

JIS

JAPANESE INDUSTRIAL STANDARD

**Methods of radiographic
examination for welded
joints in steel**

JIS Z 3104—1995

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Japanese Standards Association

In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

JAPANESE INDUSTRIAL STANDARD

J I S

Methods of radiographic examination
for welded joints in steel

Z 3104-1995

1. Scope This Japanese Industrial Standard specifies the methods of radiographic examination for welded joints in steel by the direct radiography by X-ray or γ -ray (hereafter referred to as "radiation") using X-ray films for industrial use.

Remarks 1. The standards cited in this Standard are as follows:

- JIS G 3101 Rolled steel for general structure
- JIS G 4304 Hot rolled stainless steel plates, sheets and strip
- JIS G 4305 Cold rolled stainless steel plates, sheets and strip
- JIS K 7652 Photography – Density measurements - Part 2:
Geometric conditions for transmission density [ISO 5-2: 1991]
- JIS K 7653 Photography – Density measurements - Part 3:
Spectral conditions [ISO 5-3: 1984]
- JIS Z 2300 Glossary of terms used in nondestructive testing
- JIS Z 2306 Radiographic image quality indicators for non-destructive testing
- 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

2. The corresponding International standards of this standard are given in the following:

- ISO 1106/1 : 1984 Recommended practice for radiographic examination of fusion welded joints – Part 1:
Fusion welded butt joints in steel plates up to 50 mm thick
- ISO 1106/2 : 1985 Recommended practice for radiographic examination of fusion welded joints – Part 2:
Fusion welded butt joints in steel plates thicker than 50 mm and up to and including 200 mm in thickness
- ISO 1106/3 : 1984 Recommended practice for radiographic examination of fusion welded joints – Part 3:
Fusion welded circumferential joints in steel pipes of up to 50 mm wall thickness
- ISO 5579 : 1984 Non-destructive testing – Radiographic examination of metallic materials by X- and gamma rays – Basic rules

2. Definitions The definitions of principal terms used in this Standard shall be in accordance with those given in JIS Z 2300 apply, and others shall be as specified in the following:

- (1) thickness of base metal The nominal thickness of steel being used. When the thickness of the base metal is different on both sides of the joint, as a rule, the smaller value of the thickness shall be taken.
- (2) test part The part including the weld metal and the heat affected zone under examination.

3. Kind of image quality of radiograph The image quality of the radiograph shall be classified into 5 kinds of class A, class B, class P1, class P2 and class F. Class A can be obtained in the regular radiographic technique, and class B can be obtained by the radiographic technique with greater sensitivity in the detection of flaws. Class P1 is the regular image quality obtained when one side of the circumferential welded joint in the steel pipe is radiographically examined and class P2 is the regular image quality when both sides of the circumferential welded joint in the steel pipe is radiographically examined, respectively, with respect to the radiographing method where the radiation penetrates double walls of the pipe of the circumferential welded joint in the steel pipe. Class F is the regular image quality obtained by the radiographic examination of T welded joint.

Those image qualities shall be applied as shown in Table 1 according to the type of the welded joint.

Table 1. Classification of application of image quality of radiograph

Type of welded joint	Kind of image quality
Butt welded joint in steel plates and other welded joints deemed as equivalent thereto in geometric conditions in the radiographic examination	Class A, Class B
Circumferential welded joint in steel pipes	Class A, Class B, Class P1, Class P2
T-welded joint in steel plates	Class F

4. Examination engineer The examination engineers in charge of radiographic testing shall be those who passed the tests in accordance with JIS Z 3861 or those of ability at least equivalent thereto.

5. Radiographic testing apparatus and its accessories

5.1 Radiographic testing apparatus The radiographic testing apparatus shall be the X-ray apparatus specified in JIS Z 4606, the X-ray generating apparatus by the electron accelerator, the γ -ray apparatus specified in JIS Z 4560 or any other apparatus with performance at least equivalent thereto.

5.2 Sensitive material The X-ray film for industrial use (hereafter referred to as "film") shall be of low sensitivity and ultra super-fine particle type, low sensitivity and super-fine particle type, medium sensitivity and fine particle type or high sensitivity and fine particle type. When the intensifying screen is used, the lead foil intensifying screen, the fluorescent intensifying screen or the metallic fluorescent intensifying screen shall be used.

5.3 Penetrameter The penetrameter shall be general type one of type F or type S penetrameter specified in JIS Z 2306 or those at least equivalent thereto in performance.

For making radiograph of the circumferential welded joint, as a rule, the strip-shaped penetrameter of type F or type S shall be used, but general type penetrameter of type F or type S or those at least equivalent thereto in performance may be used.

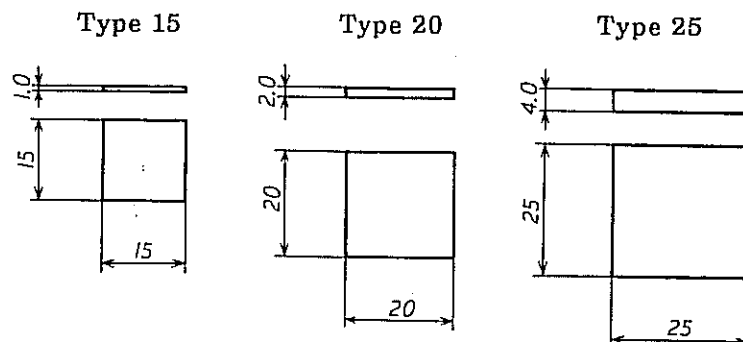
5.4 Contrast indicator The type, structure, dimensions and material of the contrast indicator shall be as follows:

- (1) The type, structure and dimensions of the contrast indicator shall be as shown in Fig. 1.

The dimensional tolerances for the contrast indicator shall be $\pm 5\%$ for thickness, and ± 0.5 mm for side length.

- (2) The material of the contrast indicator shall be steels specified in JIS G 3101, SUS 304 specified in JIS G 4304, or SUS 304 specified in JIS G 4305.

Fig. 1 Type, structure and dimensions of contrast indicator



5.5 Viewing illuminator The viewing illuminator shall be one specified in JIS Z 4561 or that at least equivalent thereto in performance.

5.6 Densitometer The densitometer which conforms to JIS K 7652 and JIS K 7653 shall be used.

6. Technique for making radiograph

6.1 Combination of radiation source with sensitive material The radiation source shall be combined with the sensitive material so as to identify the minimum perceptible wire diameter of the penetrameter.

6.2 Symbol Symbols shall be used so as to collate the radiograph with the records in making radiograph.

6.3 Radiation field The radiation field is preferably not increased more than required by using a diaphragm or a tubular diaphragm in making radiograph.

6.4 Technique for making radiograph The technique for making radiograph shall be in accordance with the Annex shown in Table 2 according to the type of the welded joint.

Table 2. Annex to specify radiographing method

Type of welded joint	Annex
Butt welded joint in steel plates and other welded joints deemed as equivalent thereto in geometric conditions in the radiographic examination	Annex 1
Circumferential welded joint in steel pipes	Annex 2
T-welded joint in steel plates	Annex 3

7. Necessary conditions for radiograph Necessary conditions for the radiograph having been taken shall be in accordance with Annex shown in Table 3 according to the type of the welded joint.

Further, the radiograph shall be free from irregular development, defects in the film or the like which may interfere evaluation of the image quality and classification of the image of the flaw.

Table 3. Annex to specify necessary conditions for radiograph

Type of welded joint	Annex
Butt welded joint in steel plates and other welded joints deemed as equivalent thereto in geometric conditions in the radiographic examination	Annex 1
Circumferential welded joint in steel pipes	Annex 2
T-welded joint in steel plates	Annex 3

8. Interpretation of radiograph

8.1 Viewing illuminator The viewing illuminator specified in 5.5 shall be used according to the classification shown in Table 4 in the interpretation of the radiograph.

Table 4. Classification of application of viewing illuminator

Type of viewing illuminator	Maximum density of 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 value of the density shown in the test part on the individual radiographs.

8.2 Viewing method The radiograph shall be evaluated by using a fixed mask suitable for the dimensions of the radiograph in a darkened room.

9. Method for classification of image of flaw The image of flaws on a radiograph shall be classified in accordance with Annex 4.

10. Records The test results shall include the following items to enable to collate the records with the tested part.

(1) Items related to test part

(1.1) Builder or manufacturer

(1.2) Name of work or product

(1.3) Symbol or number of location of test part

(1.4) Material

(1.5) Thickness of base metal (wall thickness and outside diameter of pipe)

(1.6) Type of welded joint (with/without weld reinforcement)

(2) Date of making radiograph

(3) Affiliation and name of examination engineer

(4) Test conditions

(4.1) Apparatus and material being used

- (a) Name of radiograph test equipment and its effective focal spot
- (b) Type of film and intensifying screen
- (c) Type of penetrameter
- (d) Type of contrast indicator

(4.2) Conditions of radiography

- (a) Voltage of tube being used or kind of radio-isotope
- (b) Current of tube being used or intensity of radioactivity
- (c) Time of exposure

(4.3) Radiographing arrangement

- (a) Distance between the radiation source and the film, ($L_1 + L_2$)
- (b) Distance between the surface on the radiation source side of the test part and the film, (L_2)
- (c) Effective length L_3 of the test part (both sides of double walls: $L_3 = L_3' + L_3''$)

(4.4) Conditions of development

- (a) Developer, temperature of development and time of development (manual development)
- (b) Name of automatic developing machine and developer (automatic development)

(5) Confirmation of necessary conditions of radiograph

- (5.1) Kind of viewing illuminator and viewing conditions
- (5.2) Kind of image quality (class A, class B, class P1, class P2 or class F)
- (5.3) Minimum perceptible wire diameter of penetrameter
- (5.4) Density of test part
- (5.5) Value of contrast indicator (difference in density/density)
- (5.6) Acceptance or rejection of radiograph
- (6) Date of classification of images of flaws

(7) Results of classification of images of flaws

(7.1) Results of classification of images of flaws according to the score of flaw

- (a) Classification of images of flaws of type 1
- (b) Classification of images of flaws of type 4
- (c) Presence of coexistence of images of flaws of type 1 and type 4
- (d) Classification of images of coexistent flaws

(7.2) Classification of images of flaws of type 2

(7.3) Classification of images of flaws of type 3

(7.4) Presence of coexistence of images of flaws of type 2 to the test field of vision

(7.5) Comprehensive classification

(8) Other necessary matters

(9) Remarks

Annex 1 Radiographing method of butt welded joints in steel plates and necessary conditions for radiograph

1. Scope This Annex specifies the radiographing method and necessary conditions for radiographs when the direct radiographic examination of butt welded joints in steel plates is executed.

2. Technique for making radiograph

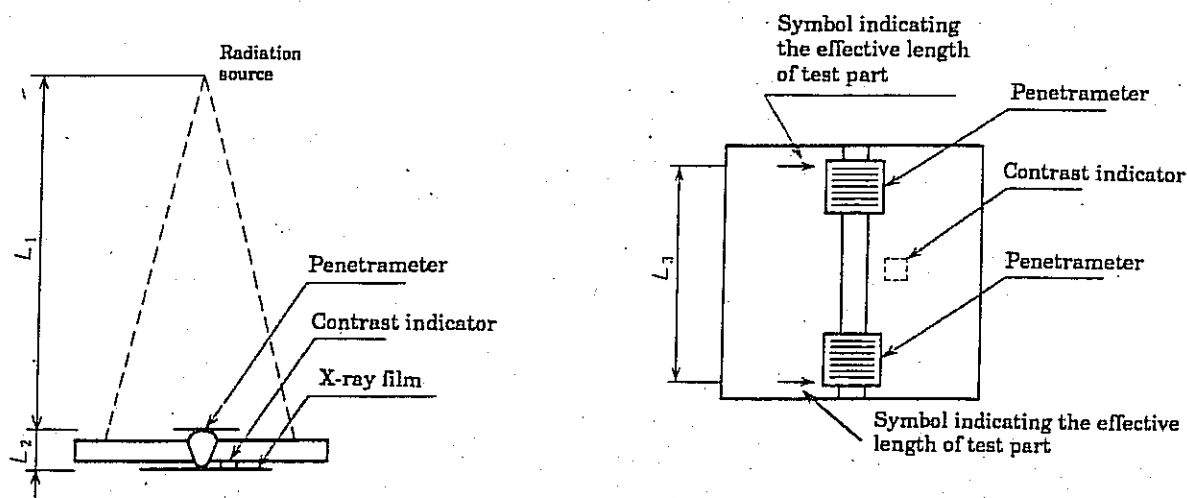
2.1 Kind of image quality of radiograph The image quality of the radiograph shall be class A and class B.

2.2 Irradiating direction of radiation As a rule, the radiograph shall be taken by irradiating the radiation from the direction where the transmitting thickness of the test part becomes minimum.

2.3 Application of penetrameter Each one penetrameter including the minimum perceptible wire diameter (see Annex 1 Table 4) shall be placed across the welded joint on the surface on the radiation source side of the test part as shown in Annex 1 Fig. 1 so that the thinnest wire of the penetrameter may be located in the vicinity of each end of the effective length L_3 of the test part. With this respect the thinnest wire shall be placed outside. The penetrameter may be placed on the film side if the distance between the penetrameter and the film is apart by at least 10 times the minimum perceptible wire diameter. In this case, the symbol F is placed on each part of the penetrameter so as to identify on the radiograph that the penetrameter is placed on the film side.

If the effective length of the test part is 3 times the width of the penetrameter or less, one penetrameter may be located in the middle.

Annex 1 Fig. 1 Radiographing arrangement



2.4 Application of contrast indicator The contrast indicator shall be used in accordance with the classification of Annex 1 Table 1 for the welded joint where the thickness of the base metal is 50 mm or less, and shall be placed on the film side of the base metal part not so far from the middle of the effective length of the test part. When the value of the contrast indicator is greater than the value indicated in Annex 1 Table 6, the contrast indicator may be placed on the radiation source side.

Annex 1 Table 1. Classification of application of contrast indicator

Unit: mm

Thickness of base metal	Type of contrast indicator
20.0 or under	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. Radiographing arrangement The relative position of the radiation source, the penetrameter, the contrast indicator and the film shall be, as a rule, the arrangement as shown in Annex 1 Fig. 1.

- (1) The distance ($L_1 + L_2$) between the radiation source and the film shall be at least m times the distance L_2 between the surface on the radiation source side of the test part and the film. The value m shall be determined in accordance with Annex 1 Table 2 according to the kind of the image quality.
- (2) The distance L_1 between the radiation source and the surface on the radiation source side of the test part shall be at least n times the effective length L_3 of the test part. The value n shall be determined in accordance with Annex 1 Table 3 according to the kind of the image quality.
- (3) The film mark indicating the effective length L_3 of the test part shall be placed on the radiation source side.

Annex 1 Table 2. Value of coefficient m

Kind of image quality	Coefficient m ⁽¹⁾⁽²⁾
Class A	$\frac{2f}{d}$ or 6, whichever is the greater
Class B	$\frac{3f}{d}$ or 7, whichever is the greater

Notes (1) f : dimension of radiation source

(2) d : minimum perceptible wire diameter of penetrameter specified in Annex 1 Table 4 (mm)

Annex 1 Table 3. Value of coefficient n

Kind of image quality	Coefficient n
Class A	2
Class B	3

4. Necessary conditions of radiograph

4.1 Minimum perceptible wire diameter of penetrameter The minimum perceptible wire diameter of the penetrameter shall not exceed the value given in Annex 1 Table 4 in the test part of the radiograph.

Annex 1 Table 4. Minimum perceptible wire diameter of penetrameter

Unit: mm

Thickness of base metal	Kind of image quality	
	Class A	Class B
4.0 or under	0.125	0.10
Over 4.0, up to and incl. 5.0	0.16	
Over 5.0, up to and incl. 6.3		
Over 6.3, up to and incl. 8.0	0.20	0.16
Over 8.0, up to and incl. 10.0		
Over 10.0, up to and incl. 12.5	0.25	0.20
Over 12.5, up to and incl. 16.0	0.32	
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		0.40
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
Over 63.0, up to and incl. 80.0	1.0	
Over 80.0, up to and incl. 100	1.25	1.0
Over 100, up to and incl. 125		
Over 125, up to and incl. 160	1.6	1.25
Over 160, up to and incl. 200		
Over 200, up to and incl. 250	2.0	1.6
Over 250, up to and incl. 320		
Over 320	2.5	2.0

4.2 Density range of radiograph The density of the radiograph shall be measured with the densitometer specified in 5.6 of the text. The radiographic density of the part except the image of flaws of the test part shall be in the range as shown in Annex 1 Table 5.

Annex 1 Table 5 Density range of radiograph

Kind of image quality	Density range
Class A	1.3 or over, up to and incl. 4.0
Class B	1.8 or over, up to and incl. 4.0

4.3 Value of contrast indicator On the radiograph where the contrast indicator is used, the density of the part of the base metal close to the contrast indicator and the density of the mid-portion of the contrast indicator shall be measured with the densitometer specified in 5.6 of the text. The value of the difference in density divided by density of the part of the base metal shall be not less than the value as shown in the Annex 1 Table 6.

Annex 1 Table 6 Value of contrast indicator

Unit: mm

Thickness of base metal	Value of contrast indicator $\left(\frac{\text{difference in density}}{\text{density}}\right)$		Type of contrast indicator
	Kind of image quality		
	Class A	Class B	
4.0 or under	0.15	0.23	Type 15
Over 4.0, up to and incl. 5.0	0.10		
Over 5.0, up to and incl. 6.3		0.16	
Over 6.3, up to and incl. 8.0	0.081	0.12	
Over 8.0, up to and incl. 10.0			
Over 10.0, up to and incl. 12.5	0.062	0.096	
Over 12.5, up to and incl. 16.0	0.046		
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		0.092	
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 the test part in one radiographing shall be in the range to meet the minimum perceptible wire diameter of the penetrometer, the density range of the radiograph, and the value of the contrast indicator.

Annex 2 Radiographing method of circumferential welded joints in steel pipes and necessary conditions for radiograph

1. Scope This Annex specifies the radiographing method and necessary conditions for radiographs when the direct radiographic examination of circumferential welded joints in steel pipes is executed.

2. Technique for making radiograph

2.1 Thickness of base metal The thickness of the base metal shall be the wall thickness of the pipe in the case of radiographic examination of the circumferential welded joints of the steel pipes. The wall thickness of the pipe, in this case, shall be the nominal thickness, and when the wall thickness of the pipes is different on both sides of the welded joint of the steel pipe, the smaller value shall be taken.

2.2 Classification of radiographing method The technique for making radiograph of the circumferential welded joints in the steel pipes shall be classified into 4 techniques, i.e., the internal source technique, the internal film technique, the double wall single image technique, and the double wall double image technique.

2.3 Kind of image quality of radiograph The kind of the image quality of the radiograph applicable for respective radiographing methods shall be in accordance with Annex 2 Table 1.

Annex 2. Table 1. Classification of application of image quality of radiograph

Radiographing method	Kind of image quality			
Internal source technique	Class A	class B*	class P1**	
Internal film technique	Class A	class B*	class P1**	
Double wall single image technique	Class A*		class P1	class P2**
Double wall double image technique			Class P1*	class P2

Notes * To be applied when greater sensitivity in the detection of flaws is required.

** To be applied when it is difficult to apply the regular radiographing technique.

3. Radiographing arrangement

3.1 Internal source technique The radiographing arrangement in the internal source technique shall be as follows:

- (1) The distance ($L_1 + L_2$) between the radiation source and the film shall be at least m times the distance L_2 between the surface on the radiation source side of the test part and the film as shown in Annex 2 Fig. 1 and Annex 2 Fig. 2.

m is the value given by $\frac{f}{d}$. Where, f is the dimension (mm) of the radiation source, and d is the minimum perceptible wire diameter (mm) of the

penetrameter specified in Annex 2 Table 3. However, in the case of the simultaneous radiography of the full circumference specified in Annex 2 Fig. 2, the aforementioned matters are not applied if the values on the minimum perceptible wire diameter of the penetrameter specified in Annex 2 Table 3 according to the kind of image quality of the radiograph to be applied are fulfilled.

- (2) As to the irradiating direction of the radiation, the center line of radiation flux shall be, as a rule, directed to the middle of the test part, and normal to the film surface.
- (3) When the strip-shaped penetrameter of type F or type S is used, each one penetrameter of the minimum perceptible wire diameter (see Annex 2 Table 3) shall be placed at the positions including both ends of the effective length L_3 of the test part across the welded joint on the surface on the radiation source side of the test part. In this case, care should be taken not to overlap two strip-shaped penetrameters each other or the strip-shaped penetrameter with the contrast indicator. However, one strip-shaped penetrameter may be acceptable when the effective length L_3 of the test part can be sufficiently covered with one strip-shaped penetrameter.
- (4) When the general type penetrameter of type F or type S is used, two penetrameters with the minimum perceptible wire diameter (see Annex 2 Table 3) shall be placed on the surface on the radiation source side of the test part across the welded joint as shown in Annex 2 Fig. 1. In this case, the penetrameter shall be placed so that the wire diameter to be perceived of each penetrameter is on or outside the boundary line of the respective effective length L_3 and also the thin line is outside thereof. One strip-shaped penetrameter shall be used when it is infeasible to place two penetrameters within the range of the effective length L_3 of the test part.
- (5) The penetrameter may be placed on the film side if the distance between the penetrameter and the film is not less than 10 times the minimum perceptible wire diameter (see Annex 2 Table 3). In this case, the symbols F shall be placed on each part of the penetrameter so as to identify that the penetrameter is placed on the film side.
- (6) The contrast indicator shall be used according to the classification of Annex 2 Table 2 when the kind of the image quality is class A or class B for the circumferential welded joint 100 mm or over in outside diameter. In this case, the contrast indicator shall be placed on the film side of the base metal part not so far from the middle of the test part. However, the contrast indicator may be placed on the radiation source side when the value of the contrast indicator is not less than the value as shown in Annex 2 Table 5.

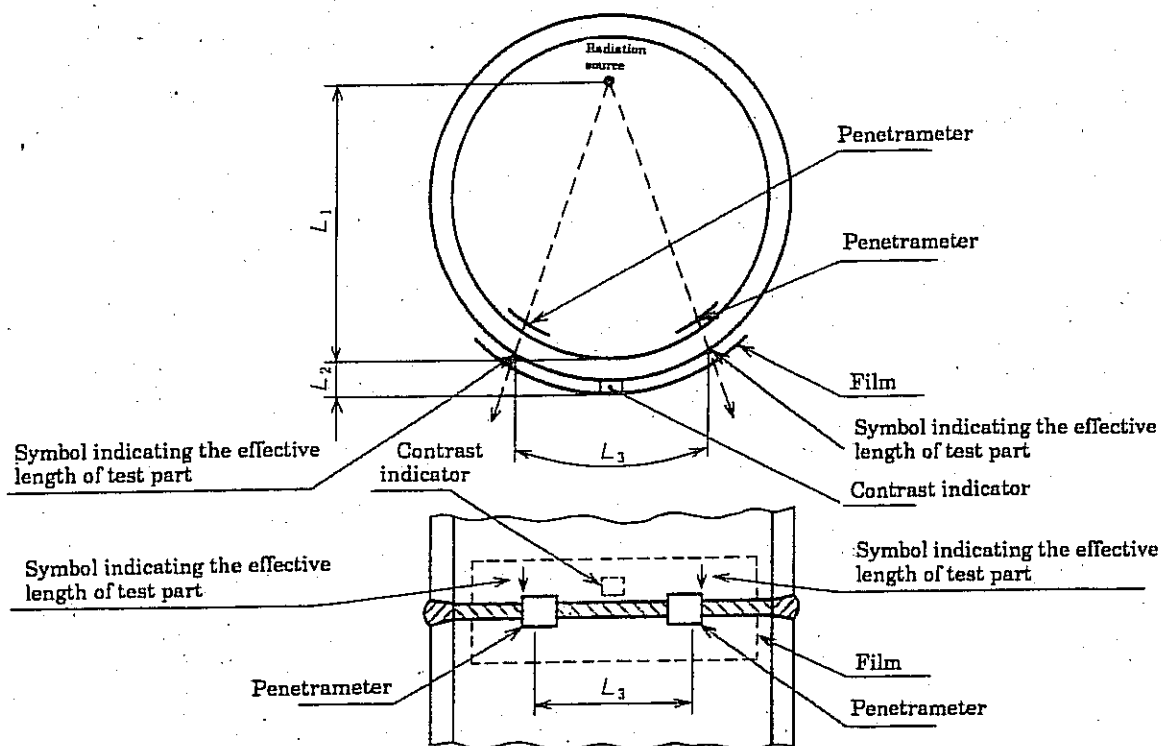
Annex 2 Table 2 Classification of application of contrast indicator

Unit: mm

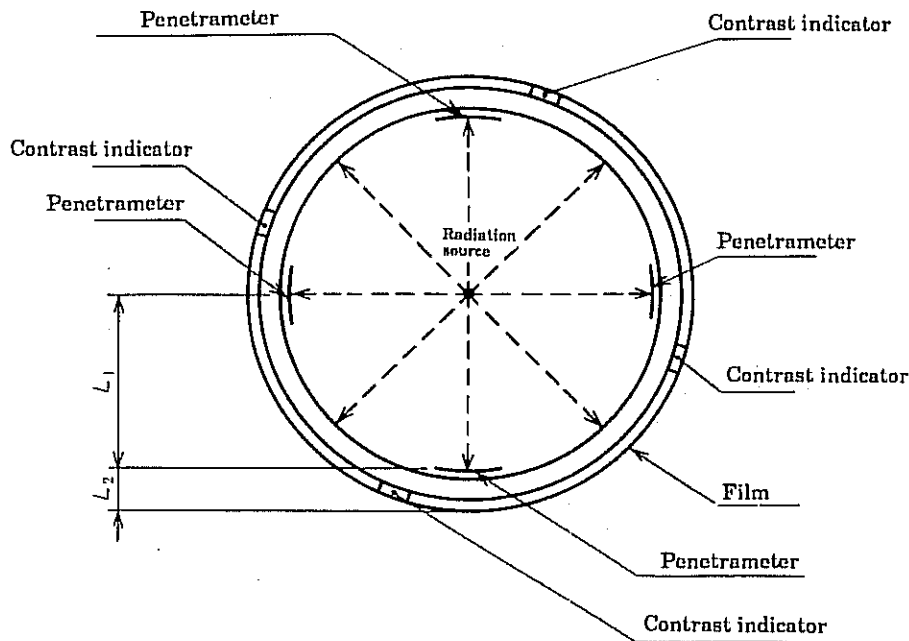
Thickness of base metal	Type of contrast indicator
20.0 or under	Type 15
Over 20.0, up to and incl. 40.0	Type 20
Over 40.0, up to and incl. 50.0	Type 25

- (7) In the simultaneous radiography of the full circumference, four penetrameters and four contrast indicators shall, as a rule, be placed at the symmetrical positions to divide the full circumference to approximately equal four parts as shown in Annex 2 Fig. 2.
- (8) The symbol indicating the effective length L_3 of the test part shall be placed, as a rule, inside the pipe when the distance between the radiation source and the film is smaller than the radius of the pipe, while outside the pipe when the said distance is larger than the radius of the pipe. However, even though in the case where the distance between the radiation source and the film is smaller than the radius of the pipe, the symbol may be placed outside the pipe if the relative position is clarified previously where the symbol is placed inside and outside the pipe according to the geometric relationship of the radiographing arrangement.

Annex 2 Fig. 1 Internal source technique (divided radiography)



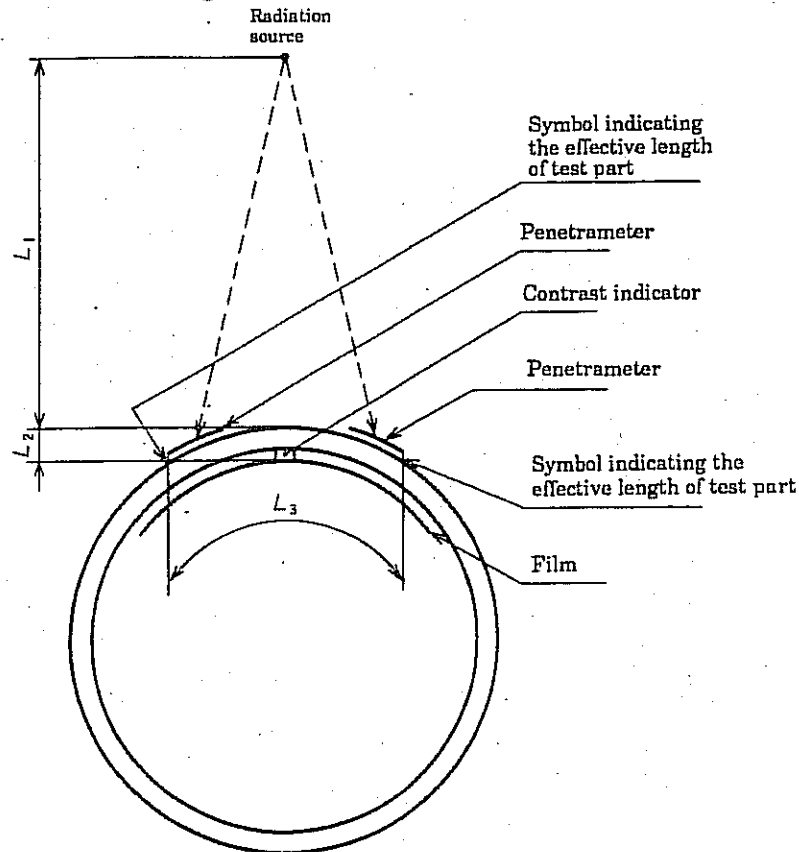
Annex 2 Fig. 2 Internal source technique (simultaneous radiography of the full circumference)



3.2 Internal film technique The radiographing arrangement of the internal film technique shall be as follows:

- (1) The distance $(L_1 + L_2)$ between the radiation source and the film shall be at least m times the distance L_2 between the surface on the radiation source side of the test part and the film as shown in Annex 2 Fig. 3. m shall be determined in accordance with 3.1(1).
- (2) The irradiating direction of the radiation shall be in accordance with 3.1(2).
- (3) The method for application of the strip-shaped penetrameter shall be in accordance with 3.1(3).
- (4) The method for application of the general type penetrameter shall be in accordance with 3.1(4).
- (5) The penetrameter shall be placed on the film side in accordance with 3.1(5).
- (6) The contrast indicator shall be used when the kind of the image quality is class A or class B for the circumferential welded joints 100 mm or over in outside diameter. In this case, the contrast indicator shall be used in accordance with 3.1(6).
- (7) The symbol indicating the effective length L_3 of the test part shall be placed outside the pipe.

Annex 2 Fig. 3 Internal film technique

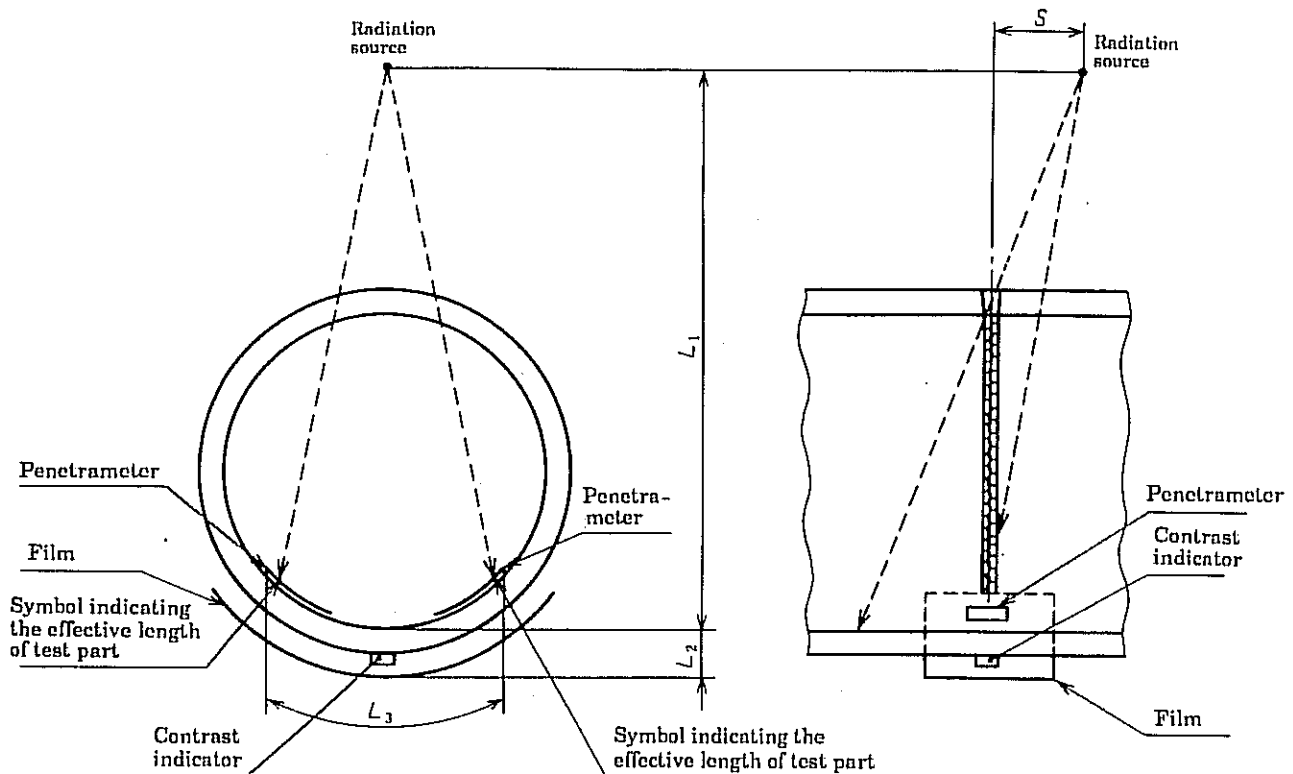


3.3 Double wall single image technique The radiographing arrangement of the double wall single image technique shall be as follows:

- (1) The distance ($L_1 + L_2$) between the radiation source and the film shall be at least m times the distance L_2 between the surface on the radiation source side of the test part and the film as shown in Annex 2 Fig. 4. m shall be determined in accordance with 3.1(1).
- (2) The radiation shall be irradiated from the direction shown in Annex 2 Fig. 4. The distance S between the planes including the radiation source and the welded joint shall be $1/4$ of L_1 or less.
- (3) The method for application of the strip-shaped penetrameter shall be in accordance with 3.1(3).
- (4) The method for application of the general type penetrameter shall be in accordance with 3.1(4). However, the radiographing method shall be in accordance with Annex 2 Fig. 4.
- (5) The penetrameter shall be placed on the film side in accordance with 3.1(5).

- (6) The contrast indicator shall be used when the kind of the image quality is class A for the circumferential welded joints 100 mm or over in outside diameter. In this case, the contrast indicator shall be used in accordance with 3.1(6).
- (7) The symbol indicating the effective length L_3 of the test part shall be placed outside the pipe.

Annex 2 Fig. 4 Double wall single image technique

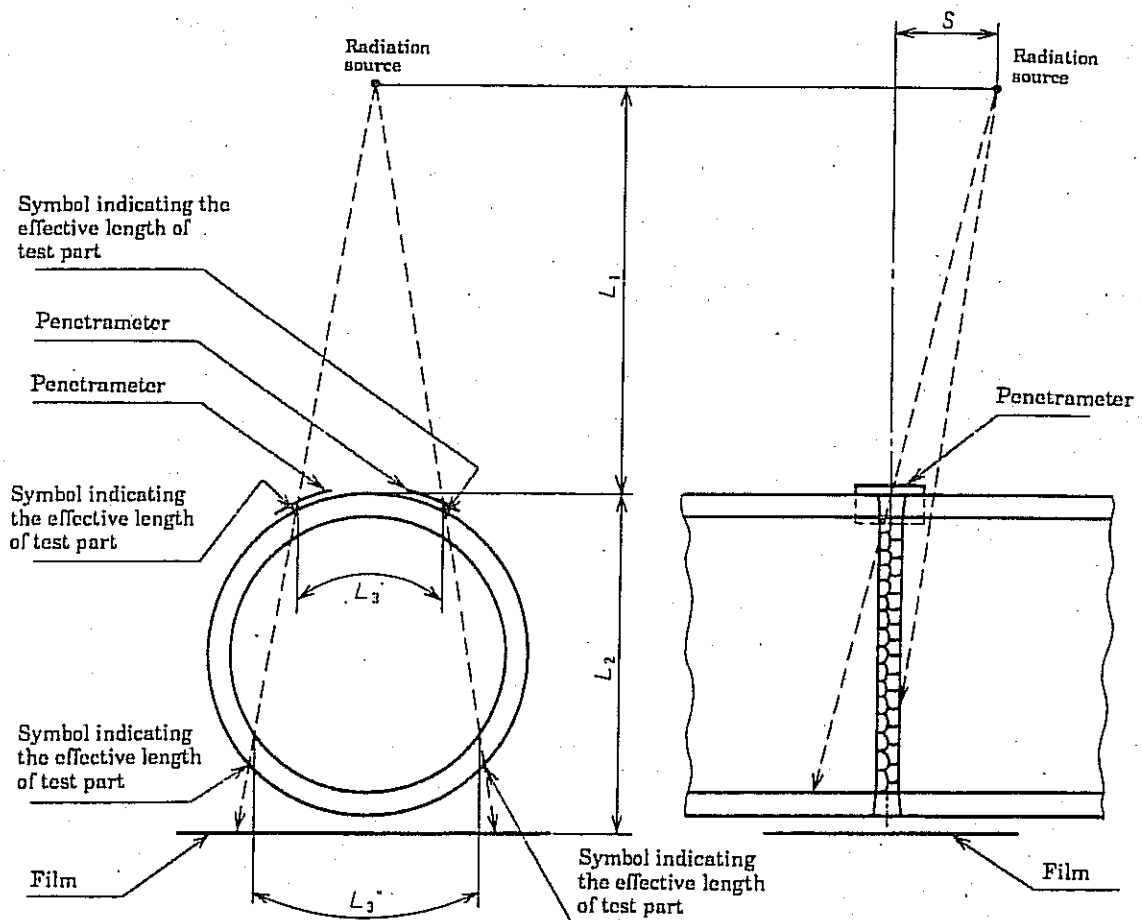


3.4 Double wall double image technique The radiographing arrangement of the double wall double image technique shall be as follows:

- (1) The distance $(L_1 + L_2)$ between the radiation source and the film shall be at least m times the distance L_2 between the surface on the radiation source side of the test part and the film as shown in Annex 2 Fig. 5. m shall be determined in accordance with 3.1(1). However, this does not apply if the penetrameter specified in Annex 2 Table 3 is identifiable.
- (2) The irradiating direction of the radiation shall be oblique to the plane including the welded joint as shown in Annex 2 Fig. 5.

- (3) As to the penetrameter, as a rule, the strip-shaped penetrameter with the minimum perceptible wire diameter (see Annex 2 Table 3) shall be used. The strip-shaped penetrameter shall be placed on the surface on the radiation source side of the welded joint across the welded joint. One strip-shaped penetrameter may be acceptable when the effective length L_3' can be sufficiently covered with one strip-shaped penetrameter. If the effective length L_3' can not be sufficiently covered with one strip-shaped penetrameter, however, each one strip-shaped penetrameter shall be placed on the positions including both ends of the effective length L_3' of the test part. In this case, two strip-shaped penetrameters shall be placed so as to avoid overlapping.
- (4) The symbols indicating the effective length L_3' and L_3'' of the test part shall be placed outside the pipe.

Annex 2 Fig. 5 Double wall double image technique



4. Necessary conditions for radiograph

4.1 Minimum perceptible wire diameter of penetrameter On the radiograph, the minimum perceptible wire diameter of the penetrameter shall not exceed the value given in Annex 2 Table 3.

Annex 2 Table 3 Minimum perceptible wire diameter of penetrameter

Unit: mm

Thickness of base metal	Kind of image quality			
	Class A	Class B	Class P1	Class P2
4.0 or under	0.125	0.10	0.20	0.25
Over 4.0, up to and incl. 5.0	0.16			
Over 5.0, up to and incl. 6.3		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				
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		0.50	
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		0.40	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 density of the radiograph shall be measured with the densitometer specified in 5.6 of the text. The radiographic density of the part except the image of flaws of the test part shall be in the range as shown in Annex 2 Table 4.

Annex 2 Table 4 Density range of radiograph

Kind of image quality	Density range
Class A	1.3 or over, up to and incl. 4.0
Class B	1.8 or over, up to and incl. 4.0
Class P1	1.0 or over, up to and incl. 4.0
Class P2	

4.3 Value of contrast indicator On the radiograph where the contrast indicator is used, the density of the part of the base metal close to the contrast indicator and the density of the mid-portion of the contrast indicator shall be measured. The value of the difference in the density divided by the density of the part of the base metal shall be not less than the value as shown in the Annex 2 Table 5.

Annex 2 Table 5 Value of contrast indicator

Unit: mm

Thickness of base metal	Value of contrast indicator $\left(\frac{\text{difference in density}}{\text{density}}\right)$		Type of contrast indicator
	Kind of image quality		
	Class A	Class B	
4.0 or under	0.15	0.23	Type 15
Over 4.0, up to and incl. 5.0	0.10		
Over 5.0, up to and incl. 6.4		0.16	
Over 6.4, up to and incl. 8.0	0.081	0.12	
Over 8.0, up to and incl. 10.0			
Over 10.0, up to and incl. 12.5	0.062	0.096	
Over 12.5, up to and incl. 16.0	0.046		
Over 16.0, up to and incl. 20.0	0.035	0.077	Type 20
Over 20.0, up to and incl. 25.0	0.049	0.11	
Over 25.0, up to and incl. 32.0		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 the test part in one radiographing shall be in the range to meet the requirements of the minimum perceptible wire diameter of the penetrometer, the density range of the radiograph, and the value of the contrast indicator. When the detection of the transverse cracks in the test part is especially required, the effective length shall meet the requirements of the minimum perceptible wire diameter of the penetrometer, the density range of the radiograph and the value of the contrast indicator, and also shall be in the range of the limit specified in Annex 2 Table 6.

Annex 2 Table 6 Effective length L_3 of test part

Radiographing method	Effective length of test part
Internal source technique (divided radiography)	1/2 or less of the distance L_1 between the radiation source and the surface on the radiation source side of test part
Internal film technique	1/12 or less of the full circumference of pipe
Double wall single image technique	1/6 or less of the full circumference of pipe

Annex 3 Radiographing method of T-welded joints in steel plates and necessary conditions for radiograph

1. Scope This Annex specifies the radiographing method and necessary conditions for radiographs when the direct radiographic examination of T-welded joints in steel plates is executed.

2. Technique for making radiograph

2.1 Kind of image quality of radiograph The image quality of the radiograph shall be class F.

2.2 Irradiating direction of radiation As a rule, the radiograph shall be taken by irradiating the radiation from the direction shown in Annex 3 Fig. 1 or Annex 3 Fig. 2.

2.3 Application of penetrameter Each one penetrameter including the minimum perceptible wire diameter (see Annex 3 Table 1) shall be placed so that the thinnest wire of the penetrameter may be located in the vicinity of each end of the effective length L_3 of the test part. In this case, the thinnest wire shall be placed outside, and the penetrameter shall be placed on the surface on the radiation source side of T2 member or on the film side. When the penetrameter is placed on the film side, the distance between the penetrameter and the film shall be at least 10 times the minimum perceptible wire diameter. In this case, the symbol F is placed on each part of the penetrameter so as to identify on the radiograph that the penetrameter is placed on the film side.

2.4 Compensating wedge The compensating wedge as shown in Annex 3 Fig. 3 shall be used in making radiograph. However, in the case of Annex 3 Fig. 1, the compensating wedge may be omitted if the thickness of the T1 member does not exceed 1/4 of the thickness of the T2 member or 5 mm, whichever is the smaller.

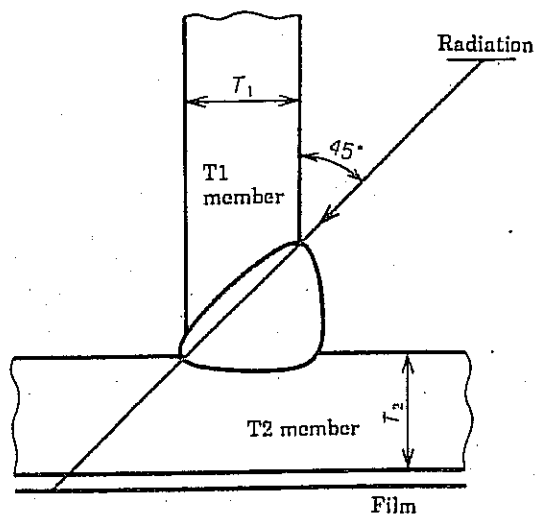
Further, in the case of Annex 3 Fig. 2, the compensating wedge need not be used if the thickness of the T1 member does not exceed 1/3 of the thickness of the T2 member or 8 mm, whichever is the smaller.

3. Radiographing arrangement The arrangement of the radiation source, the penetrameter and the compensating wedge shall be as follows:

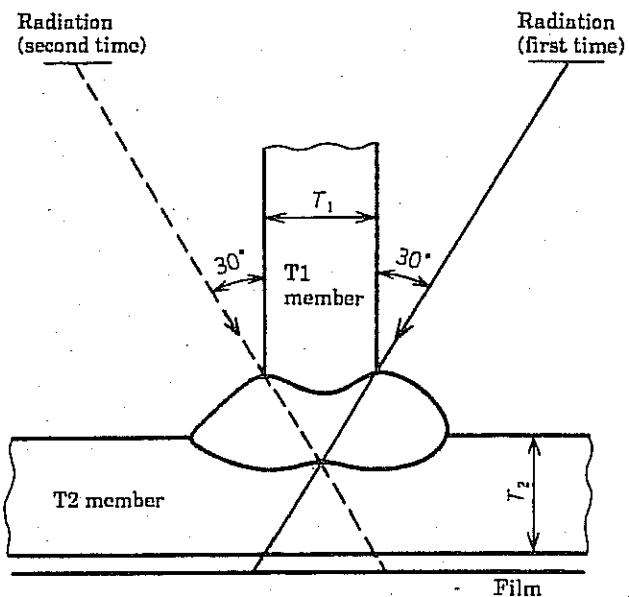
- (1) The distance ($L_1 + L_2$) shown in Annex 3 Fig. 3 shall be at least m times the distance L_2 between the surface on the radiation source side of the test part and the film. The value m shall be 6 or $\frac{2f}{d}$, whichever is the greater. Where, f is the dimension (mm) of the radiation source, and d is the value of the minimum perceptible wire diameter (mm) specified in Annex 3 Table 1.
- (2) The distance L_1 between the radiation source and the surface on the radiation source side of the test part shall be at least 2 times the effective length L_3 of the test part.

- (3) Symbol indicating the effective length of test part The symbol indicating the effective length L_3 of the test part shall be placed on the radiation source side.

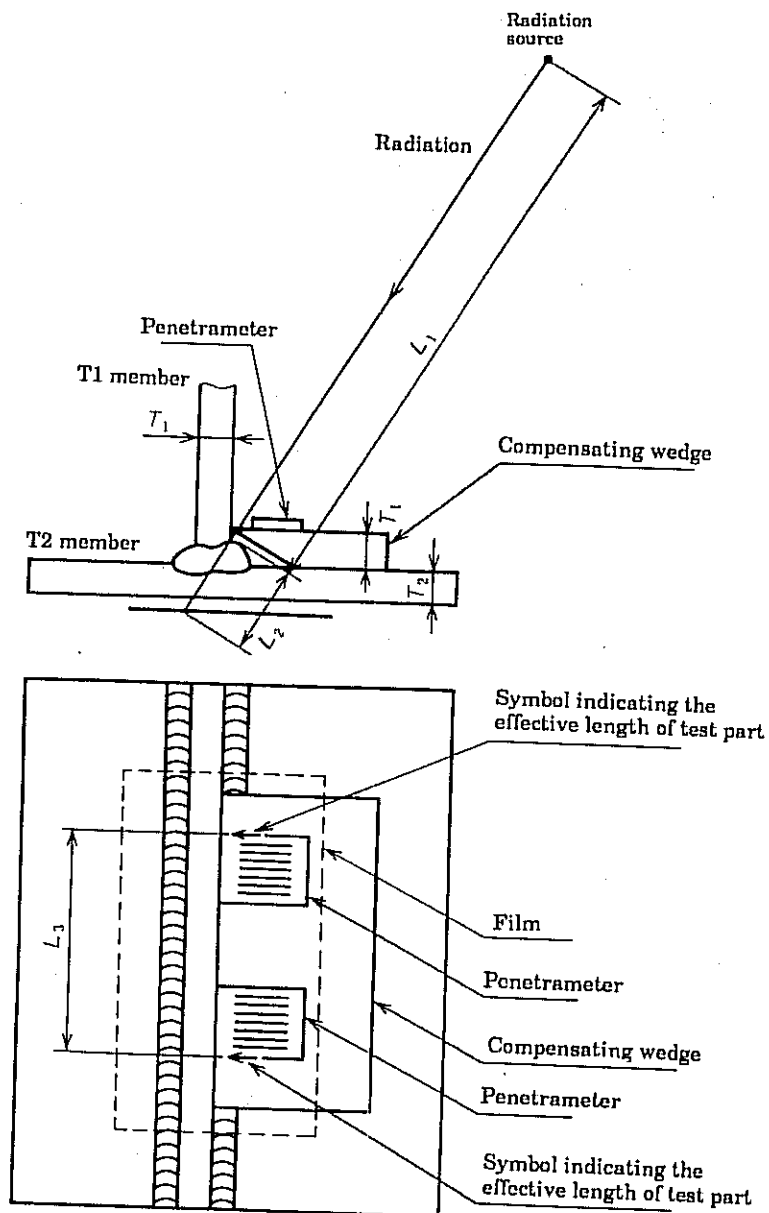
Annex 3 Fig. 1 Radiographing from one direction



Annex 3 Fig. 2 Radiographing from two directions



Annex 3 Fig. 3 Radiographing arrangement



4. Necessary conditions for radiograph

4.1 Minimum perceptible wire diameter of penetrameter On the radiograph, the minimum perceptible wire diameter of the penetrameter shall not exceed the value in Annex 3 Table 1.

Annex 3 Table 1. Minimum perceptible wire diameter of penetrameter

Unit: mm

Total thickness of T1 and T2 members	Kind of image quality
	Class F
8.0 or under	0.20
Over 8.0, up to and incl. 10.0	
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	
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	
Over 63.0, up to and incl. 80.0	1.0
Over 80.0, up to and incl. 100.0	1.25

4.2 Density range of radiograph The density of the radiograph shall be measured with the densitometer specified in 5.6 of the text. The radiographic density of the part except the image of flaws of the test part shall be 1.0 or over and up to and including 4.0.

4.3 Effective length of test part The effective length L_3 of the test part in one radiographing shall be in the range to meet the requirements of the minimum perceptible wire diameter of the penetrameter and the density range of the radiograph.

Annex 4 Method for classification of images of flaw on radiograph

1. Scope This Annex specifies the classification of images of flaws on the radiograph of welded joints in steels.
2. Procedure for classification Images of flaws (hereafter referred to as "flaw") shall be classified in accordance with the following procedure:
 - (1) View the radiograph to be classified in accordance with 8. in the text.
 - (2) Confirm that the radiograph to be classified conforms to 7. in the text.
 - (3) Execute the classification according to the category of the thickness of the base metal. When the thickness is different on both sides of the butt welded joint in steel plate, the thinner value shall be taken as the thickness of the base metal. In the case of the circumferential welded joint in steel pipes, the thinner wall thickness shall be taken as the thickness of the base metal. In the case of the T-welded joint, the thickness of the T1 member as shown in Annex 3 Fig. 1 and Annex 3 Fig. 2 shall be taken as the thickness of the base metal.
 - (4) Classify the flaws in the test part into 4 types.
 - (5) Subclassify flaws of respective types into class 1, class 2, class 3 and class 4, and then execute the comprehensive classification based on the classified results.
3. Type of flaw The flaws shall be classified into 4 types in accordance with Annex 4 Table 1. Where it is difficult to classify the flaws into type 1 or type 2, classify respective flaws into type 1 or type 2, and then the larger type and class number shall be adopted.

Annex 4 Table 1 Type of flaw

Type of flaw	Kind of flaw
Type 1	Round blow hole and similar flaw
Type 2	Elongated slag inclusion, pipe, incomplete penetration, incomplete fusion, and similar flaw
Type 3	Crack and similar flaw
Type 4	Tungsten inclusion

4. Score of flaw The score of flaw of type 1 and type 4 shall be obtained as follows:

- (1) The score of flaw shall be measured by setting the test field of vision as given in Annex 4 Table 2. Where the flaw falls on the boundary of the test field of vision, the part outside the test field of vision shall be included for measurement.
- (2) The test field of vision shall be applied to the region where the score of flaw becomes maximum in the effective length of the test part.
- (3) The score of flaw in the case of single flaw of type 1 shall be determined by using the value in Annex 4 Table 3 according to the dimension of the major diameter of the flaw. Where the major diameter of the flaw does not exceed the value in Annex 4 Table 4, the flaw shall not be regarded in calculating the score of flaw.
- (4) As to the flaw of type 4, the score of flaw shall be obtained according to the procedure (1), (2) and (3) similar that of type 1. However, the score of flaw shall be 1/2 of the value in Annex 4 Table 3 according to the dimension of the major diameter of the flaw.
- (5) The score of flaw for two or more flaws shall be the grand total of the score for each flaw in the test field of vision.
- (6) Where the flaw of type 1 is coexistent with the flaw of type 4 in one test field of vision, the grand total of both scores shall be the score of flaw.

Annex 4 Table 2 Extent of test field of vision

Unit: mm

Thickness of base metal	Up to and incl. 25	Over 25, up to and incl. 100	Over 100
Extent of test field of vision	10 × 10	10 × 20	10 × 30

Annex 4 Table 3 Score of flaw

Unit: mm

Major diameter of flaw	Up to and incl. 1.0	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
Score	1	2	3	6	10	15	25

Annex 4 Table 4 Size of flaw not to be counted

Unit: mm

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

5. Length of flaw The length of flaw shall be determined by measuring the length of the flaw of type 2. However, where the flaws are present in a row, and the distance between mutual flaws does not exceed the length of the larger flaw, the dimension being measured including the space between flaws shall be defined as the length of flaw of the relevant flaw batch.

6. Subclassification of flaw

6.1 Subclassification of flaw of type 1 and type 4 The flaws where the flaws detected by the radiograph are flaws of type 1 and type 4, shall be subclassified in accordance with the standard of Annex 4 Table 5. The figures in the table show the allowable limit of the score of flaw. Where the major diameter of the flaw exceeds 1/2 of the thickness of the base metal, the flaw shall be categorized as class 4.

Even when the major diameter of the flaw does not exceed the value in Annex 4 Table 4, there shall not be 10 or more flaws within the test field of vision for class 1.

Annex 4 Table 5 Subclassification of flaws of type 1 and type 4

Unit: mm

Subclassification	Test field of vision				
	10 × 10		10 × 20		10 × 30
	Thickness of base metal				
	10 or under	Over 10, up to and incl. 25	Over 25, up to and incl. 50	Over 50, up to and incl. 100	Over 100
Class 1	1	2	4	5	6
Class 2	3	6	12	15	18
Class 3	6	12	24	30	36
Class 4	Where the score of flaw is larger than that of class 3				

6.2 Subclassification of flaw of type 2 The flaws where the flaws detected by the radiograph are flaws of type 2, shall be subclassified in accordance with the standard of Annex 4 Table 6. The figures in the table show the allowable limit of the length of flaw. Even when the flaw is subclassified as class 1, it shall be categorized as class 2 where the incomplete penetration or the incomplete fusion is found.

Annex 4 Table 6 Subclassification of flaws of type 2

Unit: mm

Subclassification	Thickness of base metal		
	12 or under	Over 12 and under 48	48 or over
Class 1	3 or under	1/4 or less of the thickness of the base metal	12 or under
Class 2	4 or under	1/3 or less of the thickness of the base metal	16 or under
Class 3	6 or under	1/2 or less of the thickness of the base metal	24 or under
Class 4	Where the flaw length is larger than that of class 3		

6.3 Subclassification of flaw of type 3 The flaws where the flaws detected by the radiograph are flaws of type 3, shall be categorized as class 4.

6.4 Comprehensive classification The comprehensive classification to be determined based on the results of subclassification of each type of flaws in terms of the effective length of the test part shall be as follows:

- (1) Where the flaws are of only one type, this type shall be the comprehensive classification as they are.
- (2) Where the flaws are of two or more types, the larger type and class number shall be the comprehensive classification. However, in the case where the flaws of type 2 under the subject of classification coexist in the test field of vision of the flaws of type 1 and type 4, and both the classification by the score of flaw and the classification by the length of flaw are the same, the classification of the coexistent part shall be increased by one in terms of the class number. In this respect, as to the flaw of class 1, it shall be categorized as class 2 where the flaws of type 1 and type 4 are independently existent or where 1/2 of the allowable score of flaw in the coexistent case and 1/2 of the allowable length of flaw of class 2 are exceeded respectively.

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