification. No inference should be drawn from the assignment of Normative versus Informative as to the use of the Annex on the examination.

1.1.5 Calculations, formulae, definitions, and material properties used on the CWI examination will be based on data published in the Annexes to this specification. As this *Book of Specifications* applies to three applications, terms and definitions are not limited to AWS A3.0, *Standard Welding Terms and Definitions*.

1.1.6 Use of the terms “shall,” “should,” and “may” in this specification have the following significance:

1.1.6.1 Shall. Specification provisions that use “shall” are mandatory.

1.1.6.2 Should. Specification provisions that use “should” are non-mandatory practices that are considered beneficial.

1.1.6.3 May. Specification provisions that use “may” mandate the choice of optional procedures or practices that can be used as an alternative or supplement to specification requirements.

1.2 Visual Inspection

1.2.1 Visual inspection for cracks in welds and base metal and other discontinuities may be aided by a flashlight, magnifier, and mirror as may be found helpful or necessary.

1.2.2 Weld sizes, length, and locations of welds shall conform to the requirements of this specification.

1.2.3 Joint preparations, assembly, and welding techniques shall be verified.

1.2.4 Suitable measuring tools and gages shall be used where necessary.

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FOREWORD

This *Part B Book of Specifications* is intended to be used as a reference book for taking the hands-on practical examination that is part of the CWI certification examinations. This practical examination simulates actual hands-on inspection and document reviews performed by the Certified Welding Inspector (CWI). You are expected to evaluate the acceptability of test specimens and documents for both procedure and welder qualifications and production welding by using standard measurement tools, visual inspection, and documents found in the Book of Exhibits. Acceptability is based upon the information contained in this *Book of Specifications*. The practical examination will test your ability to carry out these functions.

Although this *Book of Specifications* is formatted to look like a real codebook, it is not a real codebook and it should not be used as one. While some clauses in this *Book of Specifications* appear to be similar to codebooks that you are familiar with, read this *Book of Specifications* very carefully and do not rely on your memory to make decisions with regards to answers on this examination.

Review the organization of this *Part B Book of Specifications*. There are specific clauses that relate to workmanship and visual inspection criteria in three applications: Structural, Pipeline, and Pressure Piping. There are general clauses for inspection, procedure, and performance qualification that apply to all three applications. As this *Book of Specifications* applies to three applications, terms and definitions are not limited to AWS A3.0, *Standard Welding Terms and Definitions*.

In addition to the main body of the specification, there are annexes, tables, and figures that are important in your examination decisions. They are numbered uniquely so as to avoid confusion. Make sure that you have located all the necessary annexes, tables, and figures before you answer any question.

A Book of Exhibits is used in the exam and contains examples of various documents and photos including but not limited to WPS's, PQR's WQTR's, heat treat charts, and NDE methods. Neither the test specimens nor the Book of Exhibits are available for review prior to the examination.

For some questions, narratives will give you information upon which you will be asked specific questions. The question may make reference to locations on certain specimens included in your test kit or refer to documents within the Book of Exhibits. In addition to the Book of Exhibits, all test kits have standard measuring tools necessary to complete the examination.

IMPORTANT

1. Read each question carefully and completely, including every choice provided. There will only be one correct answer. Be careful to transfer your choice of answer to the correct location on the answer sheet.

2. The weld replicas in the assigned test kit are made of plastic to assure that every test candidate receives the exact same specimens. As a consequence of the replication process, there may be color variations from actual weld metal and visible seams from the plastic assembly process. Ignore any pinholes, seams, glue squeezed out, or color variations in your determination of a correct answer.

3. You are expected to know how to use and apply each measuring and inspection instrument in the examination kit including knowing how to properly zero the instrument where relevant.

4. Use the margins or blank pages in your examination booklet to perform any required calculations. Do not write in this booklet.

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