Viewing and Interpretation of Radiographs

http://onlineshowcase.tafensw.edu.au/ndt/content/radiographic/task8/accessible.htm

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Introduction

The final stage in radiographic testing is the viewing, interpretation and reporting the results of a radiographic inspection. After all, the real purpose of a radiographic inspection is to provide information about the acceptability, or otherwise, of the product being tested.

After compeleting this task, you should be able to:

- set up and check the conditions for properly viewing a radiograph
- interpret weld radiographs for defect in accordance with Australian Standards
- interpret casting radiographs in accordance with ASME and Australian Standards.

Requirements for Inspecting Radiographs

The viewer must include a uniformly illuminated diffusing screen

AS2177 states that the examination of radiographs shall be carried out “by diffused light in a darkened room”. Most illuminators also include a rheostat that enables the brightness to be adjusted to accommodate radiographs of varying densities. In addition, it must be possible to mask the viewer so that bright, direct light is excluded from the eyes of the inspector.

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Radiograph viewing illuminator

A very important requirement is the brightness of the viewer

AS3998 requires the minimum intensity of light transmitted through a radiograph being examined to be 30 candella per square meter (cd/m^2). To achieve this, the brightness of the viewing facility must be at least that shown in the following table:

Minimum illuminator brightness required for radiograph density

Density of Radiograph	**Minimum Illuminator Brightness (cd/m^2)**
1.5	1,000
2.0	3,000
2.5	10,000
3.0	30,000
3.5	100,000

It follows that the upper limit of film density is determined by the brightness of the available illuminator. The above values are the minimum brightness to view film, based on 30 cd/m^2 intensity of transmitted light. The standard suggests that 100 cd/m^2 is a more reasonable value.

The brightness of an illuminator can be checked with a photographic light meter by following these steps:

1. Set the film speed indicator to 100 ASA or 200 ASA
2. Place the sensitive element of the meter close to the screen of the illuminator
3. Record the 'exposure' in hundredths of a second against a camera aperture setting of f10, f14.3 or f20
4. Use the table below to relate photographic exposure time to screen brightness.

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Photographic luminosity meter

The following table provides information on the relationship between screen brightness and the exposure reading obtained using the above method.

Relationship between screen brightness and the exposure reading

f number	Exposure (seconds)	Screen brightness (cd/m^2)	
		100 ASA	200 ASA
10	1/100	1,000	2,000
10	1/500	5,000	10,000
10	1/1000	10,000	20,000
14.3	1/100	2,000	4,000
14.3	1/500	10,000	20,000
14.3	1/1000	20,000	40,000
20	1/100	3,000	6,000
20	1/500	15,000	30,000
20	1/1000	30,000	60,000
20	1/1500	45,000	90,000
20	1/2000	60,000	120,000

This illuminator must be used in a darkened room

There should be only sufficient background light to enable recording of details on the viewing record. Too much background lighting may cause reflections off the film, effectively reducing contrast and making interpretation more difficult. Furthermore, the room used as a viewing room should be quiet and comfortable to avoid unnecessary distractions.

Radiographs are veiwed for short intervals

This practice is followed to prevent eye strain and maximise your concentration level. Although each interpreter will differ, it is recommended that no more than five minutes be spent viewing a radiograph.

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Upon commencing a viewing session, the interpreter must allow sufficient time for his or her eyes to become adjusted to the darkened conditions.

Radiographs should be dried before viewing

Wash water on a radiograph has a significant effect on sensitivity and increases the difficulty of detecting fine discontinuities. Be sure to dry you radiographs before viewing.

Check the quality of the radiograph

Before inspection proper can begin, the radiograph is checked for processing and handling artefacts and film density, and the IQI sensitivity is determined. The person interpreting the radiograph must be sure that the quality of the radiograph is adequate, and is in accordance with the requirements of the code or specification, so that relevant discontinuities can be detected. The results of these preliminary checks and measurements should be recorded on the viewing report.

Assessing for discontinuities is done methodically

You must resist the temptation to simply "spot the defect". A thorough examination is achieved by carefully scanning the radiograph from one side to the other, concentrating on each area of the radiograph as it is viewed. To do this properly, the interpreter must understand:

- the product that has been radiographed, including the type of material
- the method of fabrication or casting
- the type of discontinuities that are likely to occur
- how the radiograph was produced.

The other very important criteria that the interpreter must clearly understand are the acceptance/rejection criteria for the area or part being inspected. This information is generally contained in specifications or codes, or sometimes in the customer's own specification for the component.

Radiographic interpretation is a skill that can only be mastered through knowledge of the material being tested and experience. Many indications produce subtle low contrast or unsharp images that can be difficult to interpret. Material knowledge and experience are the most valuable aids that an interpreter can draw on.

Interpreting Weld Discontinuities

Weld discontinuities are designated by standard abbreviations

There is a standard set of abbreviations used to describe most weld discontinuities. These abbreviations are listed in AS4749-2001, "Non-Destructive Testing – Terminology of and Abbreviations for Fusion Weld Imperfections as Revealed by

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Radiography". Description of each discontinuity are provided, plus prints taken from an actual radiograph or a sketch to describe discontinuity. You are strongly advised to obtain a copy of this standard from Standards Australia if you are at all involved with weld radiography.

Weld imperfections are either surface or internal

There are two classes of weld discontinuities:

- surface imperfections
- internal imperfections.

Standard abbreviations for weld discontinuities are listed in the tables below.

Abbreviations for surface imperfections

Imperfection	Code
Excessive penetration	SXP
Incompletely filled groove	SGI
Undercut	SUC
Grinding mark	SMG
Hammer mark	SMH
Surface pitting	SPT
Linear misalignment	HiLo
Root Concavity	SRC
Shrinkage groove	SGS
Excessive dressing	SED
Tool mark	SMT
Torn surface	STS
Spatter	SSP

Abbreviations for internal imperfections

Imperfection	Code
Longitudinal crack	KL
Crater crack	KC
Lack of root fusion	LR
Incomplete root penetration	LP
Linear inclusion	IL
Tungsten inclusion	IT
Gas pore	GP
Crater pipe	CP
Linear porosity	PL
Uniform porosity	PU
Diffraction mottling	DM

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Transverse crack	KT
Lack of side fusion	LS
Lack of inter-run fusion	LI
Inclusion	IN
Oxide inclusion	IO
Copper inclusion	IC
Worm hole	WH
Localised porosity	PG
Elongated cavity	EC
Burn through	BT

All radiographs should be interpreted to determine their compliance with a code or standard

A typical standard is Australian Standard AS4037 which includes acceptance levels for various weld imperfections in pressure vessels. It states:

- No planar imperfections (e.g. crack or lack fusion defects) are allowed.
- In main butt welds (class 1 vessels), slag inclusions can have:
    - a maximum length of 6 mm for thicknesses of up to 18 mm
    - a maximum length of T/3 for thicknesses between 18 mm and 60 mm
    - a maximum length of 20 mm for thicknesses greater than 60 mm.

Some standards include porosity charts which are typically illustrations to provide a visual comparison to help determine the acceptablility of porosity discontinuities. Porosity imperfections may be classified as:

- isolated pores (maximum diameter 0.3T but not greater than 6 mm)
- uniform porosity
- clustered porosity
- linear porosity.

Surface Discontinuities for Welds

The following images have been provided courtesy of Agfa Gevaert Pty Ltd. These reproductions of radiographs show various weld defects as they might appear in a radiograph.

Excessive penetration (SXP)

Weld metal protruding through the root of the weld. Appears as a light continuous or more often intermittent, irregularly shaped band within the image of the weld.

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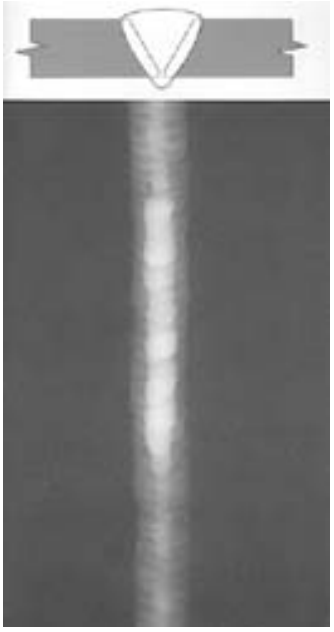
Radiograph of Excessive Penetration (Courtesy Agfa NDT)



Root concavity (SRC)

Sometimes called suck-back. A shallow groove in the root of a butt weld. Appears as a dark area along the centre of the weld.

Radiograph of Internal (Root) Concavity (Courtesy Agfa NDT)

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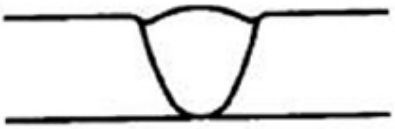
Incompletely filled groove (SGI)

A continuous or intermittent channel at the top surface of the weld and running along the length of the weld. It may be at the centre of the weld, where it is sometimes known as external concavity or insufficient fill, or may be at the edges of the weld where it is known as incompletely filled groove.

Radiograph of External Concavity (Courtesy Agfa NDT)

Incompletely Filled Groove



Undercut (SUC)

An irregular groove at the top edge (toe) of a weld caused by contraction of the weld metal, or by burning away (gouging) of the parent metal. Appears as a dark irregular band along the top edge of the weld metal.

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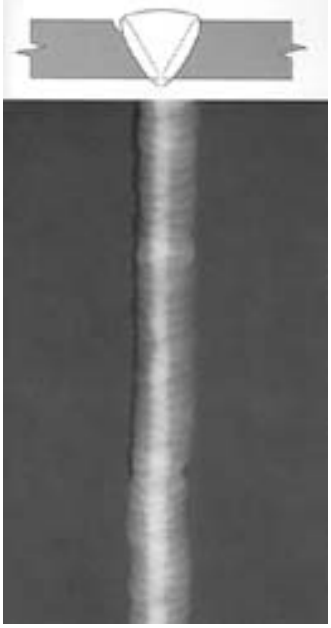
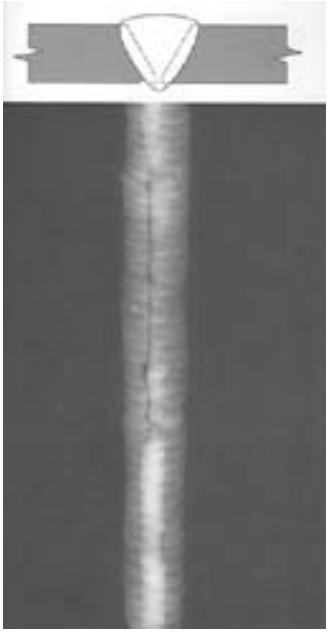
Radiograph of External Undercut (Courtesy Agfa NDT)



Undercut can also occur at the root of the weld, although this can easily be confused with lack of root fusion.

Radiograph of Internal Undercut (Courtesy Agfa NDT)



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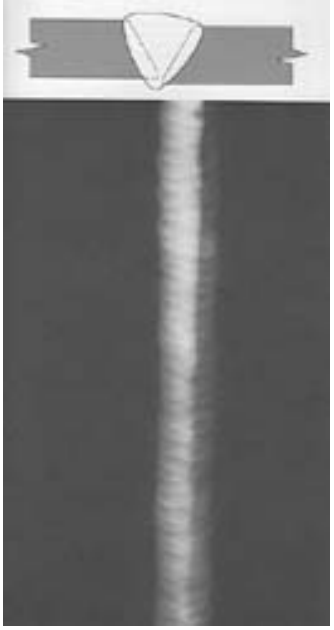
Linear misalignment (HiLo)

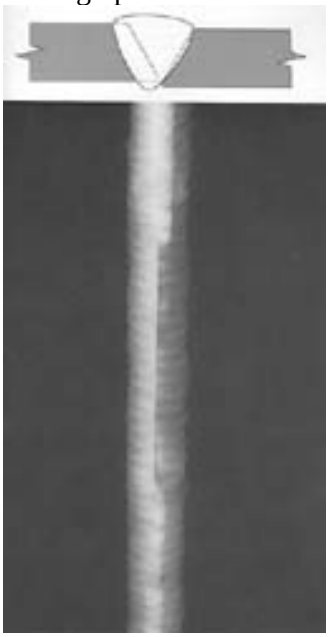
A planar misalignment of the two sides being welded. May appear as light and dark sides.

Radiograph of Linear Misaligment (Courtesy Agfa NDT)



Linear misalignment may have a linear indication associated with it caused by the protruding edge of one of the plates. This has the appearance of a lack of penetration indication.

Radiograph of Lack of Penetration (Courtesy Agfa NDT)



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Internal Discontinuities for Welds

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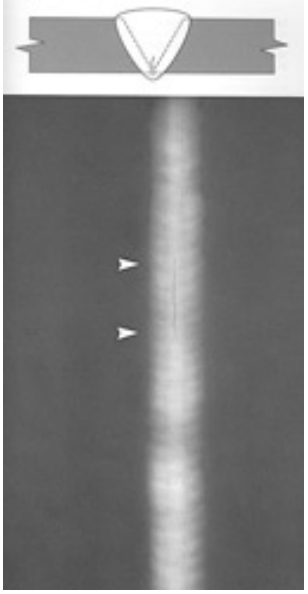
Longitudinal Crack (KL)

Cracks appear a fine dark lines, mostly jagged edges, sometimes discontinuous. Its detection is dependent on its orientation relative to the radiation beam.

Radiograph of Longitudinal Crack (Courtesy Agfa NDT)



Longitudinal root crack (KL)

This form of crack occurs mostly in the parent metal adjacent to the root run of the weld. It appears as a fine dark line, mostly jagged edges, sometimes discontinuous. Its detection is dependent on its orientation relative to the radiation beam.

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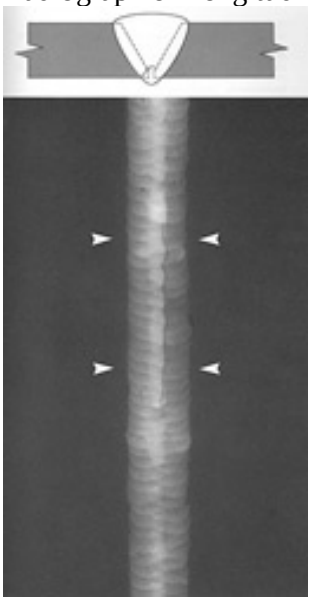
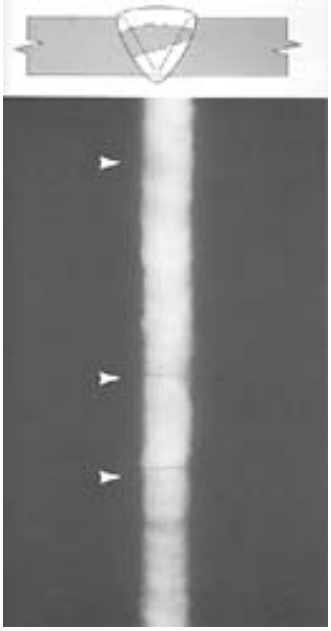
Radiograph of Longitudinal Root Crack (Courtesy Agfa NDT)



Transverse Crack (KT)

A transverse crack runs across the weld bead and sometimes into the parent metal. It appears as a fine dark line, mostly jagged edges, sometimes discontinuous. Its detection is dependent on its orientation relative to the radiation beam.

Radiograph of Transverse Crack (Courtesy Agfa NDT)



Lack of side fusion (LS)

A lack of union between the weld metal and the parent metal at the side of a weld. Its image appears as a straight dark line or band, depending on the orientation of the beam of radiation. Its detection depends on its orientation relative to the beam

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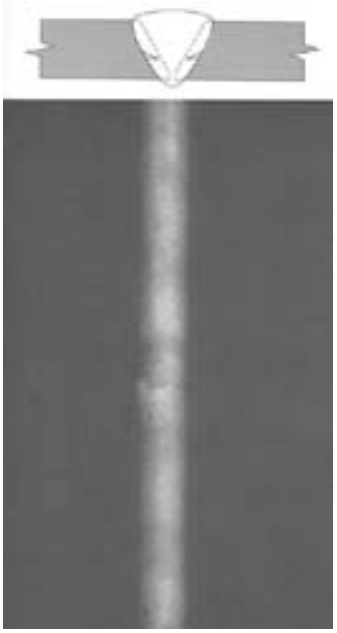
orientation, and sometimes requires an additional exposure with the beam aligned parallel to the weld preparation face.

Radiograph of Lack of Side Wall Fusion Crack (Courtesy Agfa NDT)

Lack of inter-run fusion (LI)

A lack of union between adjacent weld runs in a multi-run weld. It appears as a faint dark line with sharply defined edges.

Radiograph of Lack of Inter-run Fusion (Courtesy Agfa NDT)



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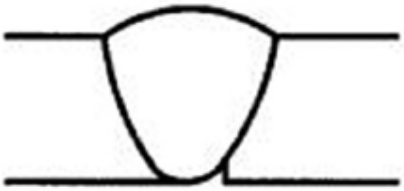
Lack of root fusion (LR)

A lack of union of the weld metal with the parent metal at the root of a weld. Appears as a straight line or band at one or both edges of the weld root image.

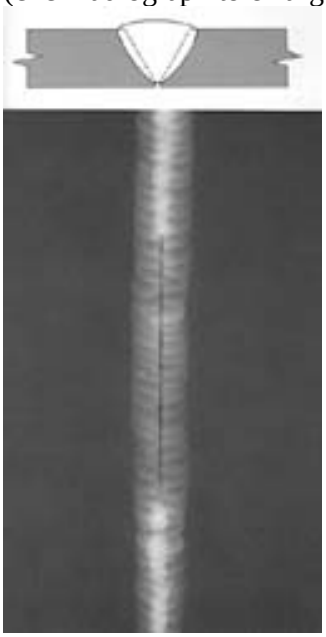
Lack of Root Fusion



Incomplete root penetration (LP)

Failure of the weld metal to extend into the root area of a joint. Appears as a dark continuous or intermittent band with mostly straight edges. In close square butt joints it may appear as a continuous or broken line. There is often a line of fine porosity associated with this defect.

Radiograph of Incomplete Root Penetration (Courtesy Agfa NDT)
(click radiograph to enlarge)



Inclusion (IN)

Slag or other foreign matter trapped between weld runds or between the weld and the parent metal. Appears as mostly irregular shapes.

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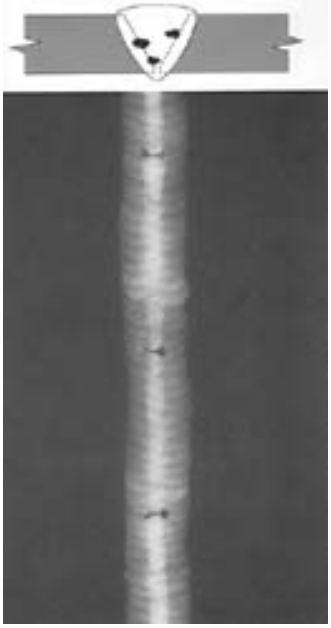
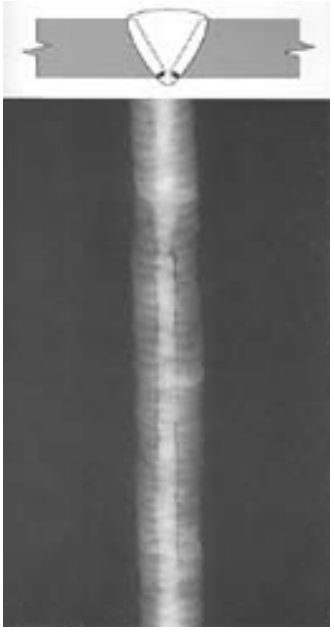
Radiograph of Inclusion (Courtesy Agfa NDT)



Linear inclusion (IL)

Also known as a slag line. Caused by lines of slag trapped, generally between the weld metal and parent metal, in a multi-run weld. Appears as one or more dark bands, mostly with irregular edges, running along a weld.

Radiograph of Linear Inclusion (Courtesy Agfa NDT)



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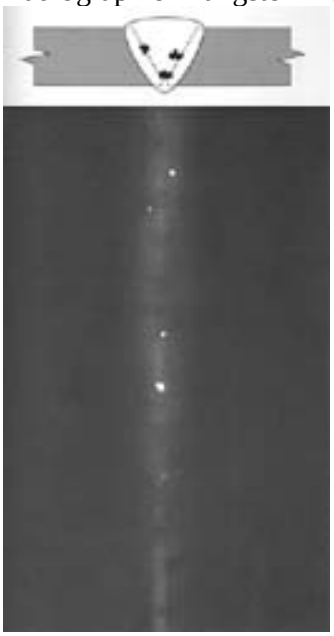
Tungsten inclusion (IT)

An inclusion of tungsten from a tungsten electrode used in the gas tungsten arc (GTAW) process. Appears as small white sharp edged images in the weld metal due to the fact that tungsten is much denser than steel or aluminium.

Radiograph of Tungsten Inclusion (Courtesy Agfa NDT)



Gas pore (GP)

A mostly spherical gas hole in the weld metal. Appears as one or more circular dark images.

Radiograph of Scattered Porosity (Courtesy Agfa NDT)

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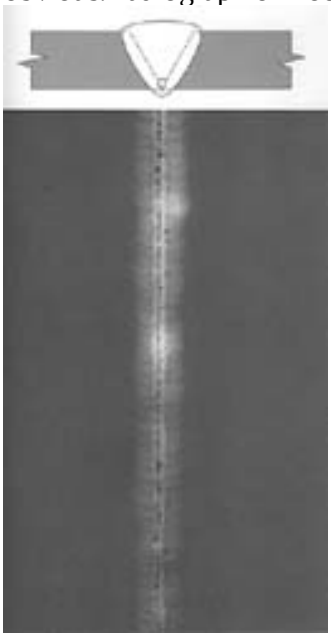
Linear porosity (PL)

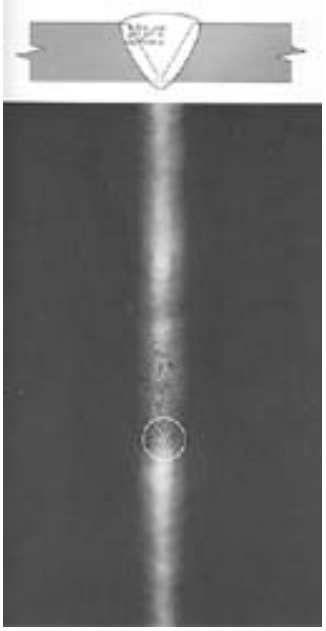
A line of mostly small round images aligned along a weld. Note that this can sometimes indicate a lack of fusion defect which may not be immediately obvious.Radiograph of Root Pass Aligned Porosity (Courtesy Agfa NDT)



Localised porosity (PG)

A group of gas pores confined to a small area of a weld. Appears as a cluster of small round indications. These discontinuities are sometimes elongated, where they are referred to as “worm holes”.

Radiograph of Cluster Porosity (Courtesy Agfa NDT)



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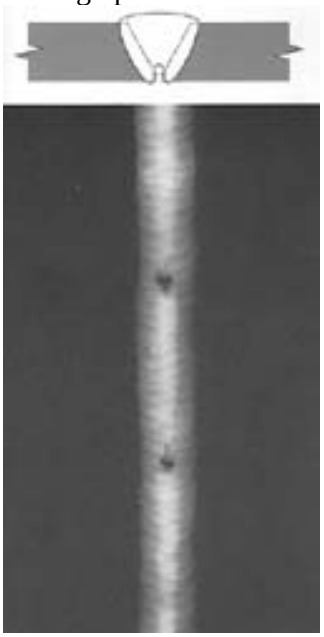
Burn through (BT)

A localised collapse of the weld pool leaving a hole in the bottom of the weld run. Appears as an irregularly shaped globular dark area.

Radiograph of Burn Through (Courtesy Agfa NDT)



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Interpreting Casting Discontinuities

In the case of castings, there are two very different systems for interpretation:

1. The American (ASTM) system.
2. Australian standard AS3507

The American (ASTM) system

This system relies on ‘reference radiographs’. These are sets of radiographs showing particular casting discontinuities at up to five levels of severity. A typical standard is ASTM E446 “Standard Reference Radiographs for Steel Castings up to two inches (51 mm) in Thickness”. This standard contains a number of reference radiographs showing particular casting discontinuities at different levels of severity. These discontinuities are categorised as gas porosity, shrinkage etc.

The radiographs are each 5"× 7" (127 mm × 178 mm) and are used to compare with 5"× 7" areas of radiographs of actual castings. Acceptance is based on perceived severity of the particular discontinuity. The standards states “where a particular severity is called for, and the radiograph being evaluated is equal to or better than the reference radiograph, the casting shall be indicated as being radiographically acceptable. If the radiograph shows a discontinuity of greater severity than the reference radiograph, the casting shall be rejected” .

The Australian standard

The Australian standard for radiography of steel castings is AS3507, “Non-destructive testing – Radiography of steel castings and classification of quality”. This standard adopts a totally different approach in that discontinuities must be quantified (measured) and the acceptance or otherwise of the casting is based on these measurements.

For gas porosity, inclusions and shrinkage discontinuities, the standard defines a viewing area that varies from 30 mm × 30 mm to 100 mm × 100 mm, depending on casting thickness.

For gas defects (porosity) and inclusions, the standard assigns a ‘severity index’ depending on the diameter or size of the discontinuity. The total of the severity indexes in the viewing area must not exceed a particular limit, determined by the class of the casting.

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Example:

The following porosity discontinuities were detected in the viewing area for a particular casting:

Porosity discontinuities detected for a particular casting

Discontinuity Diameter d (mm)	Severity Index Number	Number of Similar Size Discontinuities	Total of Individual Severity Indexes
d < 2	1	5	5
2 < d < 4	2	6	12
10 < d < 15	12	1	12
	Total of severity index numbers:		29

If the specification for maximum severity indexes for this casting is 29 or greater, the casting is radiographically acceptable. If the specification for maximum severity indexes for the casting is less than 29, the casting is not acceptable.

For shrinkage discontinuities, the maximum length and/or width of the discontinuity is measured. The total length or area of shrinkage within the viewing area must not exceed limits set for the particular class of casting. If two or more areas are detected in the viewing area, the lengths or areas are summed.

Example:

Two areas of macro-shrinkage are detected in the viewing area of a casting, one measuring 100 mm long and one measuring 20 mm long. Total length is 120 mm. If the maximum length allowed is 120 mm or greater, the casting is radiographically acceptable, otherwise the casting is not acceptable.

Casting Discontinuities

The following images show various casting discontinuities as they might appear in a radiograph.

Micro-porosity

This is a very fine, but often extensive, discontinuity caused by evolution of gas whereby very fine gas pores form around grain boundaries or between dendrite arms. They present a somewhat mottled effect in a radiograph.

Mainly effects non-ferrous metals such as magnesium and aluminium.

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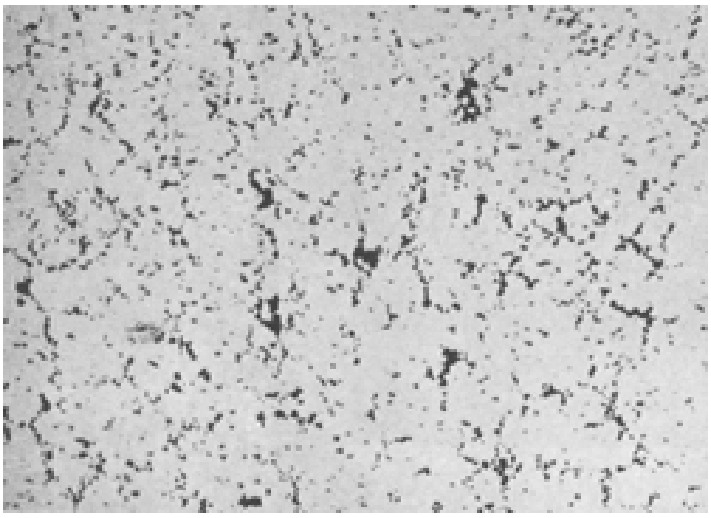
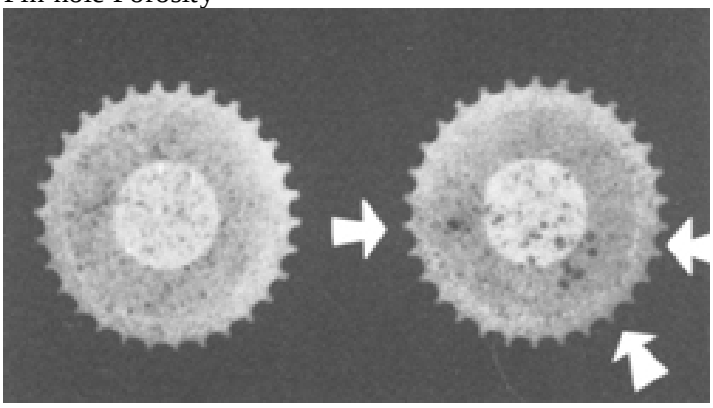
Micro-porosity



Pin-hole porosity

Small rounded cavities, typically less than 1 mm diameter, caused by evolution of gas during solidification of the molten metal. Sometimes occurs just below the surface of the casting, where it is known as sub-cutaneous pinhole porosity. Appears in a radiograph as widely distributed small dark rounded images.

Pin-hole Porosity



Gas holes

Rounded cavities generally greater than 1 mm diameter - they can be quite large - and often more randomly dispersed through the casting due to gas evolved from the metal during solidification or from the mould or core. Appears as dark areas with a smooth outline which may be circular or elongated in shape.

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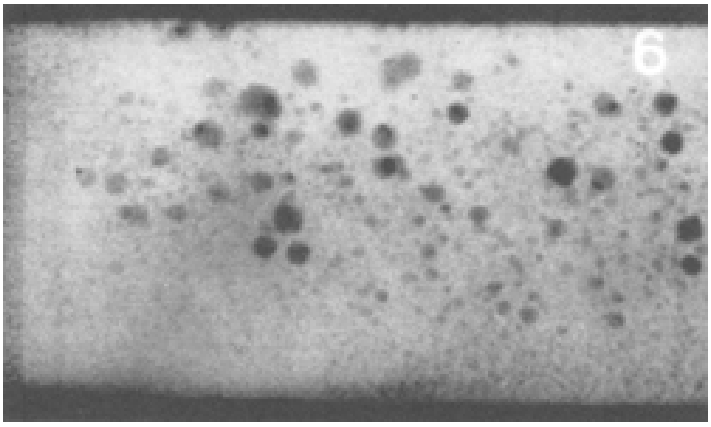
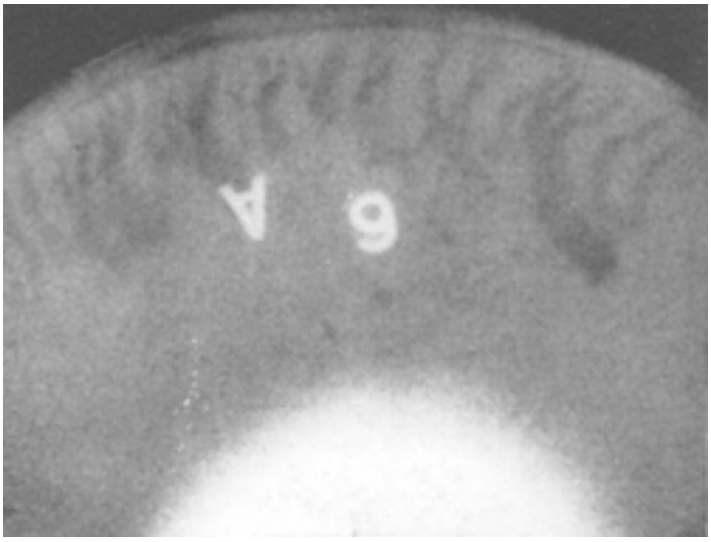
Gas Holes



Wormholes

Tube-like cavities similar to gas holes, generally located just below the surface of a casting. Caused by progressive expansion of entrapped superheated steam from moisture in a mould or core.

Wormholes



Airlock

A large cavity formed by air entrapped in the mould during pouring of the metal. Appears as a generally smooth and often irregularly shaped image.

Airlock
(click radiograph to enlarge)

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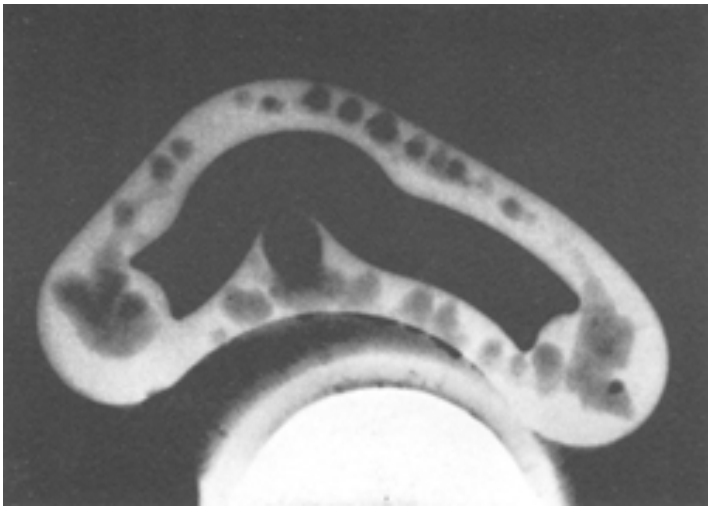
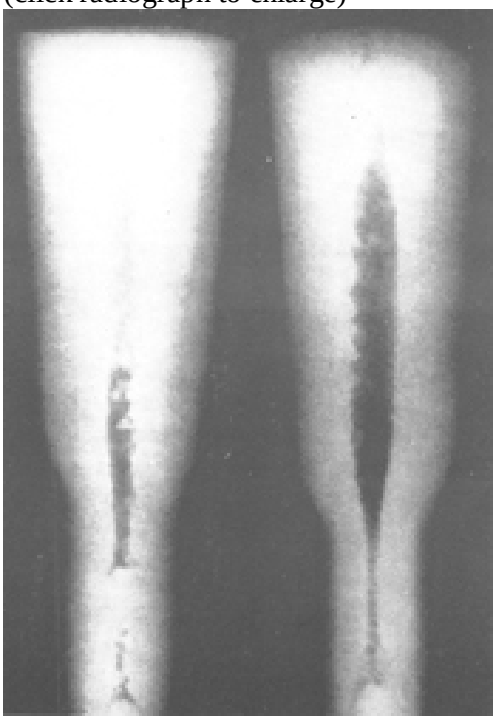


Shrinkage cavity

A discrete cavity caused by contraction of the metal during solidification. Generally rougher edges to the image and an irregular - often tapered - shape.

Shrinkage cavity in casting feeder head
(click radiograph to enlarge)



Filamentary shrinkage

A fine to course form of shrinkage in which the cavities are branching, interconnected and extensive. Appears as a network of branched irregular shapes.

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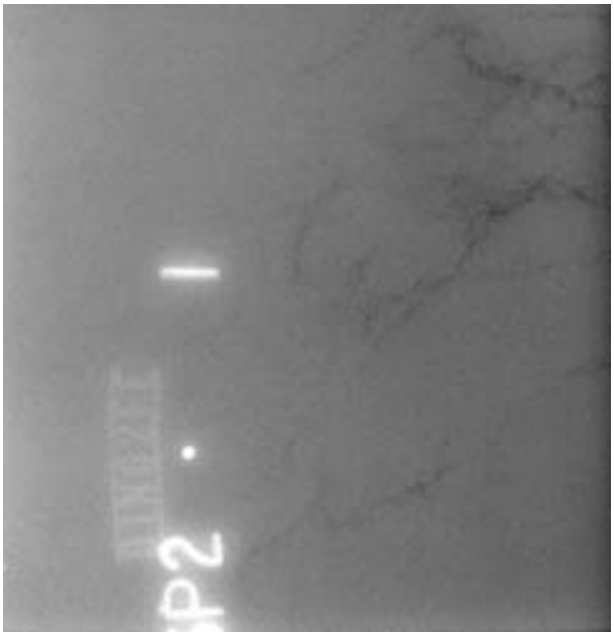
Filamentary Shrinkage



Hot tear

A discontinuity caused by fracture of the metal during its contraction as it cools during the early stages after solidification. Appears as one or more dark, jagged, lines. Hot tears tend to be a planar type of discontinuity, so detection by radiography may depend on the plane of the crack relative to the direction of the radiation beam.

Hot Tear

Stress crack

A sharper, more well defined fracture of the metal that forms generally during the later stages of cooling from solidification. May appear as a slightly jagged or a smooth dark line. They can also form when the casting is cold or during subsequent heat treatment. Again, hot tears tend to be planar so detection will depend upon the viewpoint of the radiograph.

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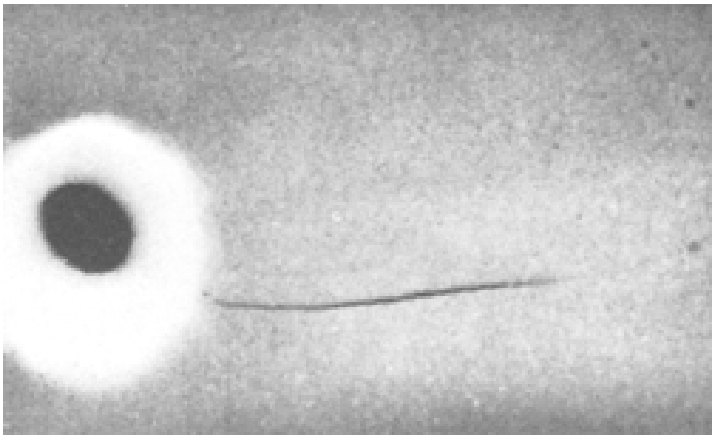
Stress Crack



Cold shut

A discontinuity formed when a stream of liquid metal, as it flows through a mould, fails to fuse with other metal in the mould. Mostly a surface discontinuity, radiographically it appears as a smooth dark line. Being a basically planar type of discontinuity, its detection by radiography may depend on the plane of the discontinuity relative to the direction of the radiation beam. It is often detected visually.

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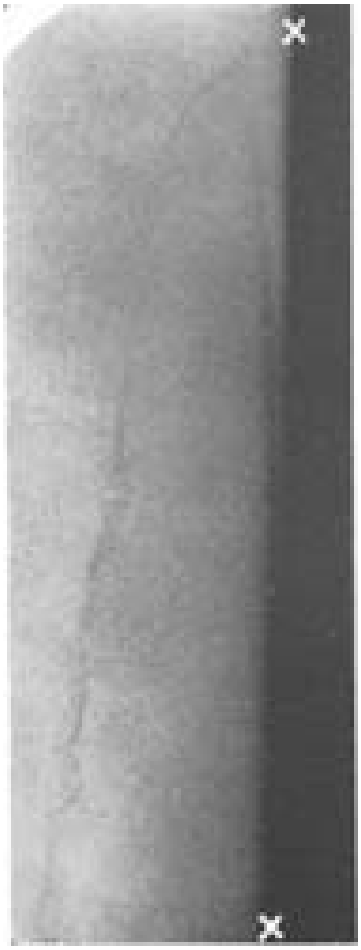
Cold Shut



Unfused chaplet/unfused chill

Chaplets and chills are metal inserts placed in a mould for various casting purposes. If the liquid metal fails to fuse to these devices, a planar discontinuity may result. The presence of rust on the chaplet or chill will generally give rise to porosity around the chaplet or chill.

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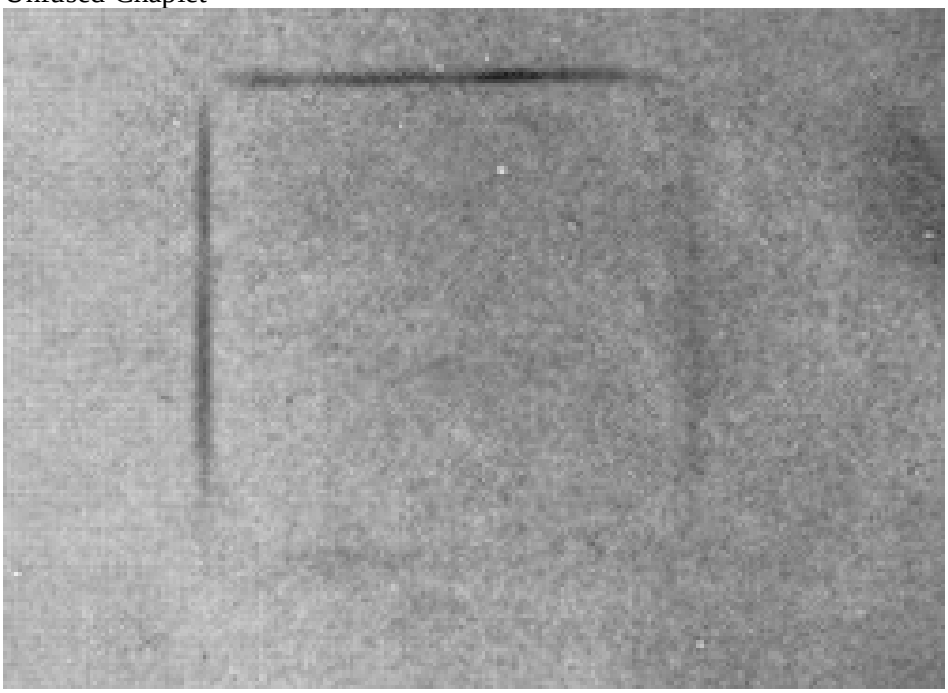
Unfused Chaplet



Inclusion

Sand from a mould, and slag or dross from a ladle of metal, can be washed into the stream of metal as it enters and flows through a mould, and become trapped in the metal as it solidifies. It may appear as a light or dark irregularly shaped image in a radiograph, and may be difficult to distinguish from a void. However, the outcome is the same - this discontinuity is generally not acceptable.

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Inclusion

Segregation

This discontinuity comprises particular components of the metal composition that have different solidification temperatures and so tend to be driven by solidifying metal and segregate at particular areas, particularly the central zones, of a casting. May appear as light or dark areas in a radiograph, or even as banded light and dark areas.

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Reporting Discontinuities

All discontinuities are recorded on the viewing report

In the case of welds, there is an accepted convention for the recording of discontinuity indications. This is described in AS4749, “Non-Destructive Testing - Terminology of and Abbreviations for Fusion Weld Imperfections as Revealed by Radiography”. The code comprises of:

- a number to indicate the distance from the horizontal of vertical distance (mm) of the start of the discontinuity from the reference mark of the lowest number on the radiograph
- letters, using standard abbreviations, to denote the type of discontinuity
- a number to denote the length of the discontinuity (mm) over which the particular imperfection extends
- each code is separated by a dash (-).

Hence 48-PL-180 indicates linear porosity (PL), starting 48 mm from the reference mark and extending over a distance of 180 mm.

The outcome of the viewing and interpretation is recorded in a report

A typical viewing report should include the following information:

- name of the test laboratory
- identification of the component
- product standard
- details of the material tested, including welding processes if relevant
- the number of the test method standard (eg. AS2177.1/ AS3507) and designation of test method
- details of the area(s) tested
- details of surface imperfections and other artefacts noted in the radiograph
- type of IQI and calculated sensitivity
- film density range achieved
- a statement of compliance or non-compliance with the acceptance criteria
- date and place of testing
- identification of the radiographer and interpreter
- report number and date.

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Summary – The Basic Steps in Interpreting a Radiograph

1. Verify that the radiograph corresponds to the part being examined.
2. Verify that radiographic coverage is complete for the particular part.
3. Verify that the image quality indicators are correct and properly used and that the proper image quality level was achieved.
4. Verify that the film densities meet requirements of the standard.
5. Check for film artifacts and indications of surface phenomena and record any on the viewing record
6. Retake any indications that cannot be resolved as an artifact or discontinuity.
7. Visually check the surfaces of the part for surface discontinuities or contours that match the appearance of the discontinuity on the radiograph.
8. Evaluate the internal discontinuities to the applicable standards and accept, reject, or hold the part for further review. Record as 'complies' or 'does not comply' on the viewing record.
9. Mark the locations on the part of any non-complying discontinuities.
10. Prepare a test report indicating the nature, extent, and disposition of all significant indications found on the radiographs.

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