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Badania radiograficzne złączy spawanych wg ASME BPVC.V:2023 / Radiographic examination of welded joints acc. to ASME BPVC.V:2023

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1. Zakres

Procedura opisuje badanie rentgenowskie złączy spawanych według ASME BPVC V:2023.

2. Zastosowanie

Procedura ma zastosowanie do badania płaskich, kątowych i obwodowych spoin czołowych złączy spawanych dla blach i rur stalowych.

3. Dokumenty odniesienia

ASME BPVC.V:2023 Boiler and pressure vessel code Nondestructive examination.

ASTM E94/E94M Standard guide for radiographic examination using industrial radiographic film.

4. Personel badań nieniszczących

Personel badań nieniszczących musi posiadać kwalifikacje i certyfikaty zgodne z NVT/RT/ASME/WPSNT2020.

5. Stosowana aparatura

5.1. Źródło promieniowania

Badanie należy przeprowadzić aparatem rentgenowskim lub izotopem promieniotwórczym odpowiednim do danego zastosowania.

5.2. Błona radiograficzna

Radiogramy należy wykonywać stosując przemysłowe błony radiograficzne (wg ASME V, Artykuł 2, par. T-231). Wybór typu błony zależy od indywidualnych wymagań użytkownika, takich jak:

- poziom wymaganej jakości radiogramu
- czasy ekspozycji
- inne czynniki jak np. ekonomiczne itp.

(wg ASTM E94/E94M, par. 9)

5.3. Okładki

Okładki z folii ołowianej należy stosować w bezpośrednim kontakcie z błoną radiograficzną.

5.4. Filtry

Nie należy stosować żadnych filtrów.

5.5. Wskaźnik jakości obrazu

Należy stosować wskaźniki obrazu typu pręcikowego. Wskaźniki pręcikowe muszą być wyprodukowane i oznakowane zgodnie z wymaganiami BPVC.V:2023, Artykuł 22, SE-747 lub analogicznymi dopuszczanymi przez ASME, z wyjątkiem tego że najwyższy numer pręcika lub numer identyfikacyjny może być pominięty. Wskaźniki jakości obrazu wg normy ASME powinny być zgodne z tymi z ASME V, Artykuł 2, Tabela T-233.2.

Należy dobrać wskaźnik jakości obrazu wytworzony ze stopu tej samej grupy lub gatunku co materiału prześwietlany lub z grupy materiałowej lub gatunku o mniejszej absorpcji promieniowania niż materiał prześwietlany.

1. Scope

This procedure describes radiographic examination of welded joints according to ASME BPVC V:2023.

2. Application

This procedure is to be applied to examination of flat, angle and circumferential butt-welded joints in plates and pipes, made of steel.

3. Referenced documents

ASME BPVC.V:2023 Boiler and pressure vessel code Nondestructive examination.

ASTM E94/E94M Standard guide for radiographic examination using industrial radiographic film.

4. NDT personnel

NDT personnel shall be qualified and certificated in accordance with NVT/RT/ASME/WPSNT2020.

5. Equipment used

5.1. Radiation source

The examination shall be carried out by means of an X-ray generator or a radiation isotope suitably for the requirements given.

5.2. Radiographic film

Radiographs shall be made using industrial radiographic film (acc. to ASME V, Article 2, par. T-231). Choice of film type depends on individual user requirements, as follows:

- radiographic quality levels
- exposure times
- other factors like cost efficiency etc.

(acc. to ASTM E94/E94M, par. 9)

5.3. Screens

Lead foil screens are used in direct contact with films.

5.4. Filters


No filters shall be used.

5.5. Image Quality Indicator (IQI)

IQI shall be wire type. Wire-type IQIs shall be manufactured and identified in accordance with the requirements or alternates allowed in ASME BPVC.V:2023, Article 22, SE-747, except that the largest wire number or the identity number may be omitted. ASME standard IQIs shall consist of those in ASME V, Article 2, Table T-233.2.

IQI shall be selected from either the same alloy material group or grade or from an alloy material group or grade with less radiation absorption than the material being radiographed.

The designated essential wire shall be as specified in ASME V, Article 2, Table T-276.


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Wymagany pręciak powinien być zgodny z wyszczególnieniem w ASME V, Artykuł 2, Tabela T-276.

Table T-233.2				IQI Group	Wire Material
Wire IQI Designation, Wire Diameter, and Wire Identity				Group 1	Stainless Steel
Set A		Set B		Group 2	Aluminium Bronze
Wire Diameter, in. (mm)	Wire Identity	Wire Diameter, in. (mm)	Wire Identity	Group 3	Inconel
0.0032 (0.08)	1	0.010 (0.25)	6	Group 4	Copper
0.004 (0.10)	2	0.013 (0.33)	7	Group 01	Titanium
0.005 (0.13)	3	0.016 (0.41)	8	Group 02	Aluminium
0.0063 (0.16)	4	0.020 (0.51)	9	Group 03	Magnesium
0.008 (0.20)	5	0.025 (0.64)	10		
0.010 (0.25)	6	0.032 (0.81)	11		
Set C		Set D			
Wire Diameter, in. (mm)	Wire Identity	Wire Diameter, in. (mm)	Wire Identity		
0.032 (0.81)	11	0.100 (2.54)	16		
0.040 (1.02)	12	0.126 (3.20)	17		
0.050 (1.27)	13	0.160 (4.06)	18		
0.063 (1.60)	14	0.200 (5.08)	19		
0.080 (2.03)	15	0.250 (6.35)	20		
0.100 (2.54)	16	0.320 (8.13)	21		

Table T-276						
IQI Selection						
Nominal Single-Wall Material Thickness Range, in. (mm)	IQI					
	Source Side			Film Side		
	Hole-Type Designation	Essential Hole	Wire-Type Essential Wire	Hole-Type Designation	Essential Hole	Wire-Type Essential Wire
≤0.25 (≤6.4)	12	2T	5	10	2T	4
>0.25 through 0.375 (>6.4 through 9.5)	15	2T	6	12	2T	5
>0.375 through 0.50 (>9.5 through 12.7)	17	2T	7	15	2T	6
>0.50 through 0.75 (>12.7 through 19.0)	20	2T	8	17	2T	7
>0.75 through 1.00 (>19.0 through 25.4)	25	2T	9	20	2T	8
>1.00 through 1.50 (>25.4 through 38.1)	30	2T	10	25	2T	9
>1.50 through 2.00 (>38.1 through 50.8)	35	2T	11	30	2T	10
>2.00 through 2.50 (>50.8 through 63.5)	40	2T	12	35	2T	11
>2.50 through 4.00 (>63.5 through 101.6)	50	2T	13	40	2T	12
>4.00 through 6.00 (>101.6 through 152.4)	60	2T	14	50	2T	13
>6.00 through 8.00 (>152.4 through 203.2)	80	2T	16	60	2T	14
>8.00 through 10.00 (>203.2 through 254.0)	100	2T	17	80	2T	16
>10.00 through 12.00 (>254.0 through 304.8)	120	2T	18	100	2T	17
>12.00 through 16.00 (>304.8 through 406.4)	160	2T	20	120	2T	18
>16.00 through 20.00 (>406.4 through 508.0)	200	2T	21	160	2T	20

GENERAL NOTE: It is recognized that the required hole-type designation or wire-type essential wire in this table may not achieve an IQI sensitivity level of 2-2T. This is intentional.

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Spoiny z wyciekami i nadlewem: Grubość, na podstawie której dobierany jest wskaźnik jakości obrazu, to nominalna grubość pojedynczej ścianki plus wysokość wycieku i nadlewu (str. wew. oraz str.zew.). Nie jest wymagane mierzenie wysokości nadlewu i wycieku. Grubości podkładek nie należy brać pod uwagę przy wyborze pręcika.

Spoiny bez nadlewu i wycieku: Grubość, na podstawie której dobierany jest wskaźnik jakości obrazu, to nominalna grubość pojedynczej ścianki. Grubości podkładek nie należy brać pod uwagę przy wyborze pręcika. (zgodnie z ASME V, Artykuł 2, punkt T-276.2)

6. Wykonanie badania

6.1. Przygotowanie do badania

6.1.1. System opisu radiogramów

Należy stosować systemową metodę trwałej identyfikacji każdego radiogramu, umożliwiającą prześledzenie wg zlecenia, elementu, spoiny lub numeru części, numer seryjny w zależności od rodzaju elementu badanego. Dodatkowo, symbol producenta lub nazwa i data radiogramu powinny być w sposób widoczny i trwałe uwidocznione na każdym radiogramie. W takim systemie oznaczania nie jest wymagane umieszczanie informacji na obrazie radiogramu. W każdym wypadku, taka informacja nie może zasłaniać badanego obszaru (ASME V, Artykuł 2, paragraf T-224).

6.1.2. Znaczniki położenia

Znaczniki położenia (rysunek T-275), które muszą się pojawić w obrazie radiogramu, powinny być umiejscowione na elemencie, a nie na kasecie / uchwycie błony. Umieszczenie znaczników położenia, jeśli dozwolone, powinno być trwale oznaczone na prześwietlanym elemencie; w innym wypadku umiejscowienie znacznika należy oznaczyć na planie w taki sposób, aby obszar zawarty na radiogramie mógł być jednoznacznie odniesiony do jego lokalizacji na badanym elemencie. Na radiogramie należy również wykazać, że wymagane pokrycie badanego obszaru zostało zapewnione. Znaczniki położenia powinny być umiejscowione jak pokazano w ASME V, Artykuł 2, rysunek T-275.

Welds with reinforcements: The thickness on which the IQI is based is the nominal single-wall thickness plus the actual weld reinforcement thickness estimated to be present on both sides of the weld (I.D. and O.D.). Physical measurement of the actual weld reinforcements is not required. Backing rings or strips shall not be considered as part of the thickness in IQI selection.

Welds without reinforcements: The thickness on which the IQI is based is nominal single-wall material thickness. Backing strips or strips shall not be considered as part of the thickness in IQI selection. (according to ASME V, Article 2, point T-276.2)

6. Examination execution

6.1. Examination preparation

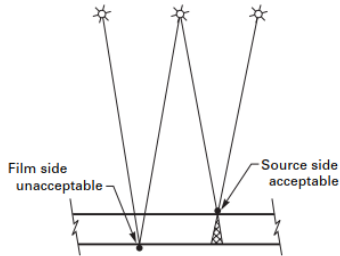
6.1.1. Identification system

A system shall be used to procedure on each radiograph permanent identification on the radiograph traceable to the contract, component, weld or part numbers, serial number as appropriate. In addition, the Manufacturer's symbol or name and the date of the radiograph shall be plainly and permanently included in each radiograph. This identification system does not necessarily require that the information appear as radiographic images. In any case, this information shall not obscure the area of interest (ASME V, Article 2, paragraph T-224).

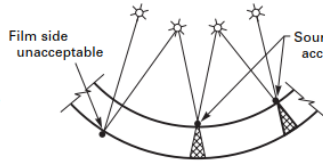
6.1.2. Location markers

Location markers (Figure T-275) which shall to appear as radiographic images on the radiograph, shall be placed on the part, not on the exposure holder / cassette. Their locations shall be permanently marked on the surface of the part being radiographed when permitted, or on a map, in a manner permitting the area of interest on radiograph to be accurately traceable to its location on the part, for the required retention period of the radiograph. Evidence shall also be provided on the radiograph that the required coverage of the region being examined has been obtained. Locations markers shall be placed as shown in ASME V, Article 2, Figure T-275.

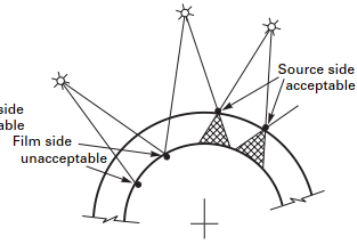
Figure T-275
 Location Marker Sketches



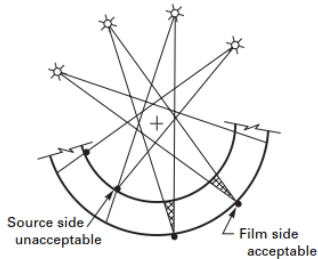
Flat component or longitudinal seam
 [See T-275.1(a)(1)]
 [See sketch (e) for alternate]
 (a)



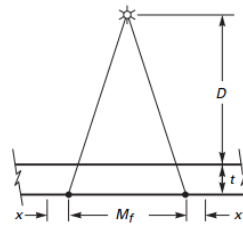
Curved components with radiation source to
 film distance less than radius of component
 [See T-275.1(a)(2)]
 (b)



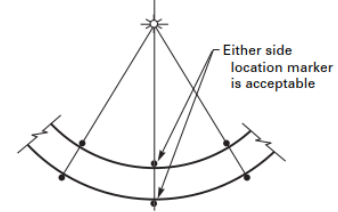
Curved components with convex surface
 towards radiation source
 [See T-275.1(a)(3)]
 (c)



Curved components with radiation source to
 film distance greater than radius of curvature
 [See T-275.1(b)(1)]
 (d)




Source side marker alternate
 Flat component or longitudinal seam
 $x = (t / D) (M_f / 2)$
 x = additional required coverage
 beyond film side location marker
 t = component thickness
 M_f = film side location marker interval
 D = source to component distance
 [See T-275.1(b)(2)]
 (e)



Curved components with radiation source
 at center curvature
 [See T-275.1(c)]
 (f)

LEGEND: Radiation source — ☆
 Location marker — •
 Component center — +

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6.1.3. Promieniowanie rozproszone

Ołowiany symbol „B”, o minimalnych wymiarach: wysokość 11 mm, grubość 1,5 mm, musi być dołączony z tyłu każdej kasety podczas każdej ekspozycji w celu określenia, czy błona jest naświetlana promieniowaniem wstecznym rozproszonym. Ołowiany symbol „B” powinien być umiejscowiony tak by był widoczny na radiogramie i spełniał wymagania T-282 ASME V. (ASME V, Artykuł 2, paragraf T-223).

Jeżeli widoczny jest jasny obraz litery „B” na ciemniejszym tle radiogramu, ochrona przed promieniowaniem wstecznym rozproszonym jest niewystarczająca, a obraz radiograficzny uważa się za nieakceptowalny. Ciemna litera „B” na jaśniejszym tle nie jest podstawą do odrzucenia obrazu.

6.2. Technika badania

Technika ekspozycji przez jedną ściankę powinna być stosowana, kiedy tylko jest to praktycznie uzasadnione. Kiedy stosowanie techniki ekspozycji przez jedną ściankę jest niepraktyczne, należy stosować technikę ekspozycji przez dwie ścianki. W celu zapewnienia wymaganego pokrycia obszaru badanego powinna być wykonana odpowiednia ilość ekspozycji (ASME V, Artykuł 2, paragraf T-271)

6.2.1. Ekspozycja przez jedną ściankę

W technice ekspozycji przez jedną ściankę, promieniowanie przechodzi tylko przez jedną ściankę złącza spawanego i jest ona klasyfikowana na radiogramie (ASME V, Artykuł 2, paragraf T-271.1)

6.2.2. Ekspozycja przez dwie ścianki

Kiedy zastosowanie techniki ekspozycji przez jedną ściankę nie jest możliwe, należy stosować jedną z poniższych technik ekspozycji przez dwie ścianki:

Klasyfikacja jednego obrazu. Dla spoin na elementach, można stosować technikę, w której promieniowanie przechodzi przez dwie ścianki, a tylko spoina na ściance od strony błony jest klasyfikowana na radiogramie. Kiedy wymagane jest prześwietlenie 100% spoiny obwodowej, należy wykonać co najmniej trzy ekspozycje co 120°.

Klasyfikacja dwóch obrazów. Dla spoin na elementach o średnicy zewnętrznej równej lub mniejszej niż 89 mm, można stosować technikę, w której promieniowanie przechodzi przez dwie ścianki i spoiny na obu ściankach są klasyfikowane na podstawie tego samego radiogramu. Do klasyfikacji dwóch ścianek wskaźnik jakości obrazu należy umieszczać od strony źródła. Ze szczególną uwagą należy upewnić się, że wymagana nieostrość geometryczna nie została przekroczona. Jeśli wymagane nieostrości geometrycznej nie może być spełnione, należy stosować technikę klasyfikacji przez 1 ściankę. Kiedy wymagane jest prześwietlenie 100% spoiny, na każdym złączu należy wykonać co najmniej dwie ekspozycje pod kątem 90°

6.1.3. Backscatter radiation

A lead symbol “B”, with minimum dimensions of 11 mm in height and 1,5 mm in thickness, shall be in direct contact with the back of each film holder or cassette during each exposure to determine if backscatter radiation is exposing the film. The lead symbol “B” shall be placed in a location so that it would appear within an area on the radiograph that meets the requirements of T-282 of ASME V. (ASME V, Article 2, paragraph T-223)

If a light image of the “B”, appears on a darker background of the radiograph, protection from backscatter is insufficient and the radiographic image shall be considered unacceptable. A dark image of the “B” on a lighter background is not cause for rejection.

6.2. Radiographic Technique

A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double-wall technique shall be used. An adequate number of exposures shall be made to demonstrate that required coverage has been obtained (ASME V, Article 2, paragraph T-271).

6.2.1. Single-wall technique


In the single-wall technique, the radiation passes through only one wall of the weld, which is viewed for acceptance on the radiograph. (according to ASME V, Article 2, paragraph T-271.1)

6.2.2. Double wall technique

When it is not practical to use a single-wall technique, one of the following double-wall techniques shall be used:

Single-wall viewing. For welds in components, a technique may be used in which the radiation passes through two walls and only the weld on the film-side wall is viewed for acceptance on the radiograph. When complete coverage is required for circumferential welds, a minimum of three exposures taken 120° to each other shall be made.

Double-wall viewing. For welds in components 89 mm or less in nominal outside diameter, a technique may be used in which the radiation passes through two walls and the weld in both wall is viewed for acceptance on the same radiograph. For double-wall viewing, only a source side IQI shall be used. Care should be exercised to ensure that the required geometric unsharpness is not exceeded. If the geometric unsharpness requirement cannot be met, then single-wall viewing shall be used. When complete coverage is required, a minimum of two exposures taken 90° to each other shall be made for each joint. As an alternative a minimum of three exposures 60° or 120°

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względem siebie. Alternatywnie można na każdym złączy wykonać minimum trzy ekspozycje pod kątem 60° lub 120° względem siebie (ASME V, Artykuł 2, paragraf T-271.2).

Należy wykonać dodatkowe ekspozycje jeżeli nie jest możliwe uzyskanie pełnego prześwietlenia technikami opisanymi powyżej.

6.2.3. Technika radiograficzna dla spoin rur

ASME V, Artykuł 2, Aneks A przedstawia techniki stosowane w badaniu radiograficznym spoin rur. Można stosować inne techniki tam, gdzie mają zastosowanie.

to each other shall be made for each joint (ASME V, Article 2, paragraph T-271.2).

Additional exposure shall be made if the required radiographic coverage cannot be obtained using the minimum number of exposure indicated above.

6.2.3. Radiographic technique for tube welds

ASME V, Article 2, Appendix A illustrates techniques used in the radiographic examination of tube welds. Other techniques may be used where appropriate.

Figure A-210-1
Single-Wall Radiographic Techniques

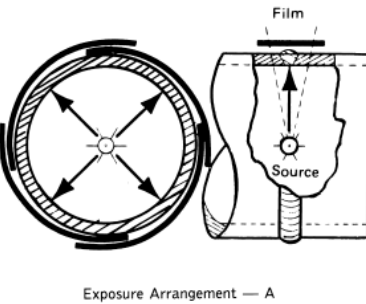
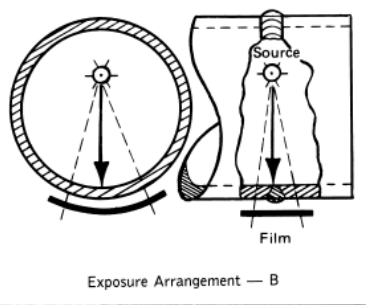
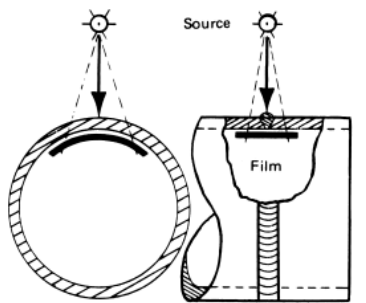
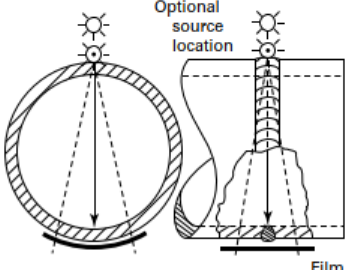
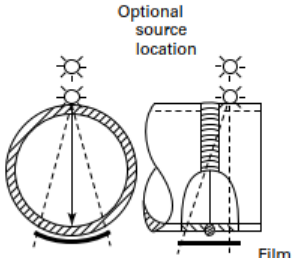
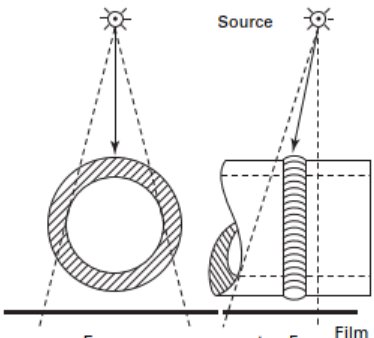
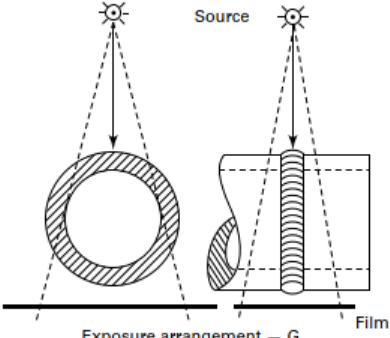

Pipe O.D.	Exposure Technique	Radiograph Viewing	Source-Weld-Film Arrangement		IQI		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Single-Wall T-271.1	Single-Wall			T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Either Side T-275.3 T-275.1(c)
Any	Single-Wall T-271.1	Single-Wall			T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Film Side T-275.1 (b)(1)
Any	Single-Wall T-271.1	Single-Wall			T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Source Side T-275.1 (a)(3)

Figure A-210-2
Double-Wall Radiographic Techniques

O.D.	Exposure Technique	Radiograph Viewing	Source-Weld-Film Arrangement		IQI		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Double- Wall: T-271.2(a) at Least 3 Exposures 120 deg to Each Other for Complete Coverage	Single-Wall	 <p>Exposure arrangement – D</p>		T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Film Side T-275.1(b) (1)
Any	Double- Wall: T-271.2(a) at least 3 Exposures 120 deg to Each Other for Complete Coverage	Single-Wall	 <p>Exposure arrangement – E</p>		T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Film Side T-275.1(b) (1)
3 1/2 in. (89 mm) or Less	Double-Wall T-271.2(b)(1) at Least 2 Exposures at 90 deg to Each Other for Complete Coverage	Double-Wall (Ellipse): Read Offset Source Side and Film Side Images	 <p>Exposure arrangement – F</p>		T-276 and Table T-276	Source Side T-277.1(a)	Either Side T-275.2
3 1/2 in. (89 mm) or Less	Double-Wall: T-271.2(b)(2) at Least 3 Exposures at 60 deg or 120 deg to Each Other for Complete Coverage	Double-Wall: Read Super-imposed Source Side and Film Side Images	 <p>Exposure arrangement – G</p>		T-276 and Table T-276	Source Side T-277.1(a)	Either Side T-275.2

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6.3. Czynności związane z badaniem

6.3.1. Przygotowanie powierzchni

Kształty spoiny lub nierówności powierzchni złącza powinny być usunięte ze strony zewnętrznej wewnętrznej (tam, gdzie to możliwe) spoiny za pomocą odpowiedniej obróbki tak, aby obraz nierówności powierzchni nie maskował lub nie był mylony z obrazem jakiegokolwiek nieciągłości na uzyskanym radiogramie (ASME V, Artykuł 2, paragraf T-222.2).

6.3.2. Kierunek promieniowania

Centralna wiązka promieniowania powinna być ukierunkowana w środek obszaru badanego, jeśli to możliwe (ASME V, Artykuł 2, paragraf T-273).

6.3.3. Nieostrość geometryczna (ograniczenia)

Zalecane maksymalne wartości dla nieostrości geometrycznej są określone poniżej (ASME V, Artykuł 2, paragraf T-274.2):

Material Thickness, in. (mm)	U_g Maximum, in. (mm)
Under 2 (50)	0.020 (0.51)
2 through 3 (50–75)	0.030 (0.76)
Over 3 through 4 (75–100)	0.040 (1.02)
Greater than 4 (100)	0.070 (1.78)

Nieostrość geometryczną radiogramu określa się zgodnie z:

$$U_g = (F * d) / D$$

gdzie:

D = odległość od źródła promieniowania do spoiny lub obiektu prześwietlanego

d = odległość, od strony źródła, od spoiny lub obiektu prześwietlanego do filmu

F = rozmiar źródła: maksymalny rzutowany wymiar źródła promieniowania (lub efektywnego ogniska) w płaszczyźnie prostopadłej do odległości D od spoiny lub obiektu poddawanego radiografii

U_g = nieostrość geometryczna

„D” i „d” należy zmierzyć w rejonie środka obszaru poddawanemu prześwietleniu.

6.3.4. Energia promieniowania

Energia promieniowania stosowana w jakiegokolwiek technice radiograficznej powinna spełniać wymagania tej procedury dotyczące gęstości i wskaźników jakości obrazu (ASME V, Artykuł 2, paragraf T-272).

Ogólnie, im niższa jest energia stosowanego źródła, tym wyższy można otrzymać kontrast, jakkolwiek, inne zmienne, takie jak geometria i warunki rozpraszania, mogą zmniejszać potencjalne korzyści większego kontrastu. Do uzyskania akceptowalnego poziomu jakości przy użyciu poszczególnych źródeł promieniowania, dla poszczególnych wartości energii, zakres

6.3. Examination related activities

6.3.1. Surface preparation

The weld ripples or weld surface irregularities on both the inside (where accessible) and outside shall be removed by any suitable process to such a degree that the image of surface irregularities cannot mask or be confused with the image of any discontinuity on the resulting radiograph. (ASME V, Article 2, paragraph T-222.2).

6.3.2. Direction of radiation

The direction of the central beam of radiation should be centered on the area of interest whenever practical (ASME V, Article 2, paragraph T-273).

6.3.3. Geometric unsharpness limitations

Recommended maximum values for geometric unsharpness are as follows (ASME V, Article 2, paragraph T-274.2):

Geometric unsharpness of the radiograph shall be determined in accordance with:

$$U_g = (F * d) / D$$

where

D = distance from source of radiation to weld or object being radiographed

d = distance from source side of weld or object being radiographed to the film

F = source size: the maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the weld or object being radiographed


U_g = geometric unsharpness

“D” and “d” shall be determined at the approximate center of the area of interest.

6.3.4. Radiation energy

The radiation energy employed for any radiographic technique shall achieve the density and IQI image requirements of this procedure (ASME V, Article 2, paragraph T-272).

In general, the lower the energy of the source utilized the higher the achievable radiographic contrast, however, other variables such as geometry and scatter conditions may override the potential advantage of higher contrast. For a particular energy, a range of thicknesses, which are multiple of the half value layer, may be radiographed to an acceptable

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prześwietlanej grubości jest wielokrotnością grubości połowicznego osłabienia. Ogólnie, satysfakcjonujące rezultaty mogą być zazwyczaj otrzymane dla energii promieniowania X pomiędzy 100 kV a 500 kV w zakresie grubości materiału między 2,5 a 10 grubości połowicznego osłabienia (half value layers - HVL) (ASME V, Artykuł 22, SE-94 paragraf 7).

Energia	Grubość materiału (stal) [mm]
120 kV	6,2 ÷ 25
150 kV	9 ÷ 36
200 kV	12,7 ÷ 51
250 kV	16 ÷ 64
400 kV (Ir 192)	22,2 ÷ 89

Z powodu wielu czynników dokładna wartość energii dla danej grubości nie może zostać ustalona na stałe. Energię promieniowania, dla której warunki ekspozycji będą najbardziej optymalne, należy ustalić eksperymentalnie, ponieważ w różnych warunkach te same parametry ekspozycji mogą powodować rozbieżne warunki końcowe naświetlania. Należy korzystać z pomocy kalkulatorów ekspozycji i innych pomocy. Niemniej jednak należy przestrzegać wymagań tej procedury dotyczących koniecznego do uzyskania odpowiedniego pręcika IQI.

6.3.5. Położenie filmu

Filmy powinny bezpośrednio przylegać do badanego elementu i być zorientowane prostopadle do centralnej wiązki promieniowania jak to tylko możliwe.

6.3.6. Położenie wskaźnika IQI

Wskaźnik jakości obrazu powinien być umiejscowiony na badanym elemencie od strony źródła. Kiedy ze względu na układ lub rozmiar spoiny nie jest praktyczne umiejscowienie wskaźnika na spoinie, może on być umieszczony na oddzielnym bloku. Oddzielny blok musi być wykonany z tego samego lub podobnego materiału (radiograficznie) i ma umożliwić umiejscowienie wskaźnika jakości obrazu. Wskaźnik jakości obrazu na oddzielnym bloku powinien być umieszczony względem błony nie bliżej niż powierzchnia elementu prześwietlanego znajdująca się od strony źródła. Oddzielny blok powinien zostać umieszczony możliwie blisko elementu prześwietlanego.

Jeżeli nie ma dostępu do umieszczenia wskaźnika jakości obrazu od strony źródła, wskaźnik powinien być umieszczony od strony filmu i przylegać do badanego elementu. Ołowiana litera "F" powinna być umieszczona w sąsiedztwie lub na wskaźniku jakości obrazu ale nie powinna zasłaniać wymaganego pręcika.

Wskaźnik jakości obrazu powinien zostać umieszczony na spoinie tak, aby kierunek długości pręcików był prostopadły do osi wzdłużnej spoiny. Nie jest wymagane, aby cała długość pręcika przechodziła przez spoinę na jej całej szerokości. Niemniej jednak, wymagany pręcik musi przechodzić przez tą część spoiny, która reprezentuje grubość ścianki i nadlewu dla której wytypowano istotny pręcik IQI. Należy również spełnić

quality level utilizing a particular radiation source. In general, satisfactory results can normally be obtain for X-ray energies between 100kV to 500kV in a range between 2,5 to 10 half value layers (HVL) of material thickness (ASME V, Article 22, SE-94 paragraf 7).

Energy	Material thickness (steel) [mm]
120 kV	6,2 ÷ 25
150 kV	9 ÷ 36
200 kV	12,7 ÷ 51
250 kV	16 ÷ 64
400 kV (Ir 192)	22,2 ÷ 89

Due to several factors, an exact value of energy for a specific thickness cannot be strictly fixed. Radiation energy best suitable for the task given needs to be experimentally acquired since in different conditions the same energy might not produce desired results. Aids in form of exposure calculators and such should be utilized. Nonetheless, all of the requirements of this procedure in relation to the required to obtain IQI wire shall be followed.

6.3.5. Film location


Films shall be in direct contact with the part being examined and perpendicular to the central beam of radiation as close as possible.

6.3.6. Placement of IQI

The IQI shall be placed on the source side of the part being examined. When, due to weld configuration or size, it is not practical to place IQI on the weld, the IQI may be placed on separate block. Separate block shall be made of the same or radiographically similar material and may be used to facilitate IQI positioning. The IQI on the separate block shall be placed no closer to the film than the source side of the part being radiographed. The separate block shall be placed as close as possible to the part being radiographed.

Where inaccessibility prevents hand placing the IQI on the source side, the IQI shall be placed on the film side in contact with the part being examined. A lead letter "F" shall be placed adjacent to or on the IQI but shall not mask the essential wire used.

The IQI shall be placed on the weld so that the length of the wires are transverse to the longitudinal axis to the weld. It is not required for the essential wire to span the full width of the weld. However, the essential wire shall span at least that portion of the weld representing the nominal single wall material thickness and reinforcement for which the IQI essential wire was selected. The density requirements of T-

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wymagania co do gęstości optycznej wg T-292 oraz czułości wg T-283 (ASME V).

Opis wskaźnika jakości obrazu oraz, jeśli stosowana, litera "F" nie powinny przebiegać bezpośrednio w obszarze spoiny, z wyjątkiem gdy z powodu układu geometrycznego jest to niepraktyczne. (ASME V, Artykuł 2, paragraf 277.1)

6.3.7. Wyznaczenie parametrów ekspozycji

Wymagane elementy wyznaczania parametrów ekspozycji muszą być powiązane z:

- rodzajem materiału,
- grubością materiału,
- rodzajem błony,
- gęstością optyczną radiogramu,
- odległością źródło-film,
- energią (kV),
- prądem (mA – min.),
- czasem ekspozycji.

Kiedy odczynniki stosowane do wywoływania błon zostają zmienione na inną markę, tabela ekspozycji powinna być skorygowana lub stosunek czas-temperatura wywoływarki może być dopasowany do tabeli ekspozycji. Całość powinna być ściśle powiązana z wytycznymi producenta środków chemicznych.

6.3.8. Zasady bezpieczeństwa

Ochrona personelu przed promieniowaniem powinna być realizowana zgodnie z "Instrukcją zasad bezpieczeństwa" i lokalnymi przepisami. Personel wykonujący badania RT jest odpowiedzialny za zapewnienie odpowiedniego poziomu bezpieczeństwa i praktyk zdrowotnych oraz ustanowienie kontroli stosowania ograniczeń w praktyce.

7. Proces wywoływania błon

W celu obróbki fotochemicznej błon należy stosować procedurę NVT_RT_ASME_FILMPROC.

8. Klasyfikacja radiogramów

8.1. Stanowisko do oceny radiogramów

Udogodnienia podczas oglądania radiogramów powinny obejmować przytłumione światło w tle o intensywności, która nie powoduje odbłasków, cieni lub ostrego światła na radiogramie, które przeszkadzają w procesie interpretacji. Wyposażenie stosowane do przeglądania radiogramów w celu ich interpretacji powinno zapewniać różne źródła światła odpowiednie dla wymaganych pręciaków wskaźnika jakości obrazu w danym zakresie gęstości. Warunki przeglądania powinny być takie, żeby światło otaczające zewnętrzne krawędzie radiogramu lub pochodzące od fragmentów radiogramu o małej gęstości nie przeszkadzało w interpretacji (ASME V, Artykuł 2, paragraf T-234).

8.2. Jakość radiogramów

Wszystkie radiogramy powinny być wolne od mechanicznych, chemicznych lub innych skaz w takim stopniu, aby nie maskowały one obrazu nieciągłości lub nie były z nim mylone w

292 and the sensitivity requirements of T-283 shall also be met (ASME V).

The IQI identification and, when used, the letter "F", shall not be in the area of interest, except when geometric configuration makes it impractical. (ASME V, Article 2, paragraph 277.1)

6.3.7. Exposure calculations

The essential elements of an exposure calculator must relate following:

- material type,
- material thickness,
- film type,
- film density,
- source to film distance,
- energy (KV),
- current (milliamperes-minutes),
- time exposure.

The exposure chart should be corrected when the processing chemicals are changed to a different manufacturer's brand or the time-temperature relationship of the processor may be adjusted to suit the exposure chart. All to be kept strictly with the chemical provider's recommendations.

6.3.8. Safety practices

Personnel protection against radiation shall be done according to "Safety practices manual" and local regulations. It is the responsibility of the personnel executing RT examination to establish appropriate safety and health practices and determine the applicability of regulatory limitation to use.

7. Film processing

Procedure NVT_RT_ASME_FILMPROC shall be used for film processing.


8. Evaluation

8.1. Facilities for viewing of radiographs

Viewing facilities shall provide subdued background lighting of an intensity that will not cause reflections, shadows, or glare on the radiograph that interfere with the interpretation process. Equipment used to view radiographs for interpretation shall provide a variable light source sufficient for the essential IQI wire to be visible for the specified density range. The viewing conditions shall be such that light from around the outer edge of the radiograph or coming through low-density portions of the radiograph does not interfere with interpretation (ASME V, Article 2, paragraph T-234).

8.2. Quality of radiographs

All radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they do not mask and are not confused with the image of any discontinuity in the area of

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obszarze prześwietlanym badanego elementu. Niedoskonałości te obejmują, ale nie ograniczają się do:

- zadymienia,
- wady wywoływania takie jak smugi, ślady wody lub odbarwienia chemiczne,
- rysy, odciski palców, pofałdowania, zanieczyszczenia, rozmazania lub rozdarcia,
- fałszywe wskazania spowodowane uszkodzonymi okładkami.

(ASME V, Artykuł 2, paragraf T-281)

8.3. Gęstość optyczna radiogramów

Gęstość optyczna filmu w miejscu wymaganego pręcika wskaźnika jakości obrazu IQI i obszaru przeglądanej powinna wynosić minimum 1,8 dla pojedynczo przeglądanej radiogramu wykonanego przy pomocy źródła promieniowania X oraz 2,0 dla radiogramów wykonanych źródłem promieniotwórczym. Maksymalna gęstość powinna wynosić 4,0 dla pojedynczo przeglądanych błon. Dopuszcza się odchyłki gęstości 0,05 z uwagi na fluktuacje odczytu densytometru.

Dozwolona wariacja gęstości optycznej radiogramu w dowolnym fragmencie obszaru ocenianego nie powinna wahać się więcej niż -15% do +30% od gęstości sąsiadującej z wymaganym pręcikiem wskaźnika jakości obrazu IQI w granicach minimum/maximum dozwolonego zakresu gęstości. (ASME V, Artykuł 2, paragraf T-282)

8.4. Czulość badania IQI

Wymagana czulość wskaźnika jakości obrazu powinna być sprawdzona zgodnie z ASME V, Artykuł 2, Tabela T-276

8.5. Nadmierne promieniowanie rozproszone

Jeśli jasny obraz litery "B" pojawi się na ciemniejszym tle radiogramu, ochrona przed promieniowaniem wstecznym rozproszonym jest niewystarczająca i radiogram należy uznać za nieakceptowalny. Ciemny obraz litery "B" na jaśniejszym tle nie stanowi podstawy do odrzucenia radiogramu. (ASME V, Artykuł 2, paragraf T-283)

9. Kryteria akceptacji

Standardy akceptacji / odrzucenia powinny być określone w specyfikacji produktu i być przedmiotem umowy pomiędzy producentem i nabywcą.

Kryteria akceptacji dla różnych norm/przepisów są przywołane w załącznikach

10. Dokumentacja

W raporcie końcowym, jako minimum, muszą znaleźć się poniższe informacje:

- identyfikacja,
- zwymiarowany plan umiejscowienia znaczników (jeżeli ma zastosowanie),

interest of the object being radiographed. Such blemishes include, but are not limited to:

- fogging,
- processing defects such as streaks, watermarks, or chemical stains,
- scratches, finger marks, crimps, dirtiness, static marks, smudges, or tears,
- false indication due to defective screens.

(ASME V, Article 2, paragraph T-281)

8.3. Radiographic density

The transmitted film density through the radiographic image of adjacent to the designated wire of a wire IQI and the area of interest shall be 1,8 minimum for single viewing for radiographs made with an X-ray source and 2,0 minimum for radiographs made with a gamma ray source. The maximum density shall be 4,0 for single viewing. A tolerance of 0,05 in density is allowed for variations between densitometer readings

The density of the radiograph anywhere through the area of interest varies shall be minus 15% or plus 30% from the density through adjacent to the designated wire of a wire IQI, within minimum/maximum allowable density ranges. (ASME V, Article 2, paragraph T-282)

8.4. IQI Sensitivity

Required IQI sensitivity shall be checked according to ASME V, Article 2, Table T-276

8.5. Excessive backscatter

If a light image of the "B", appears on a darker background of the radiograph, protection from backscatter is insufficient and the radiograph shall be considered unacceptable. A dark image of the "B" on a lighter background is not cause for rejection. (ASME V, Article 2, paragraph T-283)

9. Acceptance standards


Designation of accept/reject standards is recognized to be within the cognizance of product specifications and generally a matter of contractual agreement between producer and purchaser.

Acceptance criteria for different standards/codes are given in Appendixes.

10. Documentation

At final report, as a minimum, the following information shall be provided:

- identification,
- the dimensional map (if used) of marker placement,
- number of exposures,

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- ilość ekspozycji,
- napięcie źródła promieniowania X lub użyty izotop promieniotwórczy,
- rozmiar źródła,
- rodzaj oraz grubość materiału podstawowego i grubość spoiny,
- odległość źródło-obiekt badany,
- odległość powierzchni elementu od strony źródła od filmu,
- producent filmów i typ/oznaczenie producenta,
- ilość filmów w każdej kasecie,
- ekspozycja przez jedną lub dwie ścianki,
- klasyfikacja jednej lub dwóch ścianek,
- lista umiejscowienia każdego z radiogramów,
- ocena i rozmieszczenie materiałów i spoin badanych,
- identyfikacja (nazwa) przedstawiciela producenta, który przeprowadza końcową akceptację radiogramów,
- data oceny producenta.

(ASME V, Artykuł 2, paragrafy T-291, T-292)

11. Załączniki

- Załącznik 1: Kryteria akceptacji według ASME BPVC.I-2023
- Załącznik 2: Kryteria akceptacji według ASME BPVC.VIII.1-2023
- Załącznik 3: Kryteria akceptacji według ASME BPVC.IX-2023
- Załącznik 4: Kryteria akceptacji według ASME B31.1-2022
- Załącznik 5: Kryteria akceptacji według ASME B31.3-2022
- Załącznik 6: Kryteria akceptacji według ASME B31.12-2023
- Załącznik 7: Kryteria akceptacji według ASME B31.12-2023 (API 1104 wydanie 22-gie)

12. Uwagi do rewizji

W odniesieniu do poprzedniej wersji (główne zmiany):

- Zrewidowano w całości

- X-ray voltage or isotope type used
- source size,
- base material type and thickness, weld thickness
- source-to-object distance,
- distance from source side of object to film,
- film manufacturer and Manufacturer's type/designation,
- number of film in each film holder/cassette,
- single or double-wall exposure,
- single or double-wall viewing,
- a listing of each radiograph location,
- evaluation and disposition of the material or weld examined,
- identification (name) of the Manufacturer's representative who performed the final acceptance of the radiographs,
- date of Manufacturer's evaluation.

(ASME V, Article 2, paragraphs T-291, T-292)


11. Appendixes

- Appendix 1: Acceptance criteria acc. to ASME BPVC.I-2023
- Appendix 2: Acceptance criteria acc. to ASME BPVC.VIII.1-2023
- Appendix 3: Acceptance criteria acc. to ASME BPVC.IX-2023
- Appendix 4: Acceptance criteria acc. to ASME B31.1-2022
- Appendix 5: Acceptance criteria acc. to ASME B31.3-2022
- Appendix 6: Acceptance criteria acc. to ASME B31.12:2023
- Appendix 7: Acceptance criteria acc. to ASME B31.12:2023 (API 1104 22'nd edition)

12. Remarks to revision

In relation to the previous version (major changes):

- Revised in its entirety

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Appendix 1

Acceptance criteria according to ASME BPVC.I-2023

Terminology:

A-250.2.1 **Rounded Indications.** Indications with a maximum length of three times the width or less on the radiograph are defined as rounded indications. These indications may be circular, elliptical, conical, or irregular in shape and may have tails. When evaluating the size of an indication, the tail shall be included. The indication may be from any imperfection in the weld, such as porosity, slag, or tungsten.

A-250.2.2 **Aligned Indications.** A sequence of four or more rounded indications shall be considered to be aligned when they touch a line parallel to the length of the weld drawn through the center of the two outer rounded indications.

A-250.2.3 **Thickness t.** t is the thickness of the weld, excluding any allowable reinforcement. For a butt weld joining two parts having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the fillet weld throat shall be included in t.

Designation of reject standards is recognized according ASME Section I paragraph PW-51:

Indications shown on the radiographs of welds and characterized as imperfections are unacceptable under the following conditions:

1. any indication characterized as a **crack or zone of incomplete fusion or penetration**
2. any **other elongated indication** on the radiograph which has length greater than:

maximum allowed length [mm]	material thickness [mm]
6	$t \leq 19$
$1/3 t$	$19 < t \leq 57$
19	$t > 57$

where t - the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

3. **any group of aligned indications** that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group
4. **rounded indications** in excess of that specified by the acceptance standards given in ASME Section I paragraph A-250
- 4.1. Relevant indications (see Table A-250.3.2 for examples). Only those **rounded indications** which exceed the following dimensions shall be considered relevant

Only those **rounded indications** which exceed the following dimensions shall be considered relevant:

maximum allowed length [mm]	material thickness [mm]
$1/10 t$	$t \leq 3$
0.4	$3 < t \leq 6$
0.8	$6 < t \leq 50$
1.5	$t > 50$

Table A-250.3.2
Maximum Permissible Size of Rounded Indication
(Examples Only)

SI Units			
Thickness t , mm	Maximum Size of Acceptable Rounded Indication, mm		Maximum Size of Nonrevealing Indication, mm
	Random	Isolated	
Less than 3	$\frac{1}{4}t$	$\frac{1}{3}t$	$\frac{1}{10}t$
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.33	0.79
17	3.96	5.84	0.79
19 to 50 incl.	3.96	6.35	0.79
Over 50	3.96	9.53	1.60

4.2. Maximum size of rounded indication.

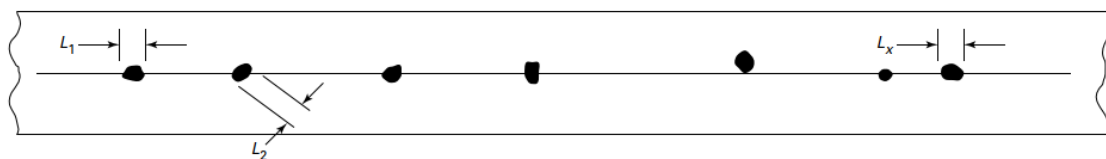
The maximum permissible size of any indication shall be:

- $\frac{1}{4}t$ or 4 mm, whichever is smaller; except that an isolated indication separated from an adjacent indication by 25 mm or more may be $\frac{1}{3}t$ or 6 mm, whichever is less.
- For t greater than 50 mm the maximum permissible size of an isolated indication shall be increased to 10 mm.

4.3. Aligned rounded indications

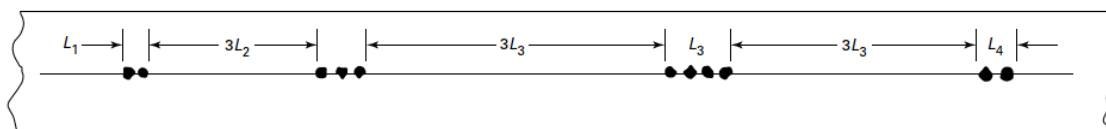
Aligned rounded indications are acceptable when the summation of the diameters of the indications is less than t in a length of $12t$ (see Figure A-250.3.4-1). The length of groups of aligned rounded indications and the spacing between the groups shall meet the requirements of Figure A-250.3.4-2.

Figure A-250.3.4-1
Aligned Rounded Indications



GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of $12t$.

Figure A-250.3.4-2
Groups of Aligned Rounded Indications



Maximum Group Length

$L = \frac{1}{4}$ in. (6 mm) for t less than $\frac{3}{4}$ in. (19 mm)

$L = \frac{1}{3} t$ for $t \frac{3}{4}$ in. (19 mm) to $2\frac{1}{4}$ in. (57 mm)

$L = \frac{3}{4}$ in. (19 mm) for t greater than $2\frac{1}{4}$ in. (57 mm)

Minimum Group Spacing

$3L$ where L is the length of the longest adjacent group being evaluated.

GENERAL NOTE: Sum of the group lengths shall be less than t in a length of $12t$.

4.4. Spacing

The distance between adjacent rounded indications is not a factor in determining acceptance or rejection, except as required for isolated indications or groups of aligned indications.

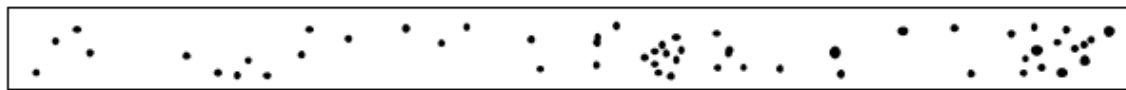
4.5. Weld thickness t less than 1/8 in. (3 mm)

For t less than 3 mm, the maximum number of rounded indications shall not exceed 12 in a 150 mm length of weld. A proportionally fewer number of indications shall be permitted in welds less than 150 mm in length.

4.6. Clustered Indications

The length of an acceptable cluster shall not exceed the lesser of 25 mm or $2t$. Where more than one cluster is present, the sum of the lengths of the clusters shall not exceed 25 mm in a 150 mm length of weld.

Figure A-250.3.6-1
Charts for $t \frac{1}{8}$ in. (3 mm) to $\frac{1}{4}$ in. (6 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]

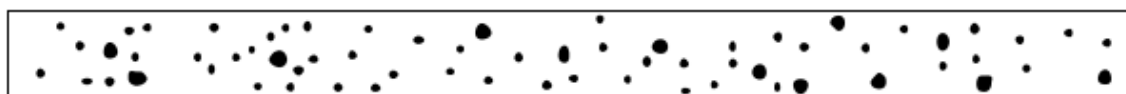
(c) Cluster

NOTES:

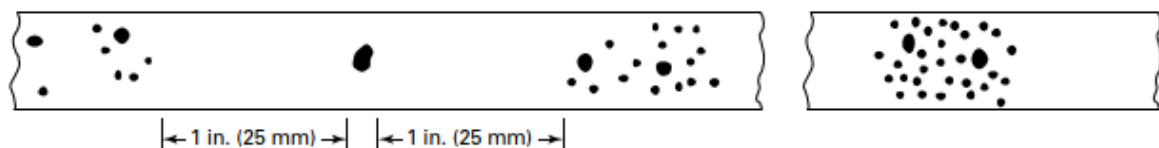
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per Table A-250.3.2.

Figure A-250.3.6-2
Charts for t Over $\frac{1}{4}$ in. (6 mm) to $\frac{3}{8}$ in. (10 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]

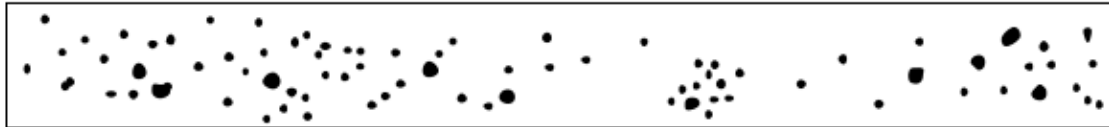
(c) Cluster

NOTES:

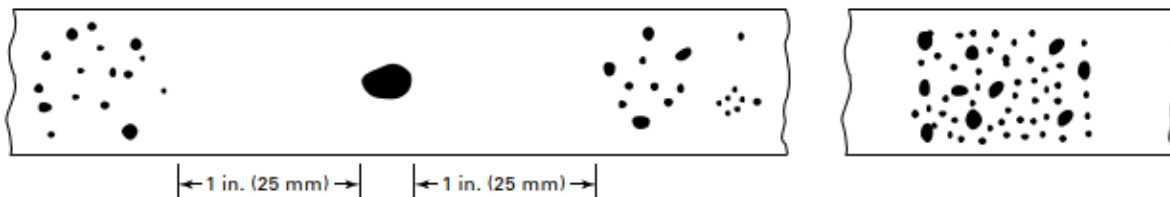
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Minimum size per Table A-250.3.2.

Figure A-250.3.6-3
 Charts for t Over $\frac{3}{8}$ in. (10 mm) to $\frac{3}{4}$ in. (19 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



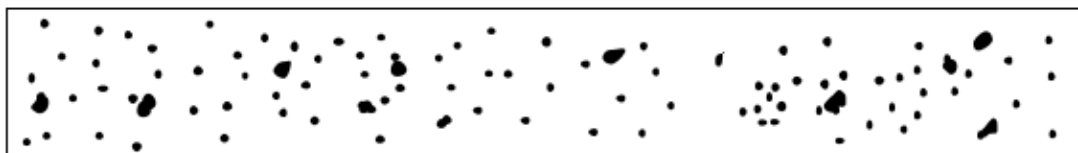
(b) Isolated Indication [Note (2)]

(c) Cluster

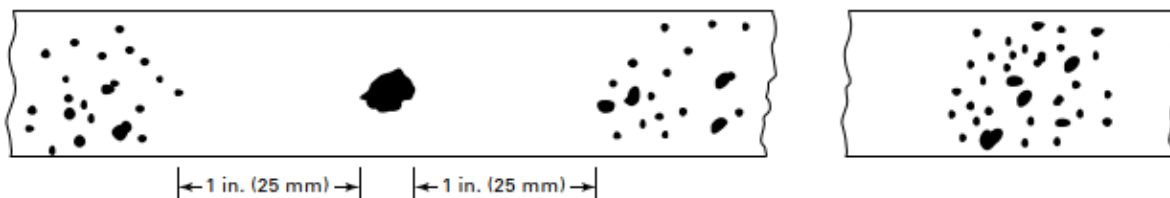
NOTES:

- (1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
- (2) Minimum size per Table A-250.3.2.

Figure A-250.3.6-4
 Charts for t Over $\frac{3}{4}$ in. (19 mm) to 2 in. (50 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



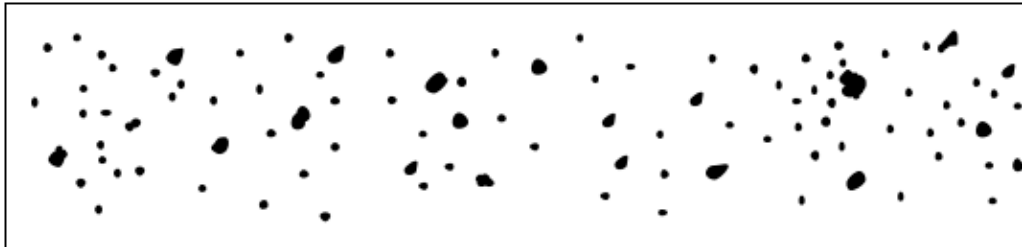
(b) Isolated Indication [Note (2)]

(c) Cluster

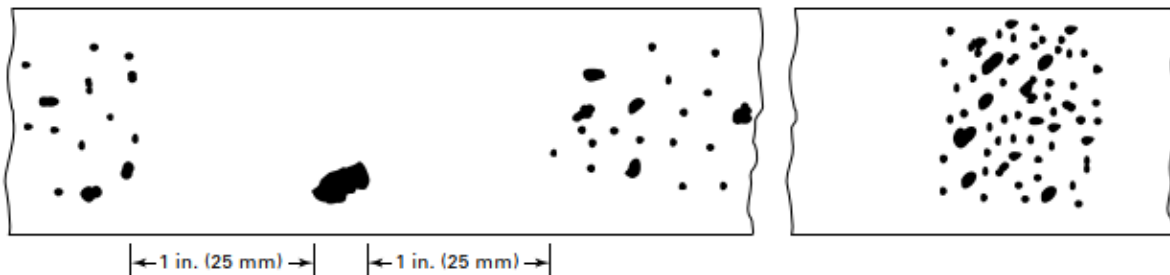
NOTES:

- (1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
- (2) Minimum size per Table A-250.3.2.

Figure A-250.3.6-5
Charts for t Over 2 in. (50 mm) to 4 in. (100 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]

(c) Cluster

NOTES:

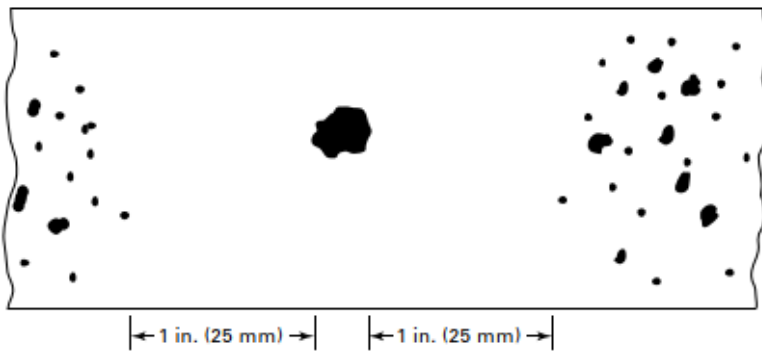
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Minimum size per [Table A-250.3.2](#).

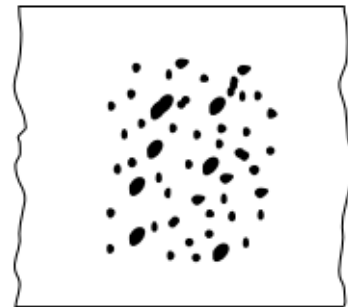
Figure A-250.3.6-6
Charts for t Over 4 in. (100 mm)



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]




(c) Cluster

NOTES:

(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Minimum size per [Table A-250.3.2](#).

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Appendix 2

Acceptance criteria according to ASME BPVC.VIII.1-2023

4-2 Terminology:

- (a) **Rounded Indications.** Indications with a maximum length of three times the width or less on the radiograph are defined as rounded indications. These indications may be circular, elliptical, conical, or irregular in shape and may have tails. When evaluating the size of an indication, the tail shall be included. The indication may be from any imperfection in the weld, such as porosity, slag, or tungsten.
- (b) **Aligned Indications.** A sequence of four or more rounded indications shall be considered to be aligned when they touch a line parallel to the length of the weld drawn through the center of the two outer rounded indications.
- (c) **Thickness t .** t is the thickness of the weld, excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t .

I. According to UW-51 (100% radiography of a weld)

Indications revealed by radiography within a weld that exceed the following criteria are unacceptable:

- 1) any indication characterized as a **crack or zone of incomplete fusion or penetration**
- 2) any **other elongated indication** on the radiograph which has length greater than:

maximum allowed length [mm]	material thickness [mm]
6	$t \leq 19$
$1/3 t$	$19 < t \leq 57$
19	$t > 57$

t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t .

- 3) any **group of aligned indications** that have an aggregate length greater than t in a length of $12t$, except when the distance between the successive imperfections exceeds $6L$ where L is the length of the longest imperfection in the group
- 4) **rounded indications** in excess of that specified by the acceptance standards given in Mandatory Appendix 4 of ASME BPVC.VIII.1-2023

4.1. **Relevant indications** (See Table 4-1 for examples). Only those rounded indications which exceed the following dimensions shall be considered relevant.

maximum allowed length [mm]	material thickness [mm]
$1/10 t$	$t \leq 3$
0.4	$3 < t \leq 6$
0.8	$6 < t \leq 50$
1.5	$t > 50$

4.2. **Maximum size of rounded indication** (see Table 4-1 for examples)

The maximum permissible size of any indication shall be:

- a) $1/4t$ or 4 mm, whichever is smaller; except that an isolated indication separated from an adjacent indication by 25 mm or more may be $1/3t$ or 6 mm, whichever is less
- b) For t greater than 50 mm the maximum permissible size of an isolated indication shall be increased to 10 mm

Table 4-1

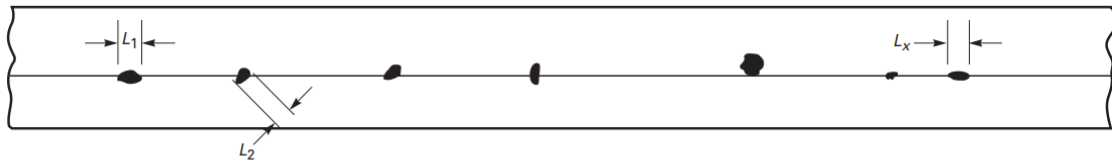
SI Units			
Thickness, t , mm	Maximum Size of Acceptable Rounded Indication, mm		Maximum Size of Nonrelevant Indication, mm
	Random	Isolated	
Less than 3	$\frac{1}{4} t$	$\frac{1}{3} t$	$\frac{1}{10} t$
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.33	0.79
17	3.96	5.84	0.79
19.0 to 50, incl.	3.96	6.35	0.79
Over 50	3.96	9.53	1.60

GENERAL NOTE: This Table contains examples only.

4.3. Aligned rounded indications

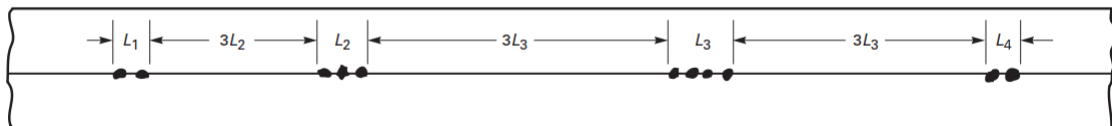
Aligned rounded indications are acceptable when the summation of the diameters of the indications is less than t in a length of $12t$ (see Figure 4-1). The length of groups of aligned rounded indications and the spacing between the groups shall meet the requirements of Figure 4-2.

Figure 4-1
Aligned Rounded Indications



GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of $12t$.

Figure 4-2
Groups of Aligned Rounded Indications



Maximum Group Length

$L = \frac{1}{4}$ in. (6 mm) for t less than $\frac{3}{4}$ in. (19 mm)
 $L = \frac{1}{3}t$ for $t \frac{3}{4}$ in. (19 mm) to $2\frac{1}{4}$ in. (57 mm)
 $L = \frac{3}{4}$ in. (19 mm) for t greater than $2\frac{1}{4}$ in. (57 mm)


Minimum Group Spacing

$3L$ where L is the length of the longest adjacent group being evaluated

GENERAL NOTE: Sum of the group lengths shall be less than t in a length of $12t$.

4.4. Spacing

The distance between adjacent rounded indications is not a factor in determining acceptance or rejection, except as required for isolated indications or groups of aligned indications.

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4.5. Rounded indication charts

The rounded indications characterized as imperfections shall not exceed that shown in the charts. The charts in Figures 4-3 through 4-8 illustrate various types of assorted, randomly dispersed and clustered rounded indications for different weld thicknesses greater than 3 mm. These charts represent the maximum acceptable concentration limits for rounded indications. The charts for each thickness range represent full-scale 150 mm radiographs, and shall not be enlarged or reduced. The distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the concentration and size of indications permitted.

4.6. Weld thickness t less than 1/8 in. (3 mm)

For t less than 3 mm, the maximum number of rounded indications shall not exceed 12 in a 150 mm length of weld. A proportionally fewer number of indications shall be permitted in welds less than 150 mm in length.

4.7. Clustered Indications

The illustrations for clustered indications show up to four times as many indications in a local area, as that shown in the illustrations for random indications. The length of an acceptable cluster shall not exceed the lesser of 25 mm or $2t$. Where more than one cluster is present, the sum of the lengths of the clusters shall not exceed 25 mm in a 150 mm length weld.

II. According UW-52 (spot radiography)

The acceptability of welds examined by spot radiography shall be judged by the following standards:

- 1) Welds in which indications are characterized as cracks or zones of incomplete fusion or penetration shall be unacceptable
- 2) Welds having indications characterized as **slag inclusions or cavities** are:
 - a) unacceptable when the indication length exceeds $2/3t$

t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t .

- b) for all thicknesses, indications less than 6 mm are acceptable, and indications greater than 19 mm are unacceptable
 - c) multiple aligned indications meeting these acceptance criteria are acceptable when the sum of their longest dimensions does not exceed t within a length of $6t$ (or proportionally for radiographs shorter than $6t$), and when the longest length L for each indication is separated by a distance not less than $3L$ from adjacent indications.
- 3) **Rounded indications** are not a factor in the acceptability of welds not required to be fully radiographed

Spot radiography extension for defective welds

When a spot, radiographed is acceptable, the entire weld increment represented by this radiograph is acceptable.

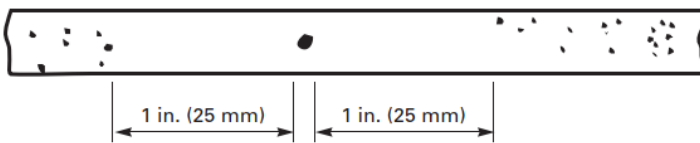
When a spot, radiographed has been examined and the radiograph discloses welding which does not comply with the minimum quality requirements, **two additional** spots shall be radiographically examined in the same weld increment at locations away from the original spot. The locations of these additional spots shall be determined by the Inspector or fabricator as provided for the original spot examination. If the two additional spots examined show welding which meets the minimum quality requirements, the entire weld increment represented by the three radiographs is acceptable provided the defects disclosed by the first of the three radiographs are removed and the area repaired by welding. The weld repaired area shall be radiographically examined in accordance with the foregoing requirements of UW-52.

If either of the two additional spots examined shows welding which does not comply with the minimum quality requirements, the **entire increment of weld represented shall be rejected**. The entire rejected weld shall be removed and the joint shall be rewelded or, at the fabricator's option, the entire increment of weld represented shall be completely radiographed and only defects need be corrected.

Figure 4-3
Charts for t Equal to $\frac{1}{8}$ in. to $\frac{1}{4}$ in. (3 mm to 6 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



(c) Cluster

NOTES:

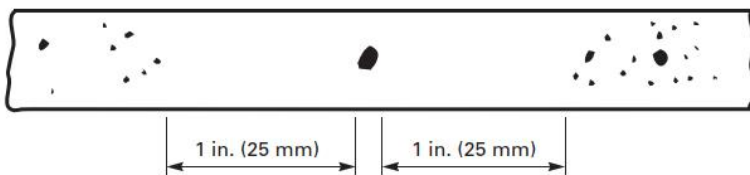
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per [Table 4-1](#).

Figure 4-4
Charts for t Over $\frac{1}{4}$ in. to $\frac{3}{8}$ in. (6 mm to 10 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



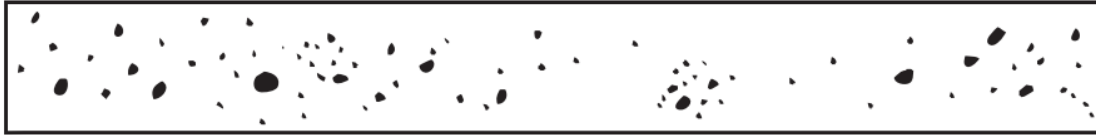
(c) Cluster

NOTES:

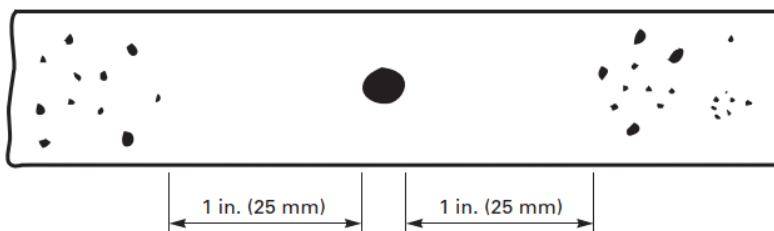
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per [Table 4-1](#).

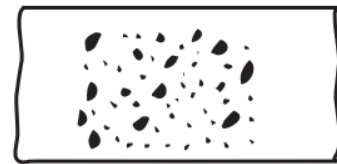
Figure 4-5
Charts for t Over $\frac{3}{8}$ in. to $\frac{3}{4}$ in. (10 mm to 19 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



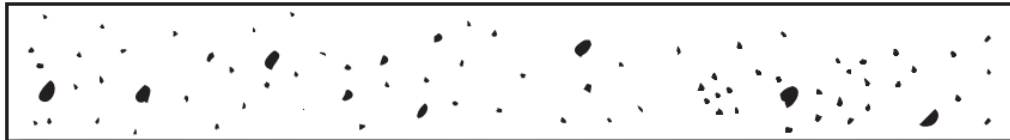
(c) Cluster

NOTES:

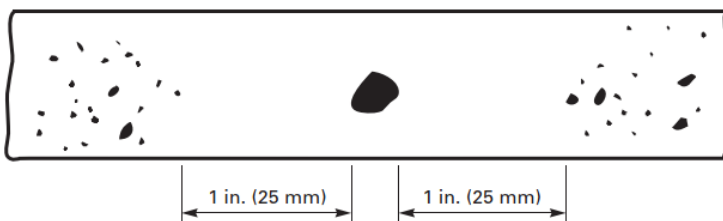
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per Table 4-1.

Figure 4-6
Charts for t Over $\frac{3}{4}$ in. to 2 in. (19 mm to 50 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



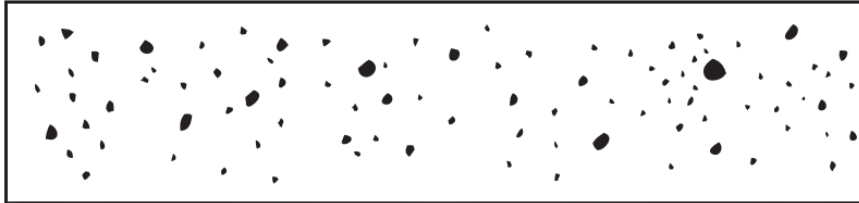
(c) Cluster

NOTES:

(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per Table 4-1.

Figure 4-7
Charts for t Over 2 in. to 4 in. (50 mm to 100 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



(c) Cluster

NOTES:

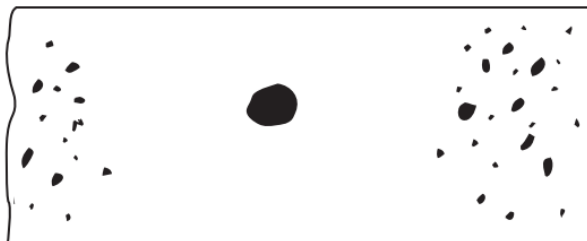
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per Table 4-1.

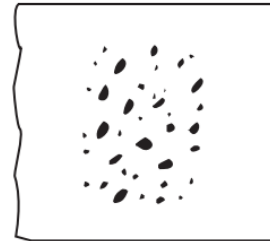
Figure 4-8
Charts for t Over 4 in. (100 mm)



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



(c) Cluster

NOTES:

(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Maximum size per Table 4-1.

Appendix 3

Acceptance criteria according to ASME BPVC.IX-2023

QW-191.1.2.1 Terminology

- (a) **Linear Indications.** Cracks, incomplete fusion, inadequate penetration, and slag are represented on the radiograph as linear indications in which the length is more than three times the width.
- (b) **Rounded Indications.** Porosity and inclusions such as slag or tungsten are represented on the radiograph as rounded indications with a length three times the width or less. These indications may be circular, elliptical, or irregular in shape; may have tails; and may vary in density.
- (c) **Thickness.** The term “thickness” or “t” refers to the thickness of the weld excluding any allowable reinforcement. For a groove weld joining two base metals having different thicknesses at the weld, thickness is the thinner of the two base metals being joined.

Welder and welding operator performance tests by radiography of welds in test assemblies shall be judged unacceptable when the radiograph exhibits any imperfections in excess of the limits specified below:

I. Linear Indications

- 1) any type of **crack or zone of incomplete fusion or penetration** are unacceptable
- 2) any **elongated slag inclusion** is unacceptable, which has a length greater than:

maximum allowed length [mm]	material thickness [mm]
3	$t \leq 10$
$1/3 t$	$10 < t \leq 57$
19	$t > 57$

- 3) any **group of slag inclusions in line** that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L is unacceptable

L is the length of the longest imperfection in the group

II. Rounded Indications:

- 1) **Relevant indications.** Only those **rounded indications** which exceed the following dimensions shall be considered relevant.

maximum allowed length [mm]	material thickness [mm]
$1/10 t$	$t \leq 3$
0.4	$3 < t \leq 6$
0.8	$6 < t \leq 50$
1.5	$t > 50$

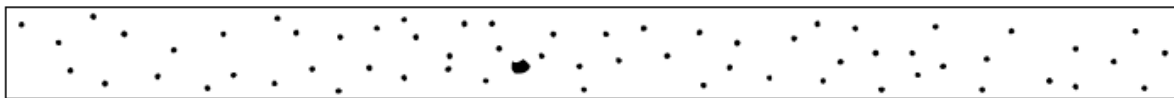
- 2) Maximum size of **rounded indications**

- a) the maximum permissible dimension for rounded indications shall be 20% of t or 3 mm, whichever is smaller
- b) for welds in material less than 3 mm in thickness, the maximum number of acceptable rounded indications shall not exceed 12 in a 150 mm length of weld. A proportionately fewer number of rounded indications shall be permitted in welds less than 150 mm in length
- c) for welds in material 3 mm or greater in thickness, the charts Figure QW-191.1.2.2(b)(4) represent the maximum acceptable types of rounded indications illustrated in typically clustered, assorted, and randomly dispersed configurations

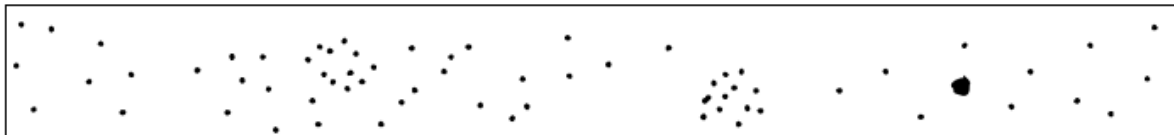
**Figure QW-191.1.2.2(b)(4)
Rounded Indication Charts**



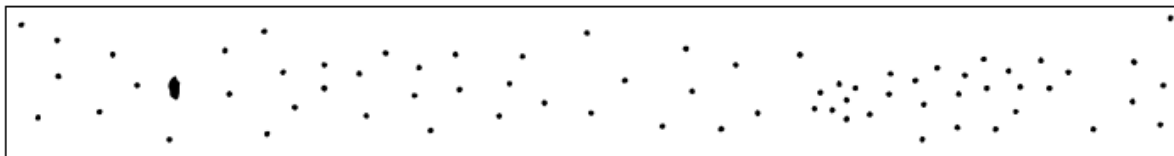
**Typical Quantity and Size Permitted
in 6 in. (150 mm) Length of Weld
1/8 in. (3 mm) to 1/4 in. (6 mm)
Thickness**




**Typical Quantity and Size Permitted
in 6 in. (150 mm) Length of Weld
Over 1/4 in. (6 mm) to 1/2 in. (13 mm)
Thickness**



**Typical Quantity and Size Permitted
in 6 in. (150 mm) Length of Weld
Over 1/2 in. (13 mm) to 1 in. (25 mm)
Thickness**



**Typical Quantity and Size Permitted
in 6 in. (150 mm) Length of Weld
Over 1 in. (25 mm) Thickness**

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Appendix 4

Acceptance criteria according to ASME B31.1-2022

Welds that are shown by radiography to have any of the following types of discontinuities are unacceptable:

- 1) any type of **crack or zone of incomplete fusion or penetration** are unacceptable
- 2) any other **elongated indication** that has a length greater than (are unacceptable):

maximum allowed length [mm]	material thickness [mm]
6	$t \leq 19$
$1/3 t$	$19 < t \leq 57$
19	$t > 57$

t is the thickness of the thinner portion of the weld. If a weld joins two members having different thickness at the weld, t is the thinner of these two thicknesses

- 3) any **group of indications** in line that have an aggregate length greater than t in a length of 12t, except where the distance between the successive indications exceeds 6L where L is the longest indication in the group
- 4) **porosity** in excess of that shown as acceptable in ASME BPVC, Section I, Nonmandatory Appendix A, A-250

4.1. Relevant indications (see Table A-250.3.2 for examples). Only those **rounded indications** which exceed the following dimensions shall be considered relevant

Only those **rounded indications** which exceed the following dimensions shall be considered relevant:

maximum allowed length [mm]	material thickness [mm]
$1/10 t$	$t \leq 3$
0.4	$3 < t \leq 6$
0.8	$6 < t \leq 50$
1.5	$t > 50$

4.2. Maximum size of rounded indication.

The maximum permissible size of any indication shall be:

- a) a) $1/4t$ or 4 mm, whichever is smaller; except that an isolated indication separated from an adjacent indication by 25 mm or more may be $1/3t$ or 6 mm, whichever is less.
- b) b) For t greater than 50 mm the maximum permissible size of an isolated indication shall be increased to 10 mm.

4.3. Aligned rounded indications

Aligned rounded indications are acceptable when the summation of the diameters of the indications is less than t in a length of 12t (see Figure A-250.3.4-1). The length of groups of aligned rounded indications and the spacing between the groups shall meet the requirements of Figure A-250.3.4-2.

4.4. Spacing

The distance between adjacent rounded indications is not a factor in determining acceptance or rejection, except as required for isolated indications or groups of aligned indications.

4.5. Weld thickness t less than 1/8 in. (3 mm)

For t less than 3 mm, the maximum number of rounded indications shall not exceed 12 in a 150 mm length of weld. A proportionally fewer number of indications shall be permitted in welds less than 150 mm in length.

4.6. Clustered Indications

The length of an acceptable cluster shall not exceed the lesser of 25 mm or 2t. Where more than one cluster is present, the sum of the lengths of the clusters shall not exceed 25 mm in a 150 mm length of weld.

- 5) for **circumferential groove welds**, **undercutting** adjacent to the cover pass (EU) or undercutting adjacent to the root pass (IU) shall be considered unacceptable should either of the following conditions exist:
- the aggregate length of EU and IU, in any combination, in any continuous 300 mm length of weld exceeds 50 mm
 - the aggregate length of EU and IU, in any combination, exceeds 1/6 of the weld length

(EU) – external undercut

(IU) – internal undercut

- 6) **undercut** on the outside (O.D) or inside (I.D.) surface of **longitudinal butt welds** is unacceptable

(O.D.) – outside diameter

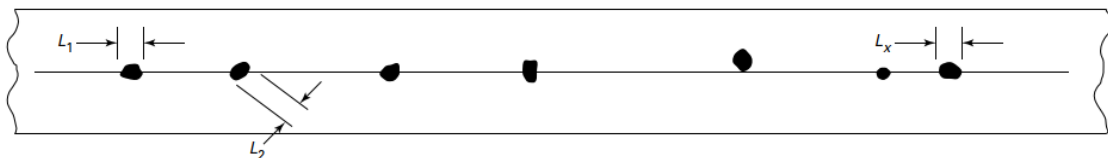
(I.D.) – internal diameter

- 7) **root concavity** is unacceptable when the density or brightness of the root image is darker than the density through the adjacent base metal

Table A-250.3.2
Maximum Permissible Size of Rounded Indication
(Examples Only)

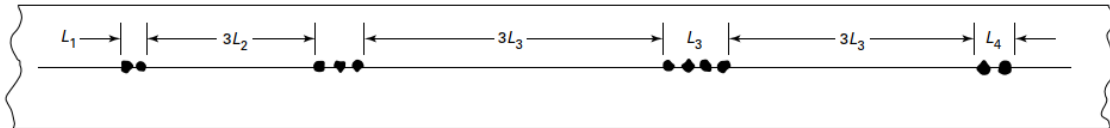
SI Units			
Thickness t , mm	Maximum Size of Acceptable Rounded Indication, mm		Maximum Size of Nonrelevant Indication, mm
	Random	Isolated	
Less than 3	$\frac{1}{4}t$	$\frac{1}{3}t$	$\frac{1}{10}t$
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.33	0.79
17	3.96	5.84	0.79
19 to 50 incl.	3.96	6.35	0.79
Over 50	3.96	9.53	1.60

Figure A-250.3.4-1
Aligned Rounded Indications



GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of $12t$.

Figure A-250.3.4-2
 Groups of Aligned Rounded Indications



Maximum Group Length

$L = 1/4$ in. (6 mm) for t less than $3/4$ in. (19 mm)

$L = 1/3 t$ for t $3/4$ in. (19 mm) to $2 1/4$ in. (57 mm)

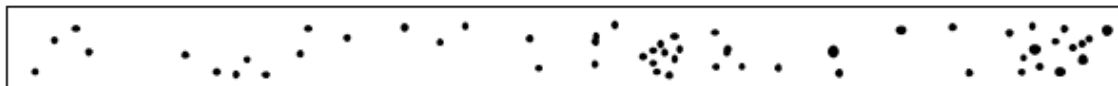
$L = 3/4$ in. (19 mm) for t greater than $2 1/4$ in. (57 mm)

Minimum Group Spacing

$3L$ where L is the length of the longest adjacent group being evaluated.

GENERAL NOTE: Sum of the group lengths shall be less than t in a length of $12t$.

Figure A-250.3.6-1
Charts for $t \frac{1}{8}$ in. (3 mm) to $\frac{1}{4}$ in. (6 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



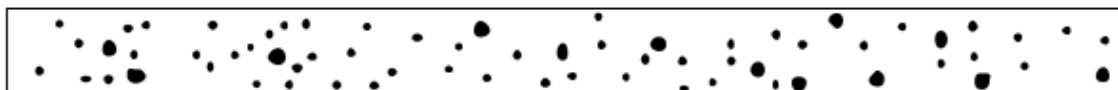
(b) Isolated Indication [Note (2)]

(c) Cluster

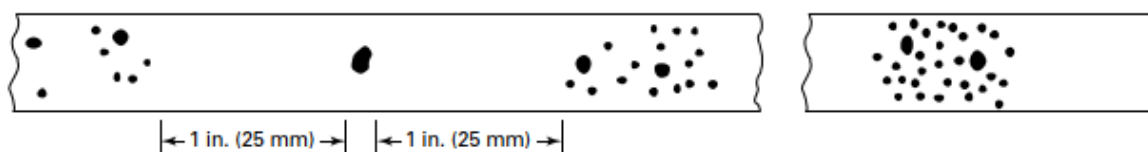
NOTES:

- (1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
- (2) Maximum size per [Table A-250.3.2](#).

Figure A-250.3.6-2
Charts for t Over $\frac{1}{4}$ in. (6 mm) to $\frac{3}{8}$ in. (10 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



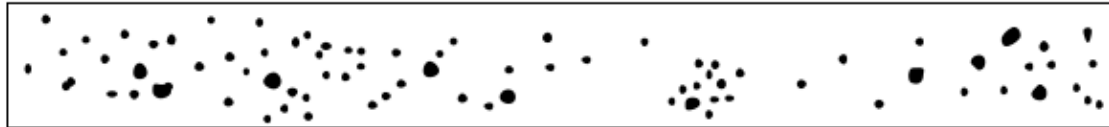
(b) Isolated Indication [Note (2)]

(c) Cluster

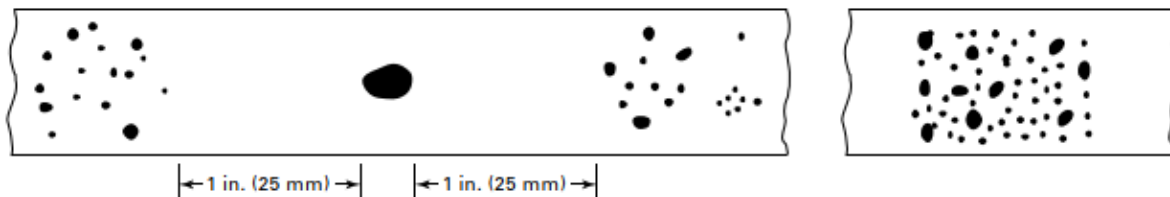
NOTES:

- (1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
- (2) Minimum size per [Table A-250.3.2](#).

Figure A-250.3.6-3
Charts for t Over $\frac{3}{8}$ in. (10 mm) to $\frac{3}{4}$ in. (19 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



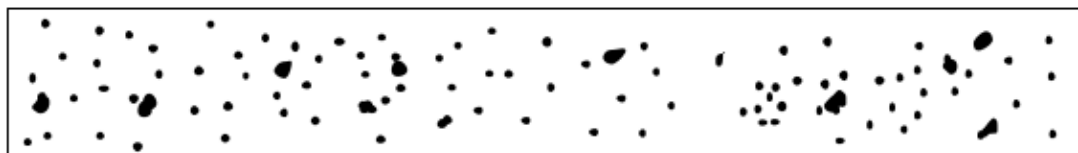
(b) Isolated Indication [Note (2)]

(c) Cluster

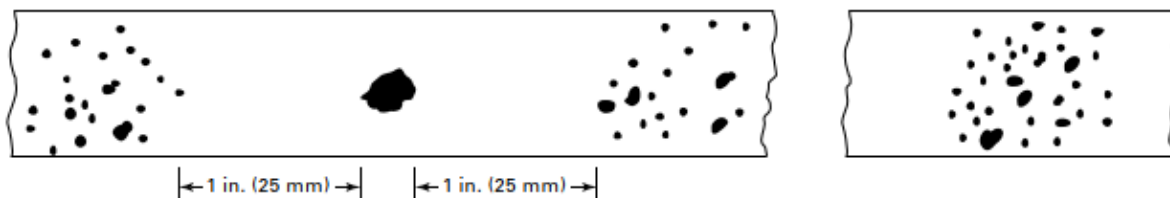
NOTES:

- (1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
- (2) Minimum size per [Table A-250.3.2](#).

Figure A-250.3.6-4
Charts for t Over $\frac{3}{4}$ in. (19 mm) to 2 in. (50 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



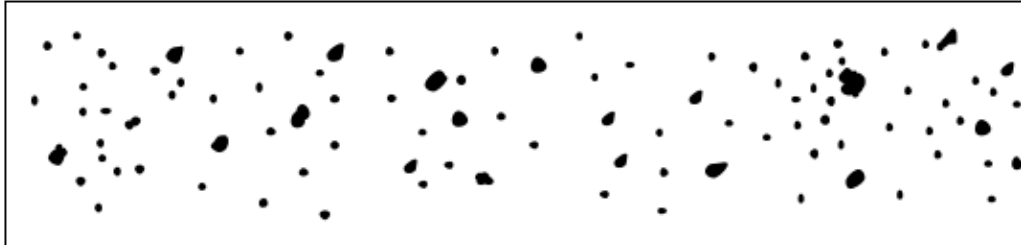
(b) Isolated Indication [Note (2)]

(c) Cluster

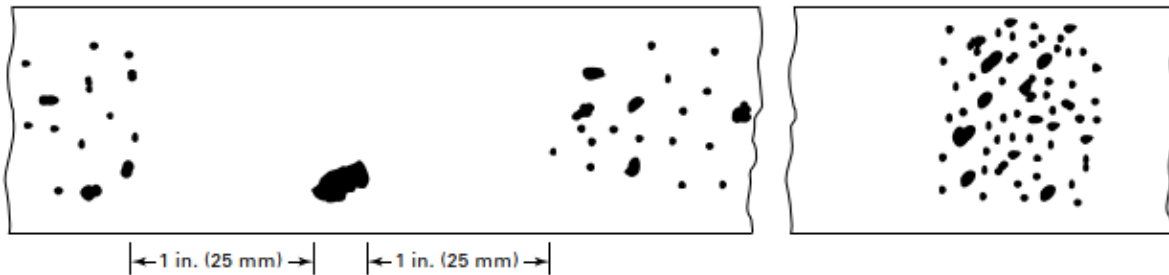
NOTES:

- (1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
- (2) Minimum size per [Table A-250.3.2](#).

Figure A-250.3.6-5
Charts for t Over 2 in. (50 mm) to 4 in. (100 mm), Inclusive



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]

(c) Cluster

NOTES:

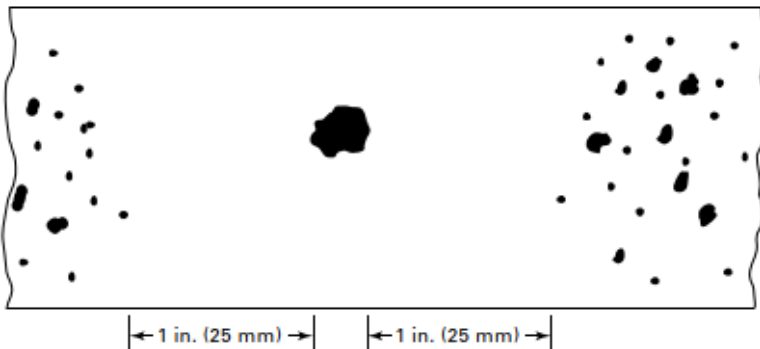
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Minimum size per [Table A-250.3.2](#).

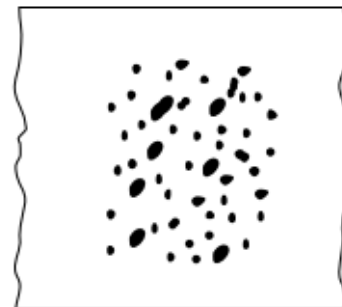
Figure A-250.3.6-6
 Charts for t Over 4 in. (100 mm)



(a) Random Rounded Indications [Note (1)]



(b) Isolated Indication [Note (2)]




(c) Cluster

NOTES:

(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(2) Minimum size per [Table A-250.3.2](#).

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Appendix 5

Acceptance criteria according to ASME B31.3-2022

Table K341.3.2 Acceptance Criteria for Welds


Type of Imperfection	Criteria (A-F) for Types of Welds, and for Required Examination Methods [Note (1)]					
	Methods		Type of Weld			
	Visual	Ultrasonics or Radiography	Girth Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]
Crack	✓	✓	A	A	A	A
Lack of fusion	✓	✓	A	A	A	A
Incomplete penetration	✓	✓	A	A	A	A
Internal porosity	...	✓	B	B	N/A	B
Linear indication	...	✓	C	C	N/A	C
Undercutting	✓	✓	A	A	A	A
Surface porosity or exposed slag inclusion	✓	...	A	A	A	A
Concave root surface (suck-up)	✓	✓	D	D	N/A	D
Surface finish	✓	...	E	E	E	E
Reinforcement or internal protrusion	✓	...	F	F	F	F

GENERAL NOTES:

- (a) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in [paras. K341.4.1](#) and [K341.4.2](#).
- (b) "N/A" indicates this Chapter does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of weld.
- (c) Check (✓) indicates examination method generally used for evaluating this kind of weld imperfection.
- (d) Ellipsis (...) indicates examination method not generally used for evaluating this kind of weld imperfection.
- (e) Symbols A through F are explained in the table on the next page.

NOTES:

- (1) Criteria given are for required examination. More-stringent criteria may be specified in the engineering design.
- (2) Longitudinal welds include only those permitted in [paras. K302.3.4](#) and [K305](#). The criteria shall be met by all welds, including those made in accordance with a standard listed in [Table K326.1](#) or in [Appendix K](#).
- (3) Fillet welds include only those permitted in [para. K311.2.2](#).
- (4) Branch connection welds include only those permitted in [para. K328.5.4](#).

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Criterion Value Notes for Table K341.3.2

Criterion			
Symbol	Measure	Acceptable Value Limits [Note (1)]	
A	Extent of imperfection	Zero (no evident imperfection)	
B	Size and distribution of internal porosity	See ASME BPVC, Section VIII, Division 1, Appendix 4	
C	Internal slag inclusion, tungsten inclusion, or linear indication. Indications are unacceptable if the amplitude exceeds the reference level, or indications have lengths that exceed Individual length [Note (2)] Cumulative length	6 mm ($\frac{1}{4}$ in.) for $\bar{T}_w \leq 19$ mm ($\frac{3}{4}$ in.) $\bar{T}_w/3$ for 19 mm ($\frac{3}{4}$ in.) < $\bar{T}_w \leq 57$ mm ($2\frac{1}{4}$ in.) 19 mm ($\frac{3}{4}$ in.) for $\bar{T}_w > 57$ mm ($2\frac{1}{4}$ in.) $\leq \bar{T}_w$ in any 12 \bar{T}_w weld length	
D	Depth of root surface concavity	Wall Thickness, \bar{T}_w , mm (in.)	Depth of Surface Concavity, mm (in.)
		≤ 13 ($\frac{1}{2}$)	≤ 1.5 ($\frac{1}{16}$)
		> 13 ($\frac{1}{2}$) and ≤ 51 (2)	≤ 3 ($\frac{1}{8}$)
		> 51 (2)	≤ 4 ($\frac{5}{32}$)
		and total joint thickness including weld reinforcement $\geq \bar{T}_w$	
E	Surface roughness	≤ 12.5 μm (500 $\mu\text{in.}$) R_a (see ASME B46.1 for definition of roughness average, R_a)	
F	Height of reinforcement or internal protrusion [Note (3)] in any plane through the weld shall be within the limits of the applicable height value in the tabulation at the right. Weld metal shall be fused with and merge smoothly into the component surfaces.	Wall Thickness, \bar{T}_w , mm (in.)	External Weld Reinforcement or Internal Weld Protrusion, mm (in.)
		≤ 13 ($\frac{1}{2}$)	≤ 1.5 ($\frac{1}{16}$)
		> 13 ($\frac{1}{2}$) and ≤ 51 (2)	≤ 3 ($\frac{1}{8}$)
		> 51 (2)	≤ 4 ($\frac{5}{32}$)

NOTES:

- (1) Where two limiting values are given, the lesser measured value governs acceptance. \bar{T}_w is the nominal wall thickness of the thinner of two components joined by a butt weld.
- (2) For ultrasonic examination, refer to para. K344.6.3 for acceptable value limits.
- (3) For groove welds, height is the lesser of the measurements made from the surfaces of the adjacent components. For fillet welds, height is measured from the theoretical throat; internal protrusion does not apply. Required thickness t_m shall not include reinforcement or internal protrusion.

Appendix 6

Acceptance criteria according to ASME B31.12-2023

Table IP-10.4.3-1 Acceptance Criteria for Weldments and Methods for Evaluating Weld Imperfections

Piping Design										Weld Imperfection	Examination Method		
Design Conditions up to Class 150 in a Ventilated Location			Design Conditions up to Class 150 Not in a Ventilated Location			Design Conditions Above Class 150			The criteria value for the type of weld and design pressure is identified by the letter symbol for the measure and acceptable value limits of each NDE method.		Visual	Radiography and Ultrasonic	Magnetic Particle and Liquid Penetrant
Type of Weld			Type of Weld			Type of Weld							
Girth and Miter Groove	Longitudinal Groove	Fillet	Girth and Miter Groove	Longitudinal Groove	Fillet	Girth and Miter Groove	Longitudinal Groove	Fillet					
A	A	A	A	A	A	A	A	A	Cracks	✓	✓	✓	
B	B	B	B	B	B	B	B	B	Lack of fusion and incomplete penetration	✓	✓	✓	
C	C	C	C	C	C	C	C	C	Surface porosity; inclusions, slag or tungsten	✓	✓	✓	
D	D	N/A	D	D	N/A	D	D	N/A	Internal porosity	...	✓	...	
F	F	N/A	F	F	N/A	E	E	N/A	Internal inclusions, slag or tungsten; elongated indications	...	✓	...	
H	H	H	H	H	H	G	G	G	Depth of undercut	✓	✓	...	
J	J	N/A	J	J	N/A	I	I	N/A	Depth of surface concavity	✓	✓	...	
K	K	K	K	K	K	K	K	K	Weld surface finish O.D. and I.D.	✓	✓	...	
L	L	L	L	L	L	L	L	L	Weld reinforcement O.D. and I.D.	✓	✓	...	

GENERAL NOTES:

- (a) Girth and miter groove welds include other complete joint penetration weldments such as for branch connections and fabricated laps.
- (b) Fillet welds include socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.
- (c) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in para. IP-10.4, or by the engineering design.
- (d) "N/A" indicates the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of weld. See Table IP-10.4.3-3 for letter symbols.
- (e) Check (✓) indicates examination method generally used for evaluating this kind of weld imperfection.
- (f) Ellipsis (...) indicates examination method not generally used for evaluating this kind of weld imperfection.
- (g) Criteria given are for required examination method(s). More stringent criteria may be specified in the engineering design.
- (h) Longitudinal groove welds (single or double) include straight seam only. Criteria are not intended to apply to welds made in accordance with a standard listed in Table IP-8.1.1-1 or Table IX-1A.


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Table IP-10.4.3-3 Criterion Value Notes for Table IP-10.4.3-1

Criterion		
Symbol	Measure	Acceptable Value Limits [Note (1)]
A	Cracks	None of weld deposit, HAZ and BM
B	Lack of fusion and incomplete penetration	None of weld deposit or weld deposit to BM
C	Surface porosity; inclusions, slag or tungsten	None of weld deposit
D	Size and distribution of internal porosity	See ASME BPV Code Section VIII, Division 1, Appendix 4
E	Internal inclusions, slag or tungsten; elongated indications Individual length Individual width Cumulative length	$\leq \bar{T}_W/4$ and ≤ 4 mm ($5/32$ in.) $\leq \bar{T}_W/4$ and ≤ 2.5 mm ($1/32$ in.) $\leq \bar{T}_W$ in any 12 \bar{T}_W weld length
F	Internal inclusions, slag or tungsten; elongated indications Individual length Individual width Cumulative length	$\leq \bar{T}_W/3$ ≤ 2.5 mm ($1/32$ in.) and $\leq \bar{T}_W/3$ $\leq \bar{T}_W$ in any \bar{T}_W weld length
G	Depth of undercut	None allowed
H	Depth of undercut [Note (2)]	≤ 1 mm ($1/32$ in.) and $\leq \bar{T}_W/4$
I	Depth of root surface concavity	None below pipe component I.D.
J	Depth of root surface concavity [Note (3)]	Total joint thickness, including weld reinforcement, $\geq \bar{T}_W$
K	Weld surface of O.D. finish [Note (4)]	Roughness average ≤ 12.5 μm R_a (500 $\mu\text{in.}$ R_a) per ASME B46.1
L	Weld reinforcement O.D. and I.D. [Note (5)]	See Table GR-3.4.6-1

NOTES:

- (1) Where two limiting values are separated by "and," the lesser of the values determines acceptance. \bar{T}_W is the nominal wall thickness of the thinner of two components joined by a butt weld.
- (2) Depth of undercut shall be applied to the O.D. and I.D. surfaces.
- (3) Concavity on the root side of a single groove weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined and the contour of the concavity is smooth without sharp edges.
- (4) Weld metal reinforcement, O.D. and I.D., shall merge smoothly into the weld surfaces.
- (5) For all butt groove welds (single and double), height is the lesser of the measurements made from the surfaces of the adjacent components. For single groove welds, I.D. reinforcement (internal protrusion) is included in a weld (see Fig. GR-3.4.4-1). Weld reinforcement, O.D. or I.D., may be flush to the adjoining surfaces. For fillet welds and added reinforcement to nonbutt groove welds, height is measured from the theoretical throat (see Fig. GR-3.4.7-1). Internal protrusion does not apply.

Appendix 7

Acceptance criteria according to ASME B31.12-2023 (API 1104 22nd edition)

9.3 Radiographic Testing

NOTE All densities referred to in 9.3.1 through 9.3.13 are based on negative images.

9.3.1 Inadequate Penetration Without High-low (IP)

IP is defined as the incomplete filling of the weld root. This condition is shown schematically in Figure 13. IP shall be considered a defect should any of the following conditions exist:

- the length of an individual indication of IP exceeds 1 in. (25 mm),
- the aggregate length of indications of IP in any continuous 12 in. (300 mm) length of weld exceeds 1 in. (25 mm),
- the aggregate length of indications of IP exceeds 8 % of the weld length in any weld less than 12 in. (300 mm) in length.

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

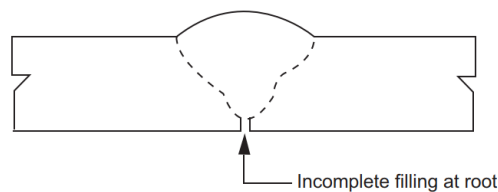


Figure 13—Inadequate Penetration Without High-low

9.3.2 Inadequate Penetration Due to High-low (IPD)

IPD 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 14. IPD shall be considered a defect should any of the following conditions exist:

- the length of an individual indication of IPD exceeds 2 in. (50 mm),
- the aggregate length of indications of IPD in any continuous 12 in. (300 mm) length of weld exceeds 3 in. (75 mm).

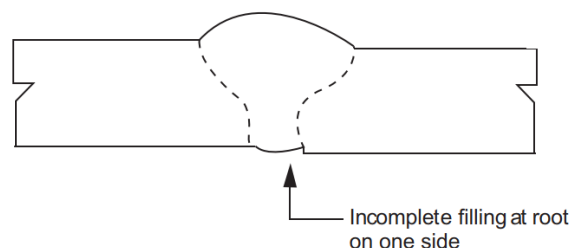


Figure 14—Inadequate Penetration Due to High-low

9.3.3 Inadequate Cross Penetration (ICP)

ICP is defined as a subsurface imperfection between the first inside pass and the first outside pass that is caused by inadequately penetrating the vertical land faces. This condition is shown schematically in Figure 15. ICP shall be considered a defect should any of the following conditions exist:

- a) the length of an individual indication of ICP exceeds 2 in. (50 mm),
- b) the aggregate length of indications of ICP in any continuous 12 in. (300 mm) length of weld exceeds 2 in. (50 mm).

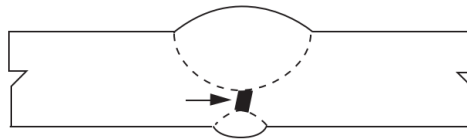


Figure 15—Inadequate Cross Penetration

9.3.4 Incomplete Fusion (IF)

IF 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 16. IF shall be considered a defect should any of the following conditions exist:

- a) the length of an individual indication of IF exceeds 1 in. (25 mm),
- b) the aggregate length of indications of IF in any continuous 12 in. (300 mm) length of weld exceeds 1 in. (25 mm),
- c) the aggregate length of indications of IF exceeds 8 % of the weld length in any weld less than 12 in. (300 mm) in length.

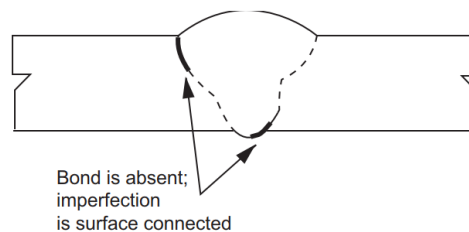



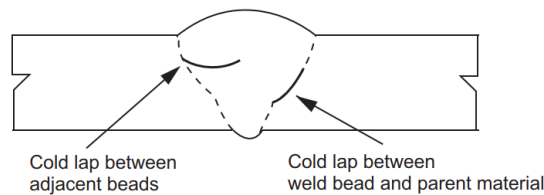
Figure 16—Incomplete Fusion at Root of Bead or Top of Joint

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9.3.5 Incomplete Fusion Due to Cold Lap (IFD)

IFD is defined as an imperfection between two adjacent weld beads or between the weld metal and the base metal that is not open to the surface. This condition is shown schematically in Figure 17. IFD shall be considered a defect should any of the following conditions exist:

- a) the length of an individual indication of IFD exceeds 2 in. (50 mm),
- b) the aggregate length of indications of IFD in any continuous 12 in. (300 mm) length of weld exceeds 2 in. (50 mm),
- c) the aggregate length of indications of IFD exceeds 8 % of the weld length.



NOTE The cold lap shown is not surface connected.

Figure 17—Incomplete Fusion Due to Cold Lap

9.3.6 Internal Concavity (IC)

IC is defined in 3.1.13 and is shown schematically in Figure 18. Any length of IC is acceptable, provided the density of the radiographic image of the IC does not exceed that of the thinnest adjacent parent material. For areas that exceed the density of the thinnest adjacent parent material, the criteria for BT (see 9.3.7) are applicable.

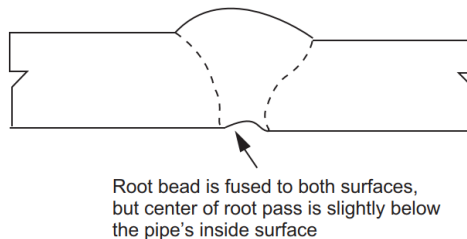



Figure 18—Internal Concavity

9.3.7 Burn-through (BT)

9.3.7.1 General

A BT is defined as a portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe.

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9.3.7.2 Large Diameter Pipe

For pipe with a specified OD greater than or equal to 2.375 in. (60.3 mm), a BT shall be considered a defect should any of the following conditions exist:

- a) the maximum dimension exceeds $\frac{1}{4}$ in. (6 mm) and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material;
- b) the maximum dimension exceeds the thinner of the specified wall thicknesses joined and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material;
- c) the sum of the maximum dimensions of separate BTs whose image density for any portion of the BTs exceeds that of the thinnest adjacent parent material and exceeds $\frac{1}{2}$ in. (13 mm) in any continuous 12 in. (300 mm) length of weld or the total weld length, whichever is less.

9.3.7.3 Small Diameter Pipe

For pipe with a specified OD less than 2.375 in. (60.3 mm), a BT shall be considered a defect when any of the following conditions exists:

- a) the maximum dimension exceeds $\frac{1}{4}$ in. (6 mm) and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material;
- b) the maximum dimension exceeds the thinner of the specified wall thicknesses joined and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material;
- c) more than one BT of any size is present and the density in any portion of the BT's image exceeds that of the thinnest adjacent parent material.

9.3.8 Slag Inclusions

9.3.8.1 General


A slag inclusion is defined as a nonmetallic solid entrapped in the weld metal or between the weld metal and the parent material. Elongated slag inclusions (ESIs)—for example, continuous or broken slag lines or wagon tracks—are usually found at the fusion zone. Isolated slag inclusions (ISIs) are irregularly shaped and may be located anywhere in the weld. For evaluation purposes, when the size of a radiographic indication of slag is measured, the indication's maximum dimension shall be considered its length.

9.3.8.2 Large Diameter Pipe

For pipe with a specified OD greater than or equal to 2.375 in. (60.3 mm), slag inclusions shall be considered a defect should any of the following conditions exist:

- a) the length of an ESI indication exceeds 2 in. (50 mm),

NOTE Parallel ESI indications separated by approximately the width of the root bead (wagon tracks) shall be considered a single indication unless the width of either of them exceeds $\frac{1}{32}$ in. (0.8 mm). In that event, they shall be considered separate indications.
- b) the aggregate length of ESI indications in any continuous 12 in. (300 mm) length of weld exceeds 2 in. (50 mm),
- c) the width of an ESI indication exceeds $\frac{1}{16}$ in. (1.6 mm),
- d) the aggregate length of ISI indications in any continuous 12 in. (300 mm) length of weld exceeds $\frac{1}{2}$ in. (13 mm),

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- e) the width of an ISI indication exceeds $1/8$ in. (3 mm),
- f) more than four ISI indications with the maximum width of $1/8$ in. (3 mm) are present in any continuous 12 in. (300 mm) length of weld,
- g) the aggregate length of ESI and ISI indications exceeds 8 % of the weld length.

9.3.8.3 Small Diameter Pipe

For pipe with a specified OD less than 2.375 in. (60.3 mm), slag inclusions shall be considered a defect should any of the following conditions exist:

- a) the length of an ESI indication exceeds three times the thinner of the specified wall thicknesses joined,

NOTE Parallel ESI indications separated by approximately the width of the root bead (wagon tracks) shall be considered a single indication unless the width of either of them exceeds $1/32$ in. (0.8 mm). In that event, they shall be considered separate indications.

- b) the width of an ESI indication exceeds $1/16$ in. (1.6 mm),
- c) the aggregate length of ISI indications exceeds two times the thinner of the specified wall thicknesses joined and the width exceeds one-half the thinner of the specified wall thicknesses joined,
- d) the aggregate length of ESI and ISI indications exceeds 8 % of the weld length.

9.3.9 Porosity

9.3.9.1 General

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. When the size of the radiographic indication produced by a pore is measured, the maximum dimension of the indication shall apply to the criteria given in 9.3.9.2 through 9.3.9.4.

9.3.9.2 Individual or Scattered Porosity

Individual or scattered porosity shall be considered a defect should any of the following conditions exist:

- a) the size of an individual pore exceeds $1/8$ in. (3 mm) in diameter or 25 % of the specified wall thickness, whichever is less;
- b) the size of an individual pore exceeds 25 % of the thinner of the specified wall thicknesses joined, but no more than $1/8$ in. (3 mm) in diameter;
- c) the distribution of scattered porosity exceeds the concentration permitted by Figure 19 or Figure 20.

9.3.9.3 Cluster Porosity (CP)

CP that occurs in any pass except the finish pass shall comply with the criteria of 9.3.9.2. CP that occurs in the finish pass shall be considered a defect should any of the following conditions exist:

- a) the diameter of the cluster exceeds $1/2$ in. (13 mm);
- b) the aggregate length of CP in any continuous 12 in. (300 mm) length of weld exceeds $1/2$ in. (13 mm).

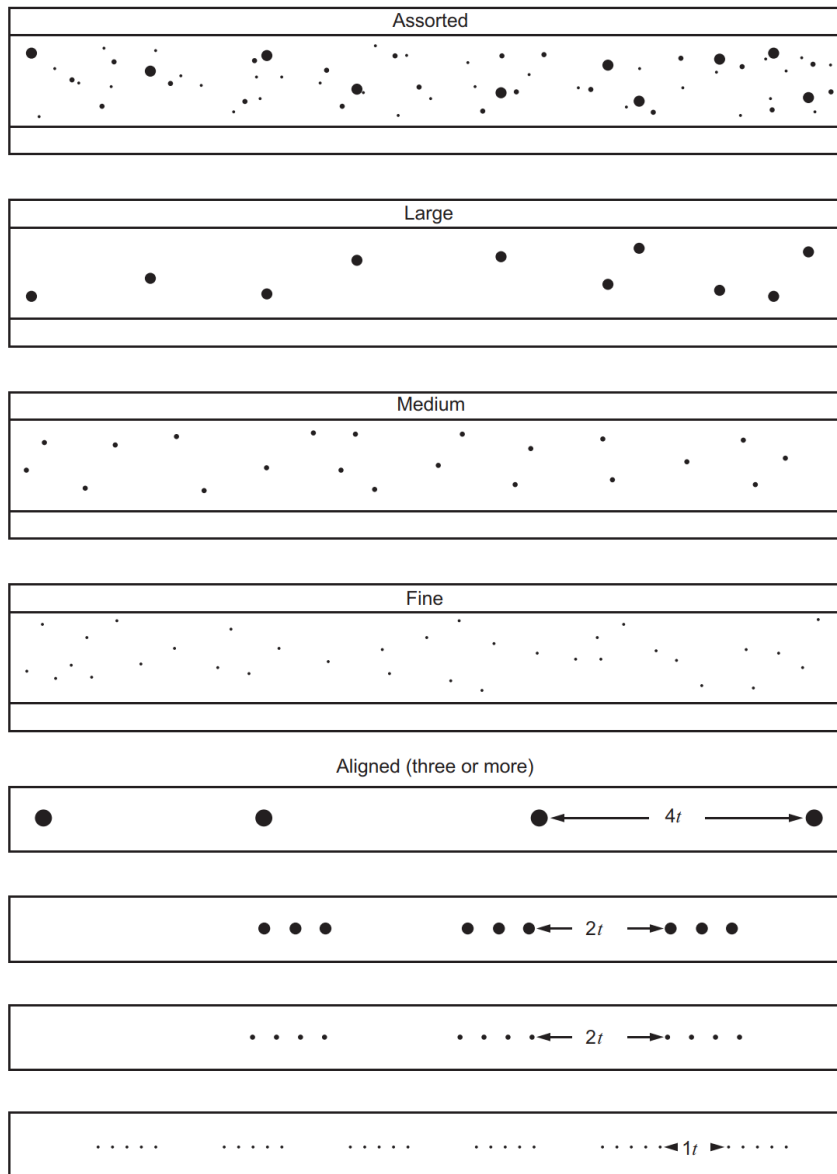


Figure 19—Maximum Distribution of Gas Pockets: Wall Thickness (t) Less Than or Equal to 0.500 in. (12.7 mm)

9.3.9.4 Hollow Bead (HB) Porosity

Hollow bead porosity is defined as elongated linear porosity that occurs in the root pass. HB shall be considered a defect should any of the following conditions exist:

- a) the length of an individual indication of HB exceeds $1/2$ in. (13 mm);
- b) the aggregate length of indications of HB in any continuous 12 in. (300 mm) length of weld exceeds 2 in. (50 mm);

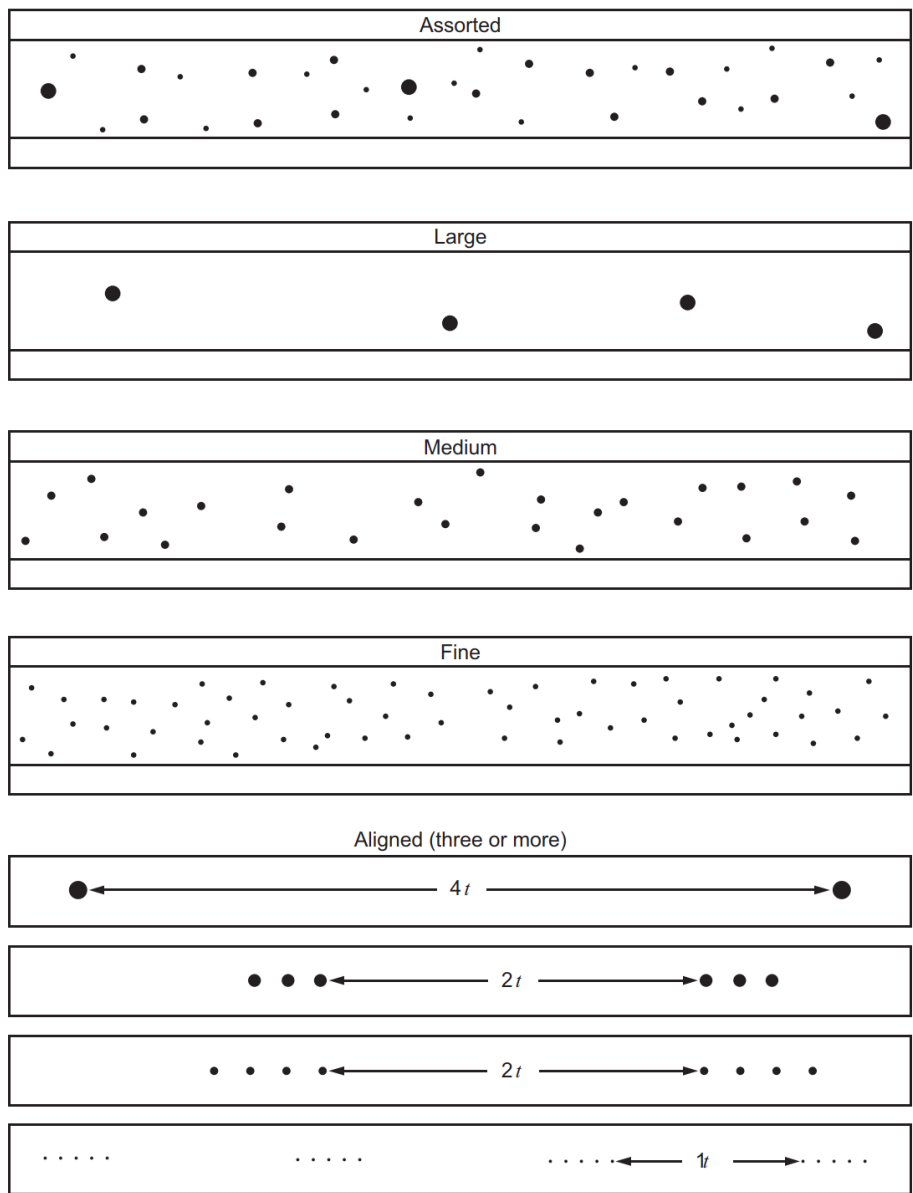


Figure 20—Maximum Distribution of Gas Pockets: Wall Thickness (t) Greater Than 0.500 in. (12.7 mm)


- c) individual indications of HB, each greater than $\frac{1}{4}$ in. (6 mm) in length, are separated by less than 2 in. (50 mm);
- d) the aggregate length of all indications of HB exceeds 8 % of the weld length.

9.3.10 Cracks

Cracks shall be considered a defect should any of the following conditions exists:

- a) the crack, of any size or location in the weld, is not a shallow crater crack or star crack;
- b) the crack is a shallow crater crack or star crack with a length that exceeds $\frac{5}{32}$ in. (4 mm).

NOTE Shallow crater cracks or star cracks are located at the stopping point of weld beads and are the result of weld metal contractions during solidification.

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9.3.11 Undercutting

Undercutting is defined as a groove melted into 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 undercutting adjacent to root pass (IU) shall be considered a defect should any of the following conditions exist:

- a) the aggregate length of indications of EU and IU, in any combination, in any continuous 12 in. (300 mm) length of weld exceeds 2 in. (50 mm);
- b) the aggregate length of indications of EU and IU, in any combination, exceeds one-sixth of the weld length.

NOTE See 9.7 for acceptance standards for undercutting when visual and mechanical measurements are employed.

9.3.12 Accumulation of Imperfections

Excluding incomplete penetration due to high-low and undercutting, any accumulation of imperfections shall be considered a defect should any of the following conditions exist:

- a) the aggregate length of indications in any continuous 12 in. (300 mm) length of weld exceeds 2 in. (50 mm),
- b) the aggregate length of indications exceeds 8 % of the weld length.

9.3.13 Base Material Imperfections

Imperfections in the base material detected by radiographic testing shall be reported to the company. The disposition of these imperfections shall be as directed by the company.