Methods of radiographic examination for welded joints in stainless steel

1 Scope This Japanese Industrial Standard specifies the methods of radiographic examination for welded joints of stainless steel, heat-resistant steel, corrosion- and heat-resistant superalloy, nickel and nickel alloy, which are carried out by the direct radiography through the irradiation of X-rays or gamma-rays (hereafter referred to as "radiation") using industrial X-ray films.

2 Normative references The standards listed in Attached Table 1 contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards (including amendments) shall be applied.

3 Definitions For the purposes of this Standard, the definitions given in **JIS Z 2300** and **JIS Z 3001**, and the following definitions apply.

a) **thickness of base metal** For a butt welded joint whose two base metals differ in thickness, the lighter thickness shall be the thickness of base metal. For a circumferentially welded joint for pipe, the lighter wall thickness shall be the thickness of base metal. And for a Tee welded joint, the thickness of T1 material as shown in Annex 3 Fig. 1 and Annex 3 Fig. 2 shall be the thickness of base metal.

b) **test part** The weld metal to be examined, including its heat-affected zone.

4 Classification of radiograph image quality The image quality of radiograph shall be classified into five grades; Grade A, Grade B, Grade P1, Grade P2 and Grade F. Grade A can be obtained by applying usual radiographic technique and Grade B can be obtained by applying a radiographic technique capable of attaining high detection sensitivity for flaws. Grade P1 and Grade P2 are normal image qualities obtainable when the radiograph of a circumferentially welded joint for pipe is taken by applying duplex penetration through its wall; the former available for the radiograph taken on one side of the joint and the latter for the radiograph taken on both sides of the joint. Grade F is normal image quality obtainable in the radiographic examination of a Tee welded joint. The application of these image qualities shall depend on the shape of welded joints, as shown in Table 1.

Table 1 Classification of radiograph image quality

Shape of welded joint	Classification of image quality
Butt welded joint for plate and other welded joints whose geometrical conditions at the time of taking radiographs can be deemed equal to those of the butt welded joint	Grade A, Grade B
Circumferentially welded joint for pipe	Grade A, Grade B, Grade P1, Grade P2
Tee welded joint	Grade F

5 **Test engineer** The test engineers who undertake the radiographic examination shall be those who have passed the examination specified in **JIS Z 3861** or those with ability equal or superior to them.

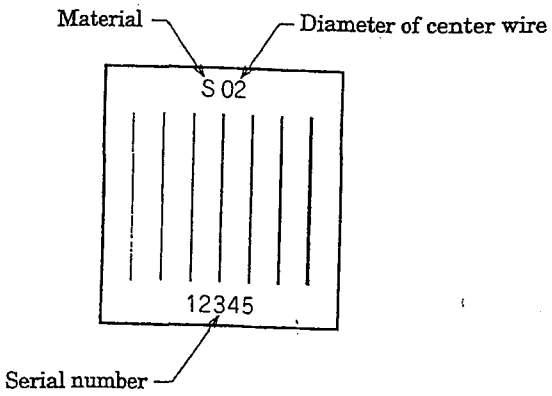
6 Radiographic equipment and auxiliary devices

6.1 **Radiographic equipment** The radiographic equipment shall be the X-ray apparatus and the X-ray generator using an electron accelerator specified in **JIS Z 4606** and the gamma-ray apparatus specified in **JIS Z 4560** and the equipment with performance equal or superior to them.

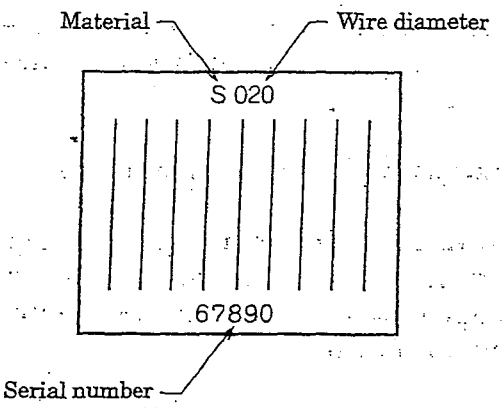
6.2 **Sensitive materials** The industrial X-ray films (hereafter referred to as "films") shall be any of low-sensitive/super ultrafine-grained type, low-sensitive/ultrafine-grained type, medium-sensitive/fine-grained type or high-sensitive/fine-grained type. Intensifying screens, when used, shall be lead-foil type, fluorescent type or metal fluorescent type.

6.3 **Penetrometer** For the penetrometer, the F-type or S-type general model specified in **JIS Z 2306** shall be used. For taking the radiographs of a circumferentially welded joint for pipe, the F-type or S-type penetrometer of a band model shall be used. But the F-type or S-type penetrometer of a general model may also be used.

Informative reference : As for the S-type penetrometer specified in **JIS Z 2306**, examples of configuration for the general model and the band model are shown in Informative Fig. 1 and Informative Fig. 2, and the relationship between nominal number and wire diameter is shown in Informative Table 1 and Informative Table 2.



Informative Fig. 1 Configuration of S-type penetrometer of general model



Informative Fig. 2 Configuration of S-type penetrometer of band model

Informative Table 1 Dimensions for S-type penetrometer of general model

Nominal number	Wire diameter and series thereof mm	Allowance on wire diameter %
S01	0.05 0.063 0.08 0.10 0.125 0.16 0.20	±5
S02	0.10 0.125 0.16 0.20 0.25 0.32 0.40	
S04	0.20 0.25 0.32 0.40 0.50 0.63 0.80	
S08	0.40 0.50 0.63 0.80 1.0 1.25 1.6	
S16	0.80 1.0 1.25 1.6 2.0 2.5 3.2	
S32	1.6 2.0 2.5 3.2 4.0 5.0 6.3	

Informative Table 2 Wire diameters for S-type penetrometer of band model

Nominal number	Wire diameter mm	Allowance on wire diameter %
S005	0.05	±5
S006	0.063	
S008	0.08	
S010	0.10	
S012	0.125	
S016	0.16	
S020	0.20	
S025	0.25	
S032	0.32	
S040	0.40	
S050	0.50	
S063	0.63	
S080	0.80	
S100	1.0	

4 **Contrastmeter** The type, structure, dimensions and material of the contrastmeter shall be as follows:

The type, structure and dimensions of the contrastmeter shall be as shown in Fig. 1.

Dimensional tolerances for the contrastmeter shall be ±5 % for thickness and ±0.5 mm for side length.

The material of the contrastmeter shall be the steel materials specified in **JIS G 3101** and the SUS 304 specified in **JIS G 4304** or **JIS G 4305**.

Unit : mm

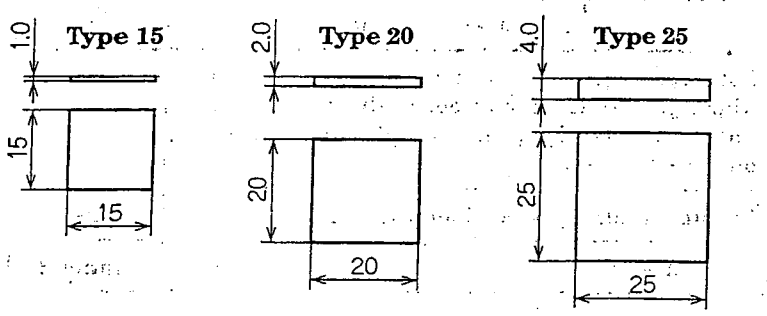


Fig. 1 The type, structure and dimensions of contrastmeter

Viewing illuminator The viewing illuminator shall be as specified in **JIS Z** or that with performance equal or superior to it.

6.6 Densitometer The densitometer subjected to proper calibration using the standard densitometer shall be used.

7 Radiographic method

7.1 Combination of irradiation source and sensitive material The combination of the irradiation source and the sensitive material shall be such that the minimum perception wire diameter of the penetrometer can be identified.

7.2 Symbol When taking radiographs, use identification symbols so that the radiograph taken can be checked with the record.

7.3 Radiation field In taking radiographs, it is preferable that the radiation field be controlled not to be unnecessarily wide by the use of a diaphragm or a treatment cone.

7.4 Radiographic method The radiographic method shall conform to the Annexes shown in Table 2, depending on the shape of a welded joint.

Table 2 Annexes specifying the radiographic method

Shape of welded joint	Annex
Butt welded joint for plate and other welded joints whose geometrical conditions at the time of taking radiographs can be deemed equal to those of the butt welded joint	Annex 1
Circumferentially welded joint for pipe	Annex 2
Tee welded joint	Annex 3

8 Requirements for radiograph As for the radiograph taken, requirements for the radiograph at the test part shall conform to the Annexes shown in Table 3, depending on the shape of a welded joint.

The radiograph shall be free of uneven development, film flaw or other defects detrimental to the assessment of image quality and the grouping of flaw image.

Table 3 Annexes specifying requirements for radiographs

Shape of welded joint	Annex
Butt welded joint for plate and other welded joints whose geometrical conditions at the time of taking radiographs can be deemed equal to those of the butt welded joint	Annex 1
Circumferentially welded joint for pipe	Annex 2
Tee welded joint	Annex 3

9 Observation of radiograph

9.1 Viewing illuminator For the observation of radiograph, the viewing illuminator specified in **6.5** shall be applied according to the division of Table 4.

Table 4 Application division for observing instrument

Type of viewing illuminator	Maximum density in radiograph (1)
Type D10	1.5 or under
Type D20	2.5 or under
Type D30	3.5 or under
Type D35	4.0 or under

Note (1) Maximum density observed at the test part in each radiograph.

9.2 **Method of observation** The observation of radiograph shall be made in a dark room using a fixed mask that suits the size of the radiograph.

10 **Method of grouping flaw images** The grouping of flaw images observed on a radiograph shall conform to Annex 4.

11 **Record** The following necessary items shall be stated on a record of test results so that the collation of the record with the test part is possible.

a) **Matters relevant to test part**

1) Builder's or manufacturer's name

2) Work or product name

3) Symbol or number of test part

4) Material

5) Thickness of base metal (wall thickness and outside diameter for tubular products)

6) Shape of welded joint (whether there is reinforcement of weld, etc.)

b) **Radiographing date**

c) **Test engineer's position and name**

d) **Test conditions**

1) Equipment and materials used

1.1) Name of radiation equipment and size of effective focus

1.2) Types of film and intensifying screen

1.3) Type of penetrometer

1.4) Type of contrastmeter

2) Radiographic conditions

2.1) Tube voltage used or type of radioactive isotope

2.2) Tube current used or intensity of radioactivity

2.3) Exposure time

3) Radiographic setup

3.1) Distance between radiation source and film ($L_1 + L_2$)

3.2) Distance between the radiation source side surface of test part and film (L_2)

3.3) Effective length of test part L_3 (both sides of double wall: $L_3 = L_3' + L_3''$)

4) Development conditions

4.1) Developer, temperature of development and time of development (for manual processing)

4.2) Name of automatic processor and developer (for automatic processing)

e) **Confirmation of requirements for radiograph**

1) Type of viewing illuminator and observing conditions

2) Classification of image quality (Grade A, Grade B, Grade P1, Grade P2 or Grade F)

3) Minimum perception wire diameter of penetrometer

4) Density at test part

5) Value on contrastmeter (density difference/density)

6) Acceptability of radiograph

f) **Date of flaw image grouping**

g) **Result of flaw image grouping**

1) Result of grouping flaw images by flaw mark

1.1) Grouping of Type 1 flaw image

1.2) Grouping of Type 4 flaw image

1.3) Whether Type 1 flaw image and Type 4 flaw image coexist

1.4) Grouping of the flaw images which coexist

2) Grouping of Type 2 flaw image

3) Grouping of Type 3 flaw image

4) Whether two or more Type 2 flaw images exist in the field of examination

5) Overall grouping

h) **Other necessary items**

i) **Remarks**

Attached Table 1

JIS G 3101	*Rolled steels for general structure*
JIS G 3446	*Stainless steel pipes for machine and structural purposes*
JIS G 3448	*Light gauge stainless steel tubes for ordinary piping*
JIS G 3459	*Stainless steel pipes*
JIS G 3463	*Stainless steel boiler and heat exchanger tubes*
JIS G 4304	*Hot rolled stainless steel plates, sheets and strip*
JIS G 4305	*Cold rolled stainless steel plates, sheets and strip*
JIS G 4312	*Heat-resisting steel plates and sheets*
JIS G 4902	*Corrosion-resisting and heat-resisting superalloy plates and sheets*
JIS G 4903	*Seamless nickel-chromium-iron alloy pipes*
JIS G 4904	*Seamless nickel-chromium-iron alloy heat exchanger tubes*
JIS H 4551	*Nickel and nickel alloy plate, sheet and strip*
JIS H 4552	*Nickel and nickel alloy seamless pipes and tubes*
JIS Z 2300	*Glossary of terms used in nondestructive testing*
JIS Z 2306	*Radiographic image quality indicators for non-destructive testing*
JIS Z 3001	*Welding terms*
JIS Z 3861	*Standard qualification procedure for radiographic testing technique of welds*
JIS Z 4560	*Industrial γ-ray apparatus for radiography*
JIS Z 4561	*Viewing illuminators for industrial radiograph*
JIS Z 4606	*Industrial X-ray apparatus for radiographic testing*

Annex 1 (normative)
Method of radiographing butt welded joint for plate and requirements for radiograph

Scope This Annex specifies the method of radiographing a butt welded joint by direct radiography using radiation and requirements for radiographs.

Radiographic method

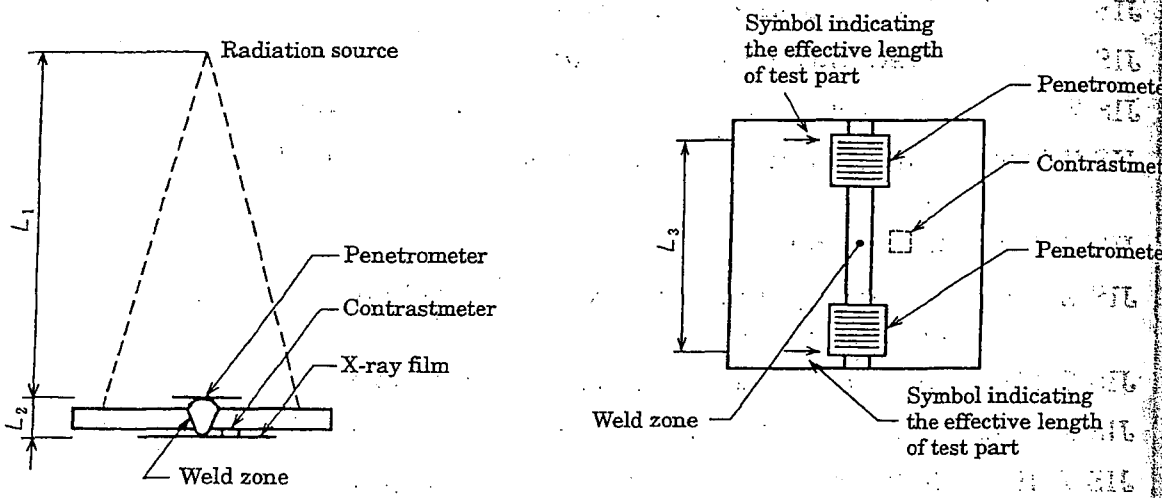
Classification of radiograph image quality The image quality of radiophs shall be classified into Grade A and Grade B.

2.2 Irradiation direction of radiation Radiographs shall be taken by irradiating the radiation from the direction that can minimize the thickness of radiation penetrating through test part.

2.3 Use of penetrometers Two penetrometers including the minimum perception wire diameter (refer to 4.1 of Annex 1) shall each be placed on the radiation source side surface of test part over the welded joint, so that the finest wire of each penetrometer comes in the vicinity of each end of the effective length L_3 of the test part, as shown in Annex 1 Fig. 1. On this occasion, the fine wire side shall be placed outward.

When the penetrometer and the film are apart from each other at a distance ten times or more the minimum perception wire diameter, the penetrometer may be placed on the film side. In this case, the symbol F should be put down on each penetrometer to make it clear from the radiographs taken that the penetrometer was located on the film side.

When the effective length of the test part is not more than three times the width of the penetrometer, one penetrometer may be placed in the middle of the test part.



Annex 1 Fig. 1 Photographic setup

2.4 Use of contrastmeter The contrastmeter shall be used in accordance with the division given in Annex 1 Table 2 for a welded joint 50 mm or less in the thickness of base metal multiplied by the coefficient B obtainable from Annex 1 Table 1 depending on the material. On this occasion, the contrastmeter shall be placed on the film side of base metal in a position not so far from the middle of the effective length of the test part. However, when the value of the contrastmeter not less than the values given in Annex 1 Table 7 can be obtained, the contrastmeter may be placed on the radiation source side.

Annex 1 Table 1 Value of coefficient B

Material of test part				Coefficient B	
JIS G 4304 JIS G 4305	JIS G 4312(1)	JIS G 4902	JIS H 4551	Division of base metal thickness to be multiplied by coefficient (mm)	
				25 or less	Over 25
	SUH21 SUH446			0.95	1.00
SUS301 SUS301L SUS301J1 SUS302 SUS302B SUS303 SUS304 SUS304J1 SUS304J2 SUS304L SUS304LN SUS304N1 SUS304N2 SUS305 SUS309S SUS310S SUS315J1 SUS315J2 SUS317J2 SUS317J3L SUS321 SUS329J1 SUS329J3L SUS329J4L SUS347 SUS403 SUS405 SUS410L SUS410 SUS410S SUS420J1 SUS420J2 SUS429 SUS429J1 SUS430 SUS430J1L SUS430LX SUS434 SUS436J1L SUS436L SUS440A SUS444 SUS447J1 SUS630 SUS631 SUSXM15J1 SUSXM27	SUH309 SUH310 SUH409 SUH409L SUH660	NCF800 NCF800H		1.00	1.00
SUS316 SUS316J1 SUS316J1L SUS316L SUS316LN SUS316N SUS316Ti SUS317 SUS317L SUS317LN		NCF718 NCF750 NCF751		1.06	1.00
	SUH330	NCF601 NCF690		1.06	1.06
		NCF80A		1.12	1.00
SUS317J1 SUS836L SUS890L		NCF825		1.12	1.06
		NCF600		1.12	1.12
		NCF625		1.25	1.00
	SUH661		NW4400 NW4402 NW5500 NW6007 NW6985 NW6002	1.25	1.12
			NW2200 NW2201	1.25	1.25
			NW6455	1.41	1.12
			NW0276 NW6022	1.41	1.25
			NW0001 NW0665	1.60	1.25

Note (1) As for the materials, which are specified in **JIS G 4312** and are identical to those specified in **JIS G 4304** and **JIS G 4305**, refer to the left column.

Annex 1 Table 2 Application division for contrastmeter

Unit : mm

Base metal thickness multiplied by coefficient	Type of contrastmeter
20.0 or less	Type 15
Over 20.0 up to and incl. 40.0	Type 20
Over 40.0 up to and incl. 50.0	Type 25

3 Radiographic setup The relative positions of radiation source, penetrometer, contrastmeter and film shall be as shown in Annex 1 Fig. 1.

a) The distance $(L_1 + L_2)$ between the radiation source and film shall be not less than m times the distance L_2 between the radiation source side surface of test part and film. The multiplier m shall be as given in Annex 1 Table 3 according to the grade of image quality.

b) The distance L_1 between the radiation source and the surface of test part shall be not less than n times the effective length L_3 of test part. The multiplier n shall be as given in Annex 1 Table 4 according to the grade of image quality.

c) Symbols indicating the effective length L_3 of test part shall be placed on the radiation source side.

Annex 1 Table 3 Value of multiplier *m*

Grade of image quality	Multiplier m (1) (2)
Grade A	$2f/d$ or 6, whichever is larger
Grade B	$3f/d$ or 7, whichever is larger

Notes (1) f : Size of radiation source (mm)

(2) d : Minimum perception wire diameter of penetrometer specified in **4.1** of Annex 1 (mm)

Annex 1 Table 4 Value of multiplier *n*

Grade of image quality	Multiplier n
Grade A	2
Grade B	3

4 Requirements for radiograph

4.1 Minimum perception wire diameter of penetrometer At the test part on the radiograph taken, the confirmation of the minimum perception wire diameter of the penetrometer shall be carried out as follows:

a) Depending on the material of test part, obtain the value of the coefficient B to multiply the thickness of base metal, using Annex 1 Table 1.

b) The minimum perception wire diameter shall be not more than the values given in Annex 1 Table 5, depending on the thickness of base metal multiplied by the coefficient B obtained from a).

Annex 1 Table 5 Minimum perception wire diameter of penetrometer

Unit : mm

Thickness of base metal multiplied by coefficient	Wire diameter of penetrometer	
	Grade A	Grade B
4.0 or less	0.125	0.10
Over 4.0 up to and incl. 5.0	0.16	0.10
Over 5.0 up to and incl. 6.3	0.16	0.125
Over 6.3 up to and incl. 8.0	0.20	0.16
Over 8.0 up to and incl. 10.0	0.20	0.16
Over 10.0 up to and incl. 12.5	0.25	0.20
Over 12.5 up to and incl. 16.0	0.32	0.20
Over 16.0 up to and incl. 20.0	0.40	0.25
Over 20.0 up to and incl. 25.0	0.50	0.32
Over 25.0 up to and incl. 32.0	0.50	0.40
Over 32.0 up to and incl. 40.0	0.63	0.50
Over 40.0 up to and incl. 50.0	0.80	0.63
Over 50.0 up to and incl. 63.0	0.80	0.80
Over 63.0 up to and incl. 80.0	1.0	0.80
Over 80.0 up to and incl. 100	1.25	1.0
Over 100 up to and incl. 125	1.25	1.0
Over 125 up to and incl. 160	1.6	1.25
Over 160 up to and incl. 200	1.6	1.25
Over 200 up to and incl. 250	2.0	1.6
Over 250 up to and incl. 320	2.0	1.6
Over 320	2.5	2.0

Density range of radiograph The photographic density in parts other than flaw image of test part shall satisfy the range specified in Annex 1 Table 6.

Annex 1 Table 6 Density range of radiograph

Grade of image quality	Density range
Grade A	1.3 or more up to and incl. 4.0
Grade B	1.8 or more up to and incl. 4.0

4.3 Value of contrastmeter On the radiograph for which the contrastmeter was used, measure the density in the part of base metal adjacent to the contrastmeter and that in the middle of the contrastmeter. The value of the contrastmeter obtainable by dividing the difference between the densities thus measured by the density in the part of base metal shall be confirmed as follows:

a) Depending on the material of test part, obtain the value of the coefficient B to multiply the thickness of base metal, using Annex 1 Table 1.

b) The value of the contrastmeter shall be not less than the values given in Annex 1 Table 7, depending on the thickness of base metal multiplied by the coefficient B obtained from **a**).

Annex 1 Table 7 Value of contrastmeter

Thickness of base metal multiplied by coefficient mm	Value of contrastmeter (density difference/density)		Type of contrast-meter
	Grade of image quality		
	Grade A	Grade B	
4.0 or less	0.15	0.23	Type 15
Over 4.0 up to and incl. 5.0	0.10	0.23	
Over 5.0 up to and incl. 6.3	0.10	0.16	
Over 6.3 up to and incl. 8.0	0.081	0.12	
Over 8.0 up to and incl. 10.0	0.081	0.12	
Over 10.0 up to and incl. 12.5	0.062	0.096	
Over 12.5 up to and incl. 16.0	0.046	0.096	
Over 16.0 up to and incl. 20.0	0.035	0.077	
Over 20.0 up to and incl. 25.0	0.049	0.11	Type 20
Over 25.0 up to and incl. 32.0	0.049	0.092	
Over 32.0 up to and incl. 40.0	0.032	0.077	
Over 40.0 up to and incl. 50.0	0.060	0.12	Type 25

4.4 Effective length of test part The effective length L_3 of test part in a single radiographing shall be within the range that satisfies the minimum perception wire diameter of the penetrometer, the density range of radiograph and the value of the contrastmeter.

Annex 2 (normative)

Method of radiographing circumferentially welded joint for pipe and requirements for radiograph

1 Scope This Annex specifies the method of radiographing a circumferentially welded joint by the direct radiography using radiation and requirements for radiographs.

2 Radiographic method

2.1 Thickness of base metal For radiographic examination of a circumferentially welded joint for pipe, the wall thickness of pipe shall be the thickness of base metal. In this case, the wall thickness of pipe shall be nominal, and when the wall thickness of pipe on one side of the welded joint is different from that on the other side, the lighter thickness shall be the thickness of base metal.

2.2 Classification of radiographic methods The methods of radiographing a circumferentially welded joint for pipe shall be classified into four types; an internal radiation source radiographic method, an internal film radiographic method, a double-wall one-side radiographic method and a double-wall both-side radiographic method.

2.3 Classification of radiograph image quality The classification of the image quality of radiographs applicable depending on the radiographic methods shall be as shown in Annex 2 Table 1.

Annex 2 Table 1 Application division for radiograph image quality

Radiographic method	Grade of image quality
Internal radiation source radiographic	Grade A, Grade B(1), Grade P1(2)
Internal film radiographic	Grade A, Grade B(1), Grade P1(2)
Double-wall one-side radiographic	Grade A(1), Grade P1, Grade P2(2)
Double-wall both-side radiographic	Grade P1(1), Grade P2

Notes (1) To be applied when high detection sensitivity is required.
(2) To be applied when usual radiographic technique is difficult to apply.

3 Radiographic setup

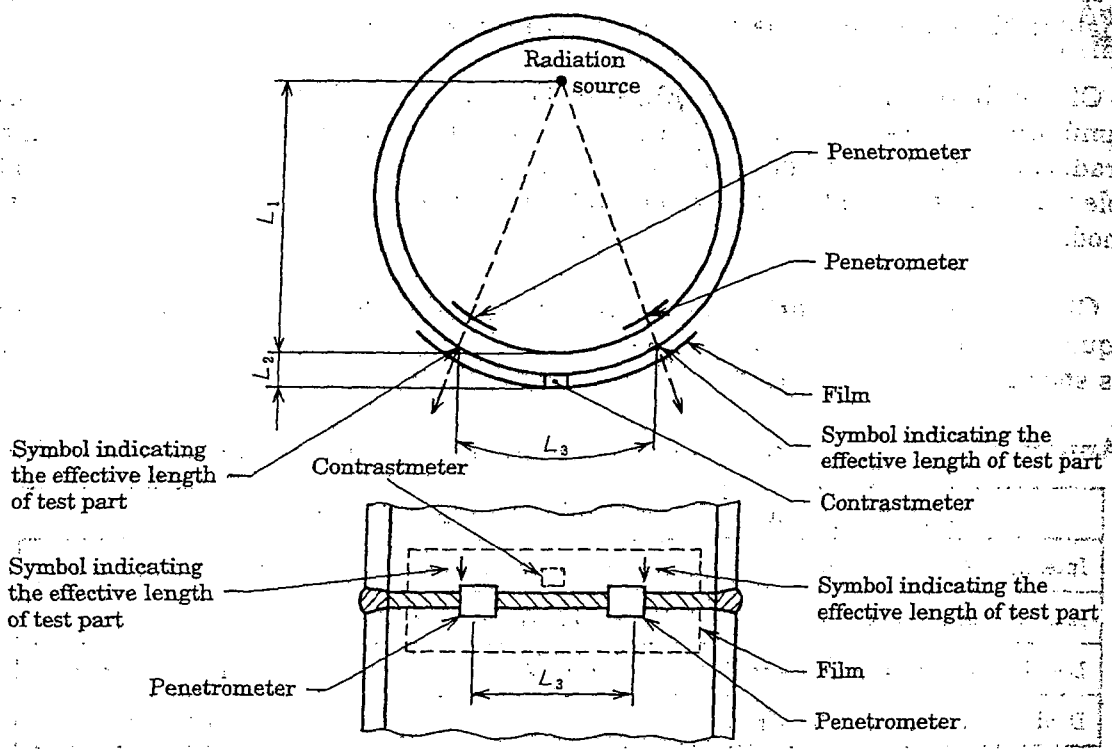
3.1 Internal radiation source radiographic method The radiographic setup for the internal radiation source radiographic method shall be as shown in Annex 2 Fig. 1 and Annex 2 Fig. 2.

1) The distance $(L_1 + L_2)$ between the radiation source and film shall be not less than m times the distance L_2 between the radiation source side surface of test part and film. The multiplier m shall be f/d, where f is the size (mm) of radiation source and d is the value of minimum perception wire diameter (mm) of

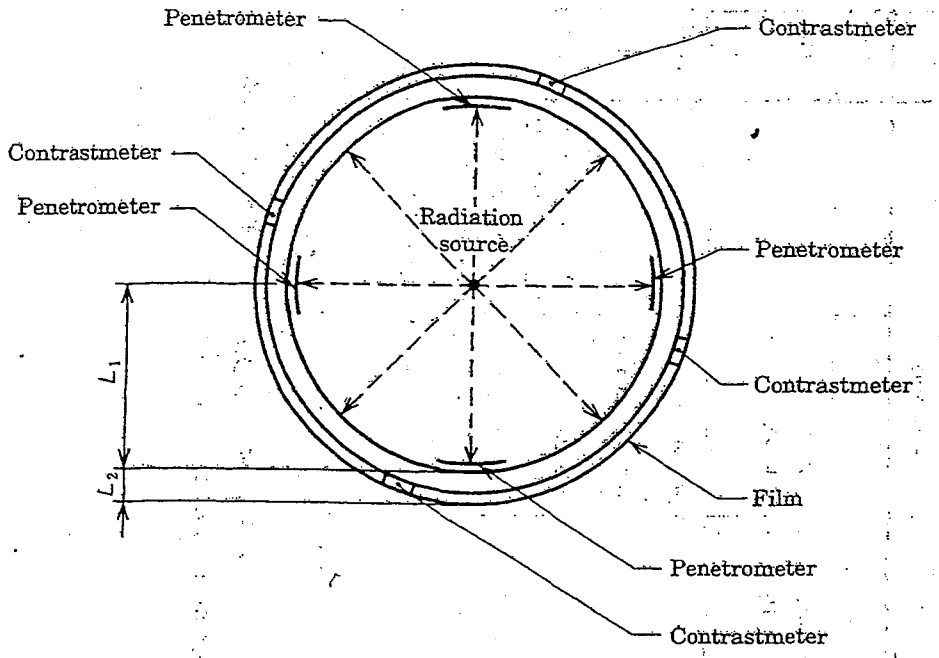
the penetrometer as specified in **4.1**. However, an exception to this is the case of the whole-circumference simultaneous exposure shown in Annex 2 Fig. 2, provided the minimum perception wire diameter of penetrometer specified in **4.1** can be satisfied.

b) The irradiation of radiation shall, as a rule, be in the direction that enables the centerline of the radiation packet to be kept in the middle of test part and also perpendicular to film plane.

c) Two F-type or S-type penetrometers of the band model which have the wire diameters specified in **4.1** shall each be placed on the radiation source side surface of test part over the welded joint in a position that includes each end of the effective length L_3 of test part. On this occasion, be sure that neither the two penetrometers nor the penetrometer and the contrastmeter overlap each other. When a single penetrometer of the band model can fully cover the effective length L_3 of test part, one penetrometer of the band model shall be used.



Annex 2 Fig. 1 Internal radiation source radiographic method (exposure in sections)



Annex 2 Fig. 2 Internal radiation source radiographic method (whole-circumference simultaneous exposure)

Annex 2 Table 2 Value of coefficient *B*

Material of test part(1)			Coefficient *B*
JIS G 3446 JIS G 3448 JIS G 3459 JIS G 3463	JIS G 4903 JIS G 4904	JIS G 4552	
SUSXM8			0.95
SUS304 SUS304H SUS304L SUS304LN SUS309 SUS309S SUS310 SUS310S SUS317J2 SUS321 SUS321H SUS329J1 SUS329J3L SUS329J4L SUS347 SUS347H SUS405 SUS409 SUS409L SUS410 SUS410Ti SUS420J1 SUS420J2 SUS430 SUS430J1L SUS430LX SUS436L SUS444 SUSXM27 SUSXM15J1	NCF800 NCF800H		1.00
SUS316 SUS316L SUS316H SUS316Ti SUS317 SUS317L	NCF690		1.06
SUS317J1 SUS836 SUS890L	NCF825 NCF600		1.12
	NCF625	NW2200 NW2201 NW4400 NW4402 NW6002 NW6007 NW6985	1.25
		NW0276 NW6022 NW6455	1.41
		NW0001 NW0665	1.60

Note (1) Symbols indicating applications (**JIS G 3446** : TKA and TKC, **JIS G 3448** : TPD, **JIS G 3459** : TP, **JIS G 3463** : TB, **JIS G 4903** : TP, **JIS G 4904** : TB), which are suffixed to the symbol of material, are omitted.

d) When the F-type or S-type penetrometer of the general model is used, the penetrometers including the minimum perception wire diameter (refer to **4.1**) shall each be placed on the radiation source side surface of the test part over the welded joint, so that the finest wire of each penetrometer comes in the vicinity of each end of the effective length L_3 of the test part. On this occasion, the fine wire side shall be placed outward. When the two penetrometers cannot be placed within the effective length L_3 of test part, one penetrometer of the band model may be used.

e) When the penetrometer and the film are apart from each other at a distance ten times or more the minimum perception wire diameter (refer to **4.1**), the penetrometer may be placed on the film side. In this case, the symbol F should be put down on each penetrometer to make it clear from the radiographs taken that the penetrometer was located on the film side.

f) For a circumferentially welded joint with an outside diameter of 100 mm or more and also for the image quality grade of Grade A or Grade B, the contrastmeter shall be used in accordance with the division given in Annex 2 Table 3, based on the thickness of base metal multiplied by the coefficient B obtainable from Annex 2 Table 2 depending on the material of test part. On this occasion, the contrastmeter shall be placed in the middle of the effective length of test part on the film side of base metal. However, when the value of the contrastmeter is not less than the values specified in Annex 2 Table 6, the contrastmeter may be placed on the radiation source side.

g) In the case of whole-circumference simultaneous exposure, four penetrometers and contrastmeters individually shall be placed in symmetry in a position that divides the circumference into virtually quarters, as shown in Annex 2 Fig. 2.

h) Symbol indicating the effective length L_3 of test part shall be placed inside the pipe, when the distance between the radiation source and film is smaller than the radius of the pipe, and shall be placed outside the pipe, in case the distance is greater than the radius of the pipe. However, when the distance between the radiation source and film is smaller than the radius of the pipe, the symbols may be placed outside the pipe, provided that the relative position of the symbols, when placed inside or outside the pipe due to a geometrical relation to radiographic setup, are made clear in advance.

Annex 2 Table 3 Application range for contrastmeter

Unit : mm

Base metal thickness multiplied by coefficient	Type of contrastmeter
20.0 or less	Type 15
Over 20.0 up to and incl. 40.0	Type 20
Over 40.0 up to and incl. 50.0	Type 25

3.2 Internal film radiographic method The radiographic setup for the internal film radiographic method shall be as shown in Annex 2 Fig. 3.

a) The distance $(L_1 + L_2)$ between the radiation source and film shall be not less than m times the distance L_2 between the radiation source side surface of test part and film. The multiplier m shall be as specified in **3.1 a)**.

b) The irradiation direction of radiation shall be as specified in **3.1 b)**.

c) The method of using the penetrometer of the band model shall be as specified in **3.1 c)**.

d) In case the penetrometer of the general model is used, **3.1 d)** shall apply.

e) In case the penetrometer is placed on the film side, **3.1 e)** shall apply.

f) The contrastmeter shall be used for a circumferentially welded joint with an outside diameter of 100 mm or more and for the image quality grades of Grade A and Grade B. Its using method shall be as specified in **3.1 f)**.

g) Symbol indicating the effective length L_3 of test part shall be placed outside the pipe.

3.3 Double-wall one-side radiographic method The radiographic setup for the double-wall one-side radiographic method shall be as shown in Annex 2 Fig. 4.

a) The distance $(L_1 + L_2)$ between the radiation source and film shall be not less than m times the distance L_2 between the radiation source side surface of test part and film. The multiplier m shall be as specified in **3.1 a)**.

b) Radiation shall be applied obliquely to the plane including a welded joint. The distance S between the radiation source and the plane including a welded joint shall be not more than a quarter of L_1.

c) The method of using the penetrometer of the band model shall be as specified in **3.1 c)**.

d) In case the penetrometer of the general model is used, **3.1 d)** shall apply.

e) In case the penetrometer is placed on the film side, **3.1 e)** shall apply.

f) The contrastmeter shall be used for a circumferentially welded joint with an outside diameter of 100 mm or more and for the image quality grade of Grade A. Its using method shall be as specified in **3.1 f)**.

g) Symbols indicating the effective length L_3 of test part shall be placed outside the pipe.

3.4 Double-wall both-side radiographic method The radiographic setup for the double-wall both-side radiographic method shall be as shown in Annex 2 Fig. 5.

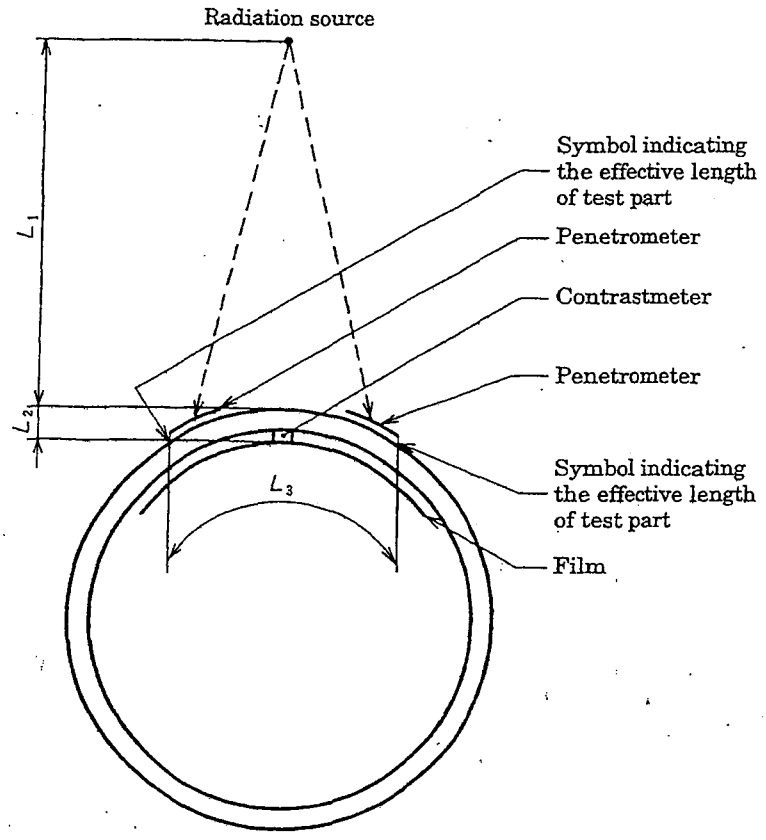
a) The distance $(L_1 + L_2)$ between the radiation source and film shall be not less than m times the distance L_2 between the radiation source side surface of test part and film. The multiplier m shall be as specified in **3.1 a)**. However, an exception to this is the case where the minimum perception wire diameter of the penetrometer specified in Annex 2 Table 4 can be identified.

b) As for the irradiation direction of radiation, radiation shall be applied obliquely to the plane including a welded joint in such a way that test part on the radiation source side and test part on the film side do not overlap each other.

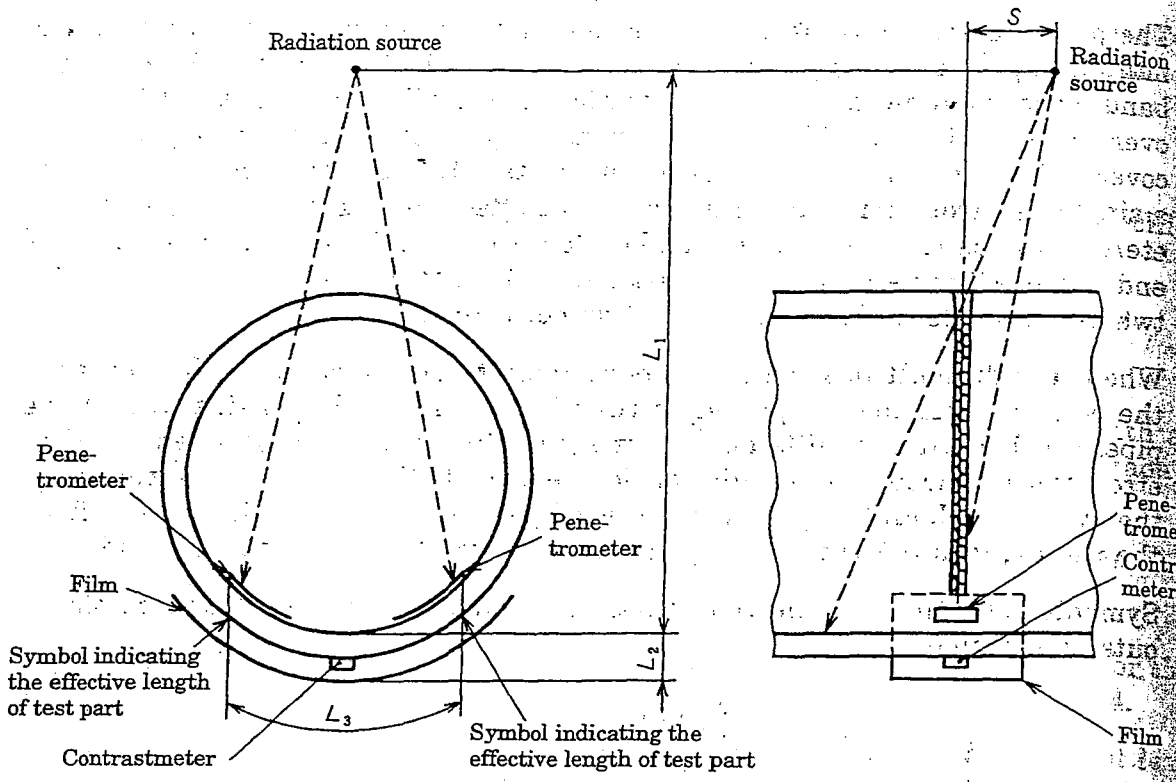
c) The penetrometer to be used shall be that of the band model composed of the minimum perception wire diameters required in **4.1**. The penetrometer of the band model shall be placed on the radiation source side surface of a welded joint over the welded joint. When a single penetrometer of the band model can fully cover the effective length L_3', one penetrometer shall be used. However, when a single penetrometer cannot fully cover the effective length L_3', two penetrometers of the band model shall each be placed in a position that includes each end of the effective length L_3' of test part. On this occasion, be sure that the two penetrometers of the band model do not overlap each other.

d) When it is difficult to arrange the penetrometer on the radiation source side, the penetrometer may be placed on the film side along the outside wall of the pipe, provided that its difference in image quality from the case when the penetrometer is placed on the radiation source side shall be clarified. In this case, the symbol F should be put down on each penetrometer to make it clear from the radiographs taken that the penetrometer was located on the film side.

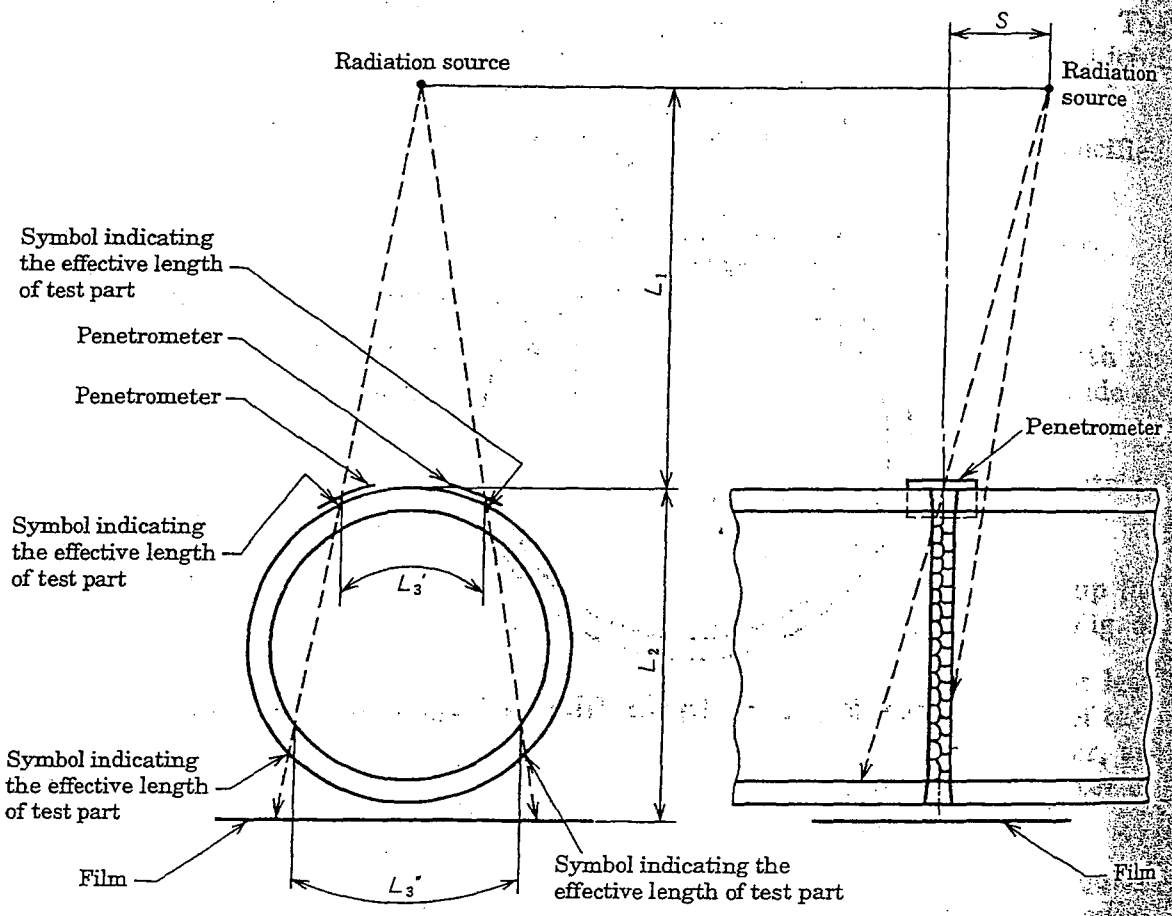
e) Symbols indicating the effective lengths L_3' and L_3'' of test part shall be placed outside the pipe.



Annex 2 Fig. 3 Inner film radiographic method



Annex 2 Fig. 4 Double-wall one-side radiographic method



Annex 2 Fig. 5 Double-wall both-side radiographic method

4. Requirements for radiograph

4.1 **Minimum perception wire diameter of penetrometer** At the test part on the radiograph taken, the confirmation of the minimum perception wire diameter of the penetrometer shall be carried out as follows:

a) Depending on the material of test part, obtain the value of the coefficient B to multiply the thickness of base metal, using Annex 2 Table 2.

b) The minimum perception wire diameter shall be not more than the values given in Annex 2 Table 4, depending on the thickness of base metal multiplied by the coefficient B obtained from a).

Annex 2 Table 4 Minimum perception wire diameter of penetrometer

Unit : mm

Thickness of base metal multiplied by coefficient	Grade of image quality			
	Grade A	Grade B	Grade P1	Grade P2
4.0 or less	0.125	0.10	0.20	0.25
Over 4.0 up to and incl. 5.0	0.16	0.10	0.20	0.25
Over 5.0 up to and incl. 6.3	0.16	0.125	0.25	0.32
Over 6.3 up to and incl. 8.0	0.20	0.16	0.32	0.40
Over 8.0 up to and incl. 10.0	0.20	0.16	0.32	0.40
Over 10.0 up to and incl. 12.5	0.25	0.20	0.40	0.50
Over 12.5 up to and incl. 16.0	0.32	0.20	0.50	0.50
Over 16.0 up to and incl. 20.0	0.40	0.25	0.63	0.63
Over 20.0 up to and incl. 25.0	0.50	0.32	0.80	0.80
Over 25.0 up to and incl. 32.0	0.50	0.40	1.0	—
Over 32.0 up to and incl. 40.0	0.63	0.50	1.25	—
Over 40.0 up to and incl. 50.0	0.80	0.63	1.6	—

4.2 **Density range of radiograph** The photographic density in parts other than the flaw image of test part shall satisfy the range specified in Annex 2 Table 5.

Annex 2 Table 5 Density range of radiograph

Grade of image quality	Density range
Grade A	1.3 or more up to and incl. 4.0
Grade B	1.8 or more up to and incl. 4.0
Grade P1	1.0 or more up to and incl. 4.0
Grade P2	

4.3 Value of contrastmeter On the radiograph for which the contrastmeter was used, measure the density in the part of base metal adjacent to the contrastmeter and that in the middle of the contrastmeter. The value of the contrastmeter obtainable by dividing the difference between the densities thus measured by the density in the part of base metal shall be confirmed as follows:

a) Depending on the material of test part, obtain the value of the coefficient B to multiply the thickness of base metal, using Annex 2 Table 2.

b) The value of the contrastmeter shall be not less than the values given in Annex 2 Table 6, depending on the thickness of base metal multiplied by the coefficient B obtained from **a**).

Annex 2 Table 6 Value of contrastmeter

Thickness of base metal multiplied by coefficient mm	Value of contrastmeter (density difference/density)		Type of contrast-meter
	Grade of image quality		
	Grade A	Grade B	
4.0 or less	0.15	0.23	Type 15
Over 4.0 up to and incl. 5.0	0.10	0.23	
Over 5.0 up to and incl. 6.3	0.10	0.16	
Over 6.3 up to and incl. 8.0	0.081	0.12	
Over 8.0 up to and incl. 10.0	0.081	0.12	
Over 10.0 up to and incl. 12.5	0.062	0.096	
Over 12.5 up to and incl. 16.0	0.046	0.096	
Over 16.0 up to and incl. 20.0	0.035	0.077	
Over 20.0 up to and incl. 25.0	0.049	0.11	Type 20
Over 25.0 up to and incl. 32.0	0.049	0.092	
Over 32.0 up to and incl. 40.0	0.032	0.077	
Over 40.0 up to and incl. 50.0	0.060	0.12	Type 25

4.4 Effective length of test part The effective length L_3 of test part in a single radiographing shall be within the range that satisfies the minimum perception wire diameter of the penetrometer, the density range of radiograph and the value of the contrastmeter. However, when especially the detection of transverse crack at test part is required, the effective length shall be within the range that satisfies not only the minimum perception wire diameter of the penetrometer, the density range of radiograph and the value of the contrastmeter, but also the limitation specified in Annex 2 Table 7.

Annex 2 Table 7 Effective length L_3 of test part

Radiographic method	Effective length of test part
Inner radiation source radiographic (exposure in sections)	Not more than 1/2 of the distance L_1 between radiation source and radiation source side surface of test part
Inner film radiographic	Not more than 1/12 of circumferential length of pipe
Double-wall one-side radiographic	Not more than 1/6 of circumferential length of pipe

Annex 3 (normative)

Method of radiographing Tee welded joint and requirements for radiograph

1 Scope This Annex specifies the method of radiographing a Tee welded joint by the direct radiography using radiation and requirements for radiographs.

2 Radiographic method

2.1 Classification of radiograph image quality The image quality of radiographs shall be Grade F.

2.2 Irradiation direction of radiation Radiographs shall, as a rule, be taken by irradiating the radiation from the direction as shown in Annex 3 Fig. 1 or Annex 3 Fig. 2.

2.3 Use of penetrometers Two penetrometers including the minimum perception wire diameter (refer to **4.1**) shall each be placed in such a way that the finest wire of each penetrometer comes in the vicinity of each end of the effective length L_3 of the test part. On this occasion, the penetrometers shall be placed on the radiation source side of T2 material or film side with the fine wire side outward.

When the penetrometers are placed on the film side, the distance between the penetrometer and film shall be not less than ten times the minimum perception wire diameter. In this case, the symbol F should be put down on the penetrometer to make it clear from the radiographs taken that the penetrometer was located on the film side.

2.4 Thickness-compensating wedge In taking radiographs, the thickness-compensating wedge as shown in Annex 3 Fig. 3 shall be used. However, in the case of Annex 3 Fig. 1, when the thickness of T1 material is not more than one-third of the thickness of T2 material or 8 mm, whichever is smaller, the thickness-compensating wedge need not be used. Further, in the case of Annex 3 Fig. 2, when the thickness of T1 material is not more than a quarter of the thickness of T2 or 5 mm, whichever is smaller, the thickness-compensating wedge need not be used.

3 Radiographic setup The relative positions of radiation source, penetrometer, thickness-compensating wedge and film shall be as follows:

a) The distance $(L_1 + L_2)$ between the radiation source and film, as shown in Annex 3 Fig. 3, shall be not less than m times the distance L_2 between the radiation source side surface of test part and film. The multiplier m shall be 6 or $2f/d$, whichever is larger, where f is the size (mm) of radiation source and d is the minimum perception wire diameter (mm) of the penetrometer as specified in **4.1**.

b) The distance L_1 between the radiation source and the radiation source side surface of test part shall be not less than twice the effective length L_3 of test part.

c) Symbols indicating the effective length L_3 of test part shall be placed on the radiation source side.

4 Requirements for radiograph

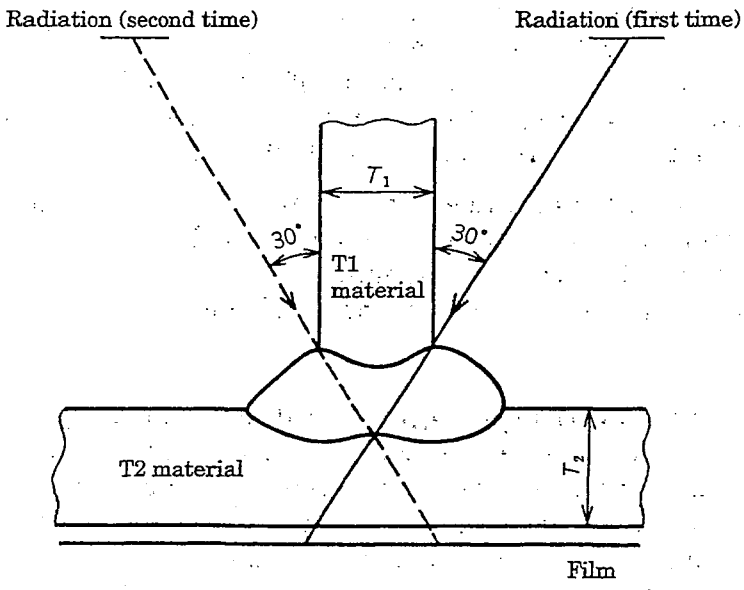
4.1 Minimum perception wire diameter of penetrometer At the test part on the radiograph taken, the confirmation of the minimum perception wire diameter of the penetrometer shall be carried out as follows:

a) Depending on the material of test part, obtain the value of the coefficient B to multiply the total thickness of T1 material and T2 material, using Annex 3 Table 1.

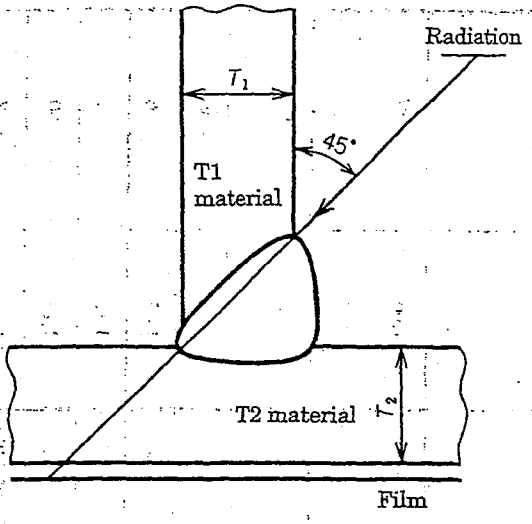
b) The minimum perception wire diameter shall be not more than the values given in Annex 3 Table 2, depending on the total thickness of T1 material and T2 material multiplied by the coefficient B obtained from a).

4.2 Density range of radiograph The photographic density in parts other than the flaw image of test part shall be 1.0 or over up to and including 4.0.

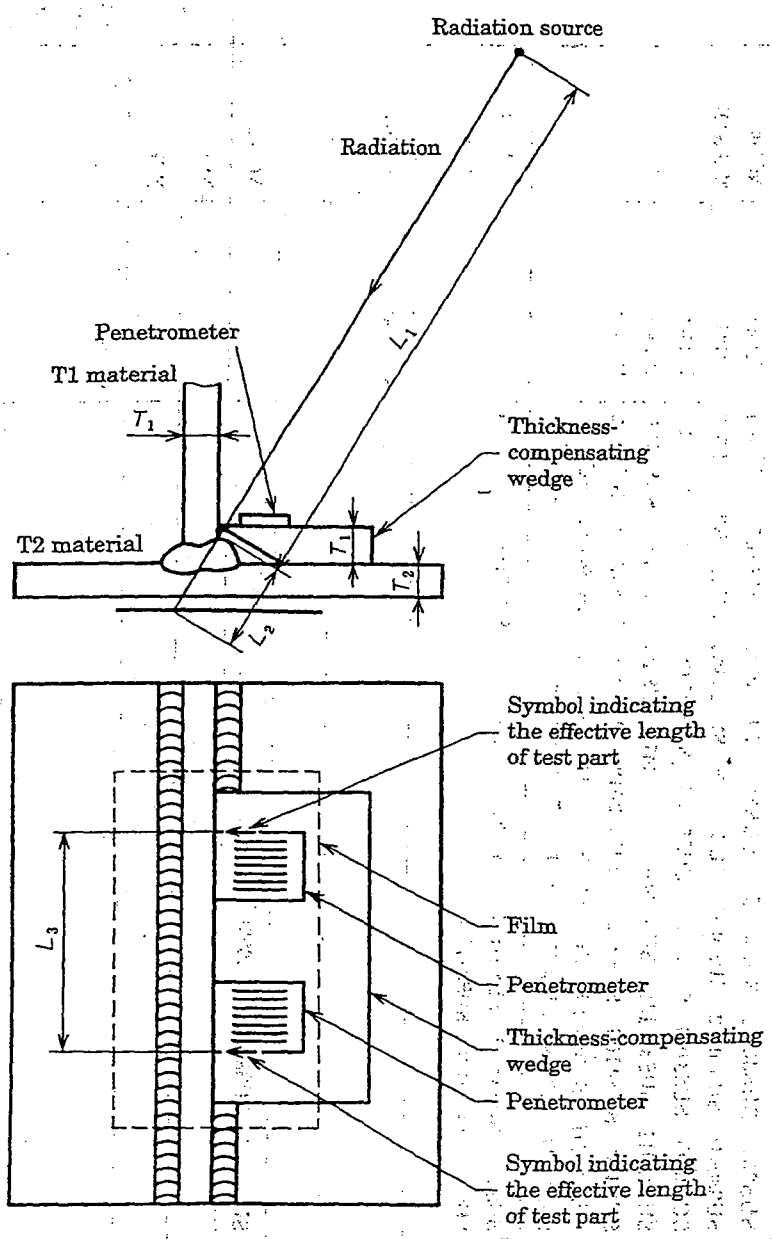
4.3 Effective length of test part The effective length L_3 of test part in a single radiographing shall be within the range that satisfies the minimum perception wire diameter of the penetrometer and the density range of radiograph.



Annex 3 Fig. 1 Photographing in two directions



Annex 3 Fig. 2 Photographing in one direction



Annex 3 Fig 3 Radiographic setup

Annex 3 Table 1 Value of coefficient *B*

Material of test part				Coefficient *B*	
JIS G 4304 JIS G 4305	JIS G 4312(1)	JIS G 4902	JIS H 4551	Division of base metal thickness to be multiplied by coefficient (mm)	
				25 or less	Over 25
	SUH21 SUH446			0.95	1.00
SUS301 SUS301L SUS301J1 SUS302 SUS302B SUS303 SUS304 SUS304J1 SUS304J2 SUS304L SUS304LN SUS304N1 SUS304N2 SUS305 SUS309S SUS310S SUS315J1 SUS315J2 SUS317J2 SUS317J3L SUS321 SUS329J1 SUS329J3L SUS329J4L SUS347 SUS403 SUS405 SUS410L SUS410 SUS410S SUS420J1 SUS420J2 SUS429 SUS429J1 SUS430 SUS430J1L SUS430LX SUS434 SUS436J1L SUS436L SUS440A SUS444 SUS447J1 SUS630 SUS631 SUSXM15J1 SUSXM27	SUH309 SUH310 SUH409 SUH409L SUH660	NCF800 NCF800H		1.00	1.00
SUS316 SUS316J1 SUS316J1L SUS316L SUS316LN SUS316N SUS316Ti SUS317 SUS317L SUS317LN		NCF718 NCF750 NCF751		1.06	1.00
	SUH330	NCF601 NCF690		1.06	1.06
		NCF80A		1.12	1.00
SUS317J1 SUS836L SUS890L		NCF825		1.12	1.06
		NCF600		1.12	1.12
		NCF625		1.25	1.00
	SUH661		NW4400 NW4402 NW5500 NW6007 NW6985 NW6002	1.25	1.12
			NW2200 NW2201	1.25	1.25
			NW6455	1.41	1.12
			NW0276 NW6022	1.41	1.25
			NW0001 NW0665	1.60	1.25

Note (1) As for the materials, which are specified in **JIS G 4312** and are identical to those specified in ***JIS G 4304*** and ***JIS G 4305***, refer to the left column.

Annex 3 Table 2 Minimum perception wire diameter of penetrometer

Unit : mm

Total thickness of T1 material and T2 material multiplied by coefficient	Grade of image quality
	Grade F
8.0 or less	0.20
Over 8.0 up to and incl. 10.0	0.20
Over 10.0 up to and incl. 12.5	0.25
Over 12.5 up to and incl. 16.0	0.32
Over 16.0 up to and incl. 20.0	0.40
Over 20.0 up to and incl. 25.0	0.50
Over 25.0 up to and incl. 32.0	0.50
Over 32.0 up to and incl. 40.0	0.63
Over 40.0 up to and incl. 50.0	0.80
Over 50.0 up to and incl. 63.0	8.0
Over 63.0 up to and incl. 80.0	1.0
Over 80.0 up to and incl. 100.0	1.25

Annex 4 (normative)

Method of grouping flaw images using radiograph

1 Scope This Annex specifies the method of grouping flaw images on the radiograph of a welded joint.

2 Procedure of grouping The grouping of flaw images (hereafter referred to as "flaws") shall be performed in accordance with the following procedure:

a) As to the radiograph to be classified, its compliance with the provision in **8** of the text shall be confirmed.

b) The radiograph to be classified shall be observed in accordance with **9** of the text.

c) The classification shall be performed in accordance with the division of the thickness of base metal. The definition of the thickness of base metal shall be as given in **3** of the text.

d) The flaws that exist in the test part shall be classified into four types.

e) For each type of flaw, the group number, Group 1, Group 2, Group 3 or Group 4 shall be given based on the measured dimensions of the flaw.

f) An overall grouping shall be made, based on the results of classification for each flaw.

3 Classification of flaws Flaws shall be classified into four types in accordance with Annex 4 Table 1. Especially as for the flaws which are indistinguishable between Class 1 and Class 2, they shall first be classified individually into either Class 1 or Class 2 and, when their group numbers are decided, the larger group number shall finally be taken for the class and group number for each of them.

Further, in the case of the radiograph of a welded joint of stainless steel, there are cases where an X-ray diffraction pattern similar to the flaw image shown for reference in Annex 5 is observed. This pattern, however, shall not be considered for classification.

Annex 4 Table 1 Classification of flaws

Class of flaw	Types of flaw
Class 1	Round blowholes and similar flaws
Class 2	Long and narrow slag inclusion, pipe, incomplete penetration, lack of fusion and similar flaws
Class 3	Cracks and similar flaws
Class 4	Inclusion of tungsten

Flaw marks The method of obtaining flaw marks for Class 1 and Class 4 flaws shall be as follows:

Flaw sizes shall be measured by setting up the field of examination as shown in Annex 4 Table 2. When any flaw lies over the boundary line of the field of examination, the size including the portion outside the field shall be measured.

The field of examination shall apply to an area within the effective length of test part, where flaw marks are likely to be highest.

When there is a single Class 1 flaw, the flaw marks shall be the value given in Annex 4 Table 3, according to the size of its major diameter. However, a flaw not exceeding the value given in Annex 4 Table 4 in major diameter shall be neglected.

As for Class 4 flaws, the flaw marks shall be obtained by the methods **a**), **b**) and **c**), as in the case of Class 1 flaws. However, the flaw marks shall be a half of the value given in Annex 4 Table 3, according to the size of the major diameter of a flaw.

When there are two or more flaws, the flaw marks shall be the sum of the flaw marks for individual flaws existing in the field of examination. However, a flaw not exceeding the value given in Annex 4 Table 4 in major diameter shall be neglected.

When Class 1 and Class 4 flaws coexist in the same field of examination, the flaw marks shall be the sum of the flaw marks for both.

Annex 4 Table 2 Area of field of examination

Unit : mm

Thickness of base metal	25 or less	Over 25 up to and incl. 100	Over 100
Area of field of examination	10 × 10	10 × 20	10 × 30

Annex 4 Table 3 Flaw marks

Major diameter of flaw (mm)	1.0 or less	Over 1.0 up to and incl. 2.0	Over 2.0 up to and incl. 3.0	Over 3.0 up to and incl. 4.0	Over 4.0 up to and incl. 6.0	Over 6.0 up to and incl. 8.0	Over 8.0
Number	1	2	3	6	10	15	25

Annex 4 Table 4 Size of flaw to be neglected

Unit : mm

Thickness of base metal	Size of flaw
20 or less	0.5
Over 20 up to and incl. 50	0.7
Over 50	1.4 % of base metal thickness

5 Flaw length The measured length of a Class 2 flaw shall be taken as the flaw length. However, when flaws exist in a line and the distance between two flaws is not more than the length of any flaw, the measured length including the distance between the two flaws shall be the flaw length for that flaw group.

6 Grouping of flaw images

6.1 Grouping of Class 1 and Class 4 flaw images In cases where the flaws detected on the radiograph are of Class 1 and Class 4, their grouping shall be made in accordance with the standard of Annex 4 Table 5. The figures in the table show allowances on flaw marks within the field of examination for each individual group number. However, a flaw exceeding a half of the thickness of base metal in major diameter shall be classified into Group 4.

For Group 1, 10 or more flaws are not allowed to exist in the field of examination even if their major diameters are not more than the values given in Annex 4 Table 4.

Annex 4 Table 5 Grouping of Class 1 and Class 4 by flaw mark

Group number	Field of examination (mm)				
	10 × 10		10 × 20		10 × 30
	Thickness of base metal (mm)				
	10 or less	Over 10 up to and incl. 25	Over 25 up to and incl. 50	Over 50 up to and incl. 100	Over 100
	Flaw marks				
Group 1	1	2	4	5	6
Group 2	3	6	12	15	18
Group 3	6	12	24	30	36
Group 4	Those with flaw mark more than that for Group 3				

6.2 Grouping of Class 2 flaw images In cases where the flaws detected on the radiograph are of Class 2, their grouping shall be made in accordance with the standard of Annex 4 Table 6. The figures in the table show allowances on flaw length. However, even when a flaw has been classified as Group 1, it shall be classified into Group 2 if it involves incomplete penetration or a lack of fusion.

Annex 4 Table 6 Grouping of Class 2 by flaw length

Unit : mm

Group number	Thickness of base metal		
	12 or less	Over 12 to and excl. 48	48 or more
Group 1	3 or less	Not more than 1/4 of thickness of base metal	12 or less
Group 2	4 or less	Not more than 1/3 of thickness of base metal	16 or less
Group 3	6 or less	Not more than 1/2 of thickness of base metal	24 or less
Group 4	Those with flaw length longer than that for Group 3		

6.3 **Grouping of Class 3 flaw images** In cases where the flaws detected on the radiograph are of Class 3, they shall be classified into Group 4.

6.4 **Overall grouping** The overall grouping which focuses on an area within the effective length of test part and is to be decided based on the result of the classification of each type of flaws shall be as follows:

a) In cases where the flaws detected are classified into one type, that classification shall be taken as the overall grouping.

b) In cases where the flaws detected are classified into two or more types, the larger group number decided for them shall be taken as the overall grouping. However, when a Class 2 flaw as an object of grouping is included in the field of examination established for Class 1 and Class 4 flaws and its grouping by flaw mark is identical to that by flaw length, the overall grouping as to the area where those flaws exist together shall be shifted to a larger group number next to the original number. In this case, Group 1 in particular shall be classified as Group 2 only when it exceeds both a half of the allowable flaw mark for the coexistence of Class 1 and Class 4 flaws and a half of the allowable flaw length for Class 2.

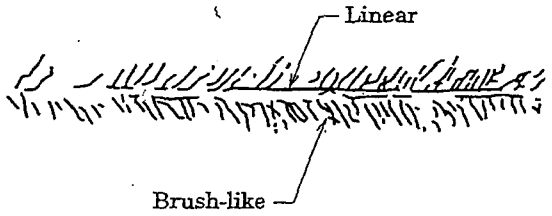
Annex 5 (informative)

Method of distinguishing between X-ray diffraction patterns and flaw images

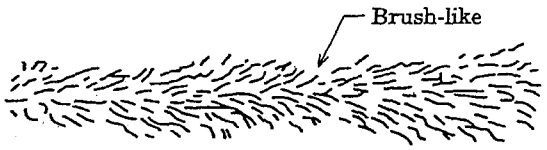
This Annex (informative) describes supplementary matters related to the text and does not constitute a part of this Standard.

1 Scope This Annex indicates the method of distinguishing between the X-ray diffraction patterns and the flaw images that appear on the radiograph of a welded joint.

2 X-ray diffraction pattern The X-ray diffraction patterns are divided into linear, brush-like and spotted patterns. Schematic diagrams for typical linear and brush-like diffraction patterns are shown in Annex 5 Fig. 1 and Annex 5 Fig. 2.



Annex 5 Fig. 1 Schematic diagram for linear and brush-like patterns in X-ray diffraction



Annex 5 Fig. 2 Schematic diagram for brush-like pattern in X-ray diffraction

3 Methods of confirming diffraction pattern Discrimination between X-ray diffraction patterns and flaw images is carried out by the method of comparing a diffraction pattern with reference photos and the photographic method.

3.1 Method of comparing with reference photo Discrimination is made through comparison between the configuration of the diffraction pattern observed and a reference photo similar to it in terms of the thickness of the test body and welding conditions applied.

3.2 Photographic method Discrimination is made by changing such photographic conditions as the distance between the test body and film, glancing angle and radiation energy, thereby causing such phenomena as the dislocation or disappearance of a diffraction pattern to occur. Specifically, the photographic methods available include an angle method, a diffusion method, a grid method, a quality-changing method, a mask method and a mesh-utilization method.