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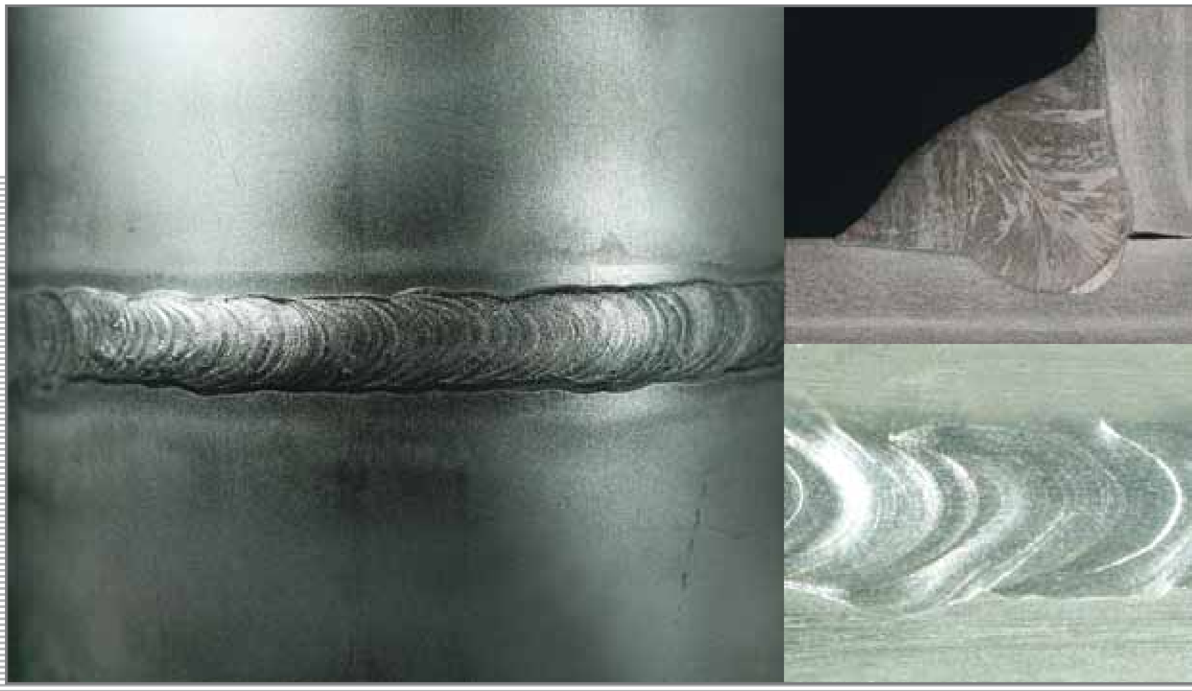
The European Stainless Steel Development Association

Reference Photo Guide for Stainless Steel Welds



Materials and Applications Series, Volume 14

Euro Inox

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Members of Euro Inox include:

- European stainless steel producers;
- national stainless steel development associations;
- development associations of the alloying element industries.

The prime objectives of Euro Inox are to create awareness of the unique properties of stainless steel and to further its use in existing applications and in new markets. To achieve these objectives, Euro Inox organises conferences and seminars and issues guidance in printed and electronic form, to enable architects, designers, specifiers, fabricators and end users to become more familiar with the material. Euro Inox also supports technical and market research.

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Contents

Introduction

Welding is a particularly common fabrication technique for stainless steel. Most stainless steel grades are easy to weld. If properly done, welds can be as strong, corrosion-resistant and visually appealing as the base material.

However, inadequate welds can have unwanted consequences:
- The corrosion resistance of the fabrication can be compromised in the welded area and lead to problems later.
- Structural problems may occur.
- In decorative applications, it can become impossible to grind and polish the welds to the requested aesthetic standards.

In architectural applications, much care is taken to ensure the good appearance of welds in visible areas. Weld quality in non-visible fabrication parts is not always paid the necessary attention. These areas may be exposed to pollutants, typically chlorides and sulphur from exhaust gases, coastal atmosphere or aerosols of de-icing salt. However, unlike the decorative side, they may never be inspected and cleaned, and especially if they are sheltered and not washed by rain, accumulation of corrosive deposits is possible. Good weld quality is therefore important in hidden as well as visible joints.

How and where to use this photo guide

The aim of this photo guide is to give visual acceptance criteria showing different welding procedures, degrees of surface finishing and weld geometries. It will help purchasers, architects, designers, inspectors and engineers choose suitable welding procedures for their applications. The photo guide can also be used as a reference document for contract agreements, so misunderstandings and disputes after final inspection can be avoided.

The focus of this document is on the appearance of the cap run. In many applications, the appearance of the root side is crucial, if it is exposed to liquid or gaseous media. This, however, exceeds the scope of the present photo guide.

The brochure does not focus on defect types. These can be studied in ISO 5817 [1]. The reader should also bear in mind that visual inspection cannot replace micrographic examination.

The photos show an overview of the weld
- in the as-welded condition;
- in post-weld cleaned condition;
- as a close-up of the surface (to better illustrate rippling and surface phenomena);
- as a cross-section through the weld (to show the geometry of the weld reinforcement).

[1] ISO 5817:2003 – Welding – Fusion-welded joints in steel, nickel, titanium and other alloys (beam welding excluded) – Quality levels for imperfections

About welding process selection

Seven different welding procedures in three quality levels are shown here. In each case, the most typical parameters for the welding procedure are used respectively. For each test, the parameters are listed. Other combinations of parameters can also be selected to produce the same weld appearance.

The welding methods presented here are:

- Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas Arc Welding (TIG), here called GTAW.
- Gas Metal Arc Welding (GMAW) or Metal-Arc Inert Gas Welding (MIG), Metal-Arc Active Gas Welding (MAG), both here called GMAW. Both spray- and short-arc modes are used in this guide.
- Shielded Metal Arc Welding (SMAW) or Manual Metal Arc (MMA), here called SMAW.
- Flux-Cored Arc Wire Welding (FCAW), here called FCAW.

If GTAW or GMAW welding is used, the liquid weld pool is protected from the surrounding atmosphere by shielding gas (Ar or Ar + O_2/ CO_2).

When GMAW welding is carried out, the arc mode might play an important role in the appearance. In the tests underlying the present publication, only short-arc and spray-arc have been used.

The appearance of the weld reinforcement is strongly dependent on the welding procedure. It is generally accepted that an automatic process produces a smoother surface than a manual welding procedure. The GTAW, laser and plasma processes normally result in much smoother surfaces than SMAW and GMAW short-arc processes. The most favourable position to achieve a flat, smooth weld is a slightly inclined position.

Slag protects the weld pool if SMAW or FCAW is used.

Productivity

When a welder chooses a welding method, the appearance of the weld is not the only thing that matters. Another very important factor is the level of productivity of the selected welding process. As an example, GMAW and FCAW are faster processes than GTAW (in kg/h), see Figure 1. Laser and plasma are normally fully automatic processes that are not suitable for in-situ welding. If the sheet/tube material is thinner than about 1 mm, the most commonly used welding method is GTAW. In practice, manual welding is very difficult to perform with other methods without burning through. If the material is very thin, overlap joints can serve as an alternative to butt welds.

Different types of weldment surface appearance and how to improve the result

The most common visible phenomena on welds, beside conventional weld defects, are:

- varying coarseness of rippling;
- sticking surface slag;
- concave/convex reinforcement;
- spatter.

Some of these are a consequence of the welding method used. Other reasons could be directly related to the skill of the welder.

In horizontal welding, the most important factor in achieving a smooth weld surface with fine or no rippling is to use a suitable welding method. Examples of such methods are GTAW, plasma, laser or FCAW. SMAW with rutile-acid coatings and spray-arc GMAW welding give a surface with a fine-rippling pattern, although not as aesthetically pleasing as, for example, a good GTAW weld. In upward vertical welding with SMAW, the welder often uses a zigzag technique although this will always produce a rather wavy, rippling pattern.

Modern pulse-mode GMAW power sources give a much better surface than older spray-arc type machines.

In welding methods that involve the formation of slag (SMAW, FCAW), the slag is normally easy to remove. However, when using gas shielding methods, alloying elements in the wire together with active components in the gas may cause slag particles that can become embedded in the weld-bead surface. Alloying components that produce slag particles include silicon and manganese. Active gas components reacting with those elements include oxygen and carbon dioxide. Using low-silicon wire and reducing the amount of oxygen and carbon dioxide in the shielding gas can reduce the amount of slag. Embedded slag particles from GMAW welding can normally only be removed by grinding.

The geometrical profile of the weld reinforcement can influence weldment properties. A convex bead with a sharp toe angle will reduce fatigue properties and sometimes even corrosion resistance. Welding procedures often resulting in a convex profile are short-arc GMAW and SMAW, with basic electrodes. Convex beads may also form if too low a current (SMAW), too low voltage (GMAW spray-arc) or excessive stick-out (FCAW) are used.

To achieve an optimal appearance when using gas shielding welding methods, it is important to have sufficient gas flow. Typical gas shielding volumes are given below:

- GTAW 4-8 l/min
- GMAW 12-16 l/min
- FCAW 20-25 l/min

A concave weld profile is the desired form in most cases. However, there is a risk that the weld throat will be too thin and penetration will be too shallow. Situations in which the weld-bead profile might be negative may occur when the welder has used too high a welding speed – for example with SMAW or with GTAW, especially when welding vertically down.

Heavy spatter is in most cases not accepted. This is mostly caused by unsuitable welding parameters, non-optimized shielding gas or too long arc/stick-out.

Quality levels demonstrated

The welding procedures used in the test series underlying this photo guide have been performed manually, in different positions. The steel grade is 1.4301. The material thickness is between 2 mm and 6 mm.

The welds are in three different classes of appearance with different welding processes, positions and joint types. For each combination or welding method, position or joint type, the welds have been divided into three different classes. The three quality levels here used are:

- **Superior**
  The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

- **Good**
  The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

- **May be acceptable**
  The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

Welds that did not fulfil the minimum requirements were not included. The idea was to show an excellent weld that in many cases only requires a slight polishing/pickling to be accepted by the end-user. The level "may be acceptable" might be used where appearance is not of vital importance, if it meets corrosion resistance and mechanical properties requirements.

Post-weld treatment

In most applications, it is essential to clean the weld and remove tint, slag and other defects, to restore corrosion-resistance properties. For this reason, parts of the welds were brushed and pickled. Spatter, surface porosities, cracks and crevices are also to be avoided from a corrosion-resistance point of view. In most cases, they must be removed mechanically.

Importance of geometrical deviations

A weld free of defects will in most cases still give some degree of geometrical deviation from weld metal to parent material in the transition area. Such geometrical deviations might influence properties.

Trained welders

When selecting a specific welding procedure and appearance level, the training and qualification of the welders are critical. If the "superior" level is needed, highly skilled welders must be involved. If post-weld rectification (grinding and subsequent polishing) must be carried out, the costs might be up to three times higher than the welding costs.

Welding costs – productivity

In most cases, cost is a key criterion when choosing a welding process and specifying the desired appearance. To illustrate this point, Figure 1 can be used as a guideline. The quality levels are comparable only within a specific welding procedure. As an example, in Figure 1, a "superior" performance GMAW spray weld does not give as good an appearance as a "good" FCAW. In this context, productivity is expressed in kg/h of fused filler metal.

Further reading

This document is complementary to the following Euro Inox publications and further reading is suggested:

1. Welding of Stainless Steel (Materials and Applications Series, Volume 3), http://www.euro-inox.org/pdf/map/BrochureWeldability_EN.pdf

2. Pickling and Passivating of Stainless Steel (Materials and Applications Series, Volume 4), http://www.euro-inox.org/pdf/map/Passivating_Pickling_EN.pdf

3. Mechanical Finishing of Decorative Stainless Steel Surfaces (Materials and Applications Series, Volume 6), http://www.euro-inox.org/pdf/map/MechanicalFinishing_EN.pdf

4. Guidelines on the Welded Fabrication of Stainless Steel (Materials and Applications Series, Volume 9)

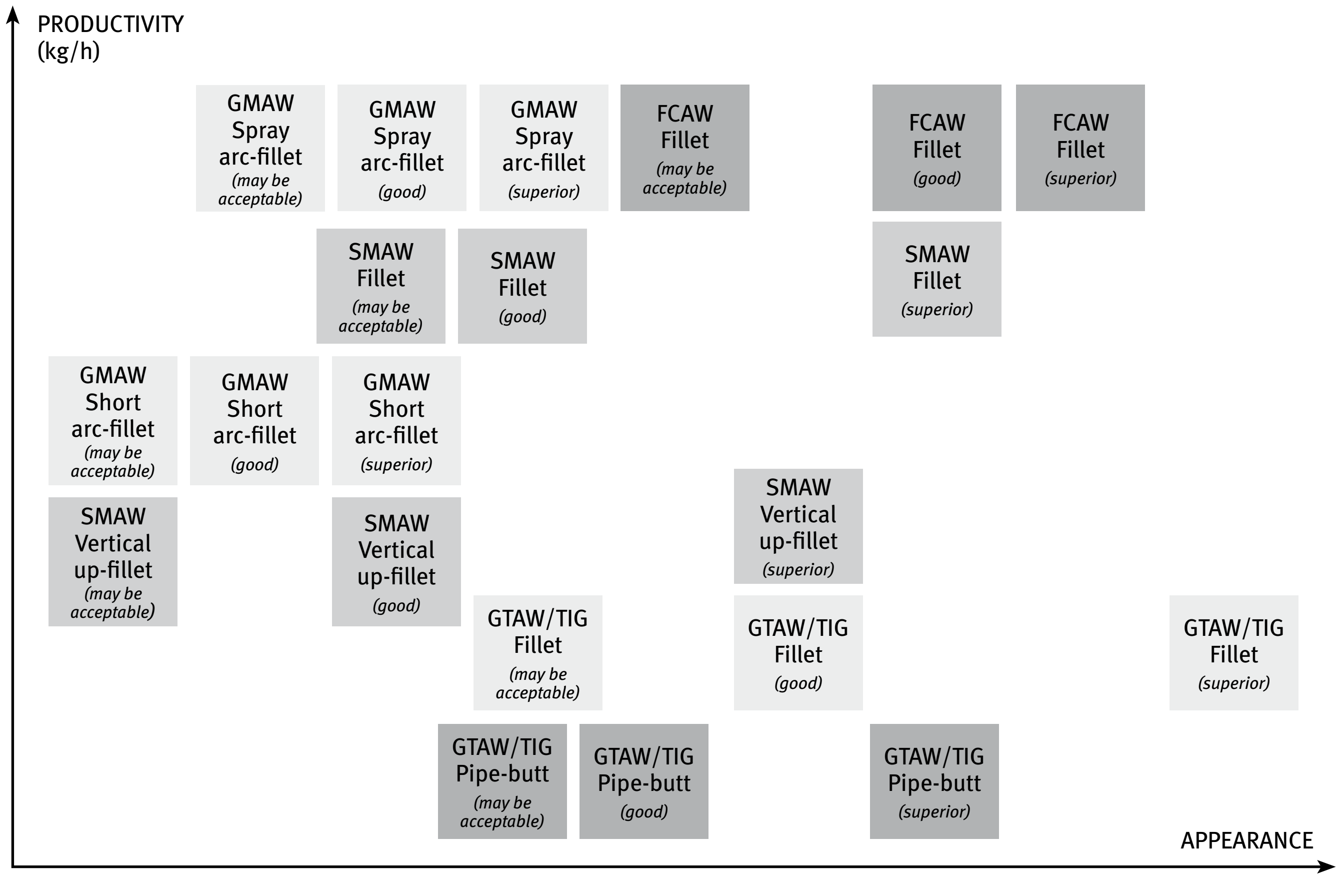

Figure 1: Level of productivity of the selected welding process

The reference photo guide includes seven detachable folders. Follow the colour code:

1 GTAW fillet weld in horizontal position (PB)

2 GMAW fillet weld in horizontal position – short arc (PB)

3 GMAW fillet weld in horizontal position – spray arc (PB)

4 FCAW fillet weld in horizontal position (PB)

5 SMAW fillet weld in horizontal position (PB)

6 SMAW fillet weld in vertical up position (PF)

7 GTAW pipe weld (PA rotating)

Superior: The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

Good: The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

May be acceptable: The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

Note:
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Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas Welding (TIG), here referred to as GTAW.

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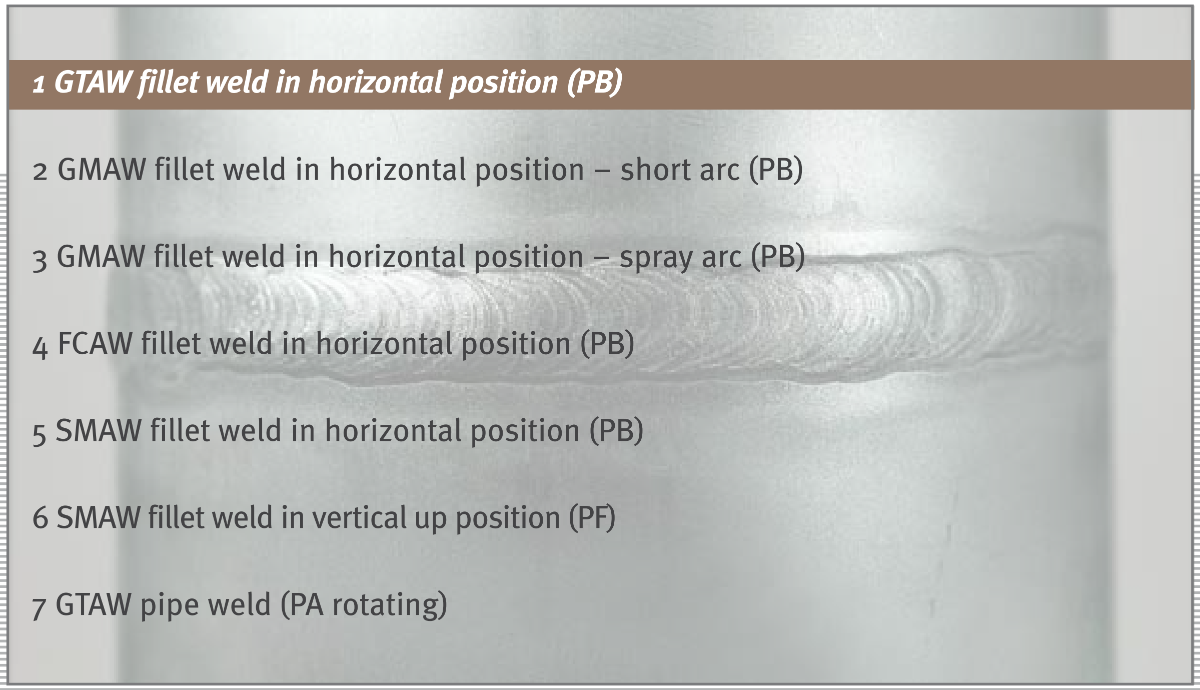

1 GTAW fillet weld in horizontal position (PB)

2 GMAW fillet weld in horizontal position – short arc (PB)

3 GMAW fillet weld in horizontal position – spray arc (PB)

4 FCAW fillet weld in horizontal position (PB)

5 SMAW fillet weld in horizontal position (PB)

6 SMAW fillet weld in vertical up position (PF)

7 GTAW pipe weld (PA rotating)

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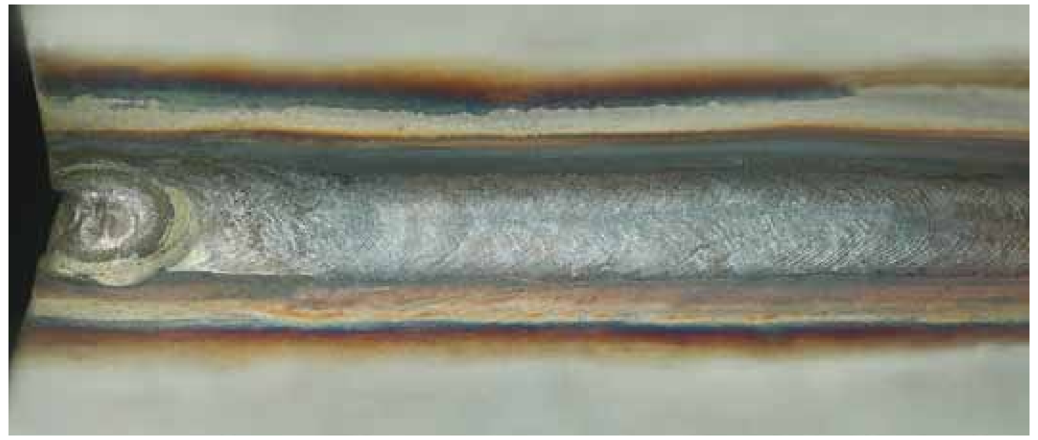
Superior



Filler: 2.4 mm, 19.9L Si wire   *I*: 90 - 110 A   *v*: 6 - 9 cm/min
Gas: Pure Ar   *U*: 10 - 12 V
Observations: As-welded condition. Very fine rippling, even bead, very thin surface oxides.

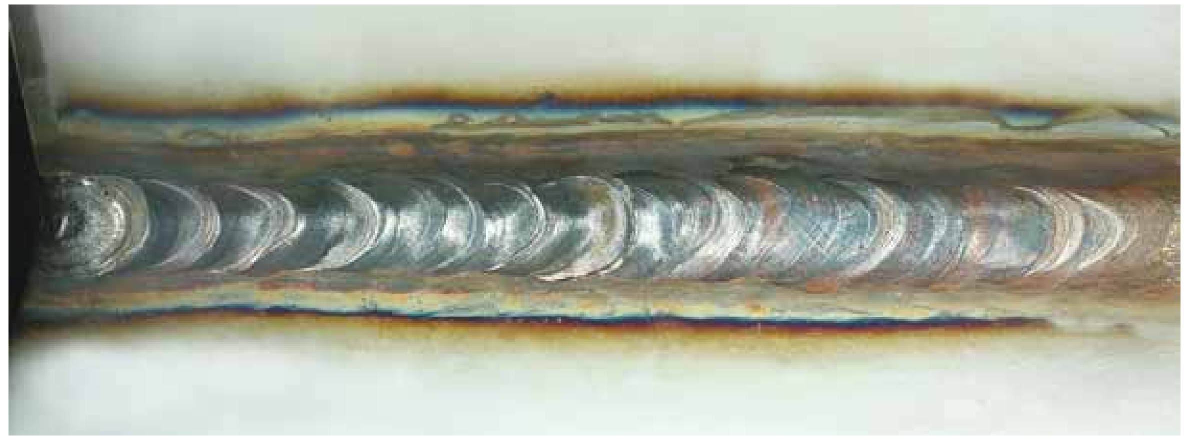
Cleaned weld (pickled).
Fine reinforcement without defects/slag/spatter.

Close-up of the weld surface.

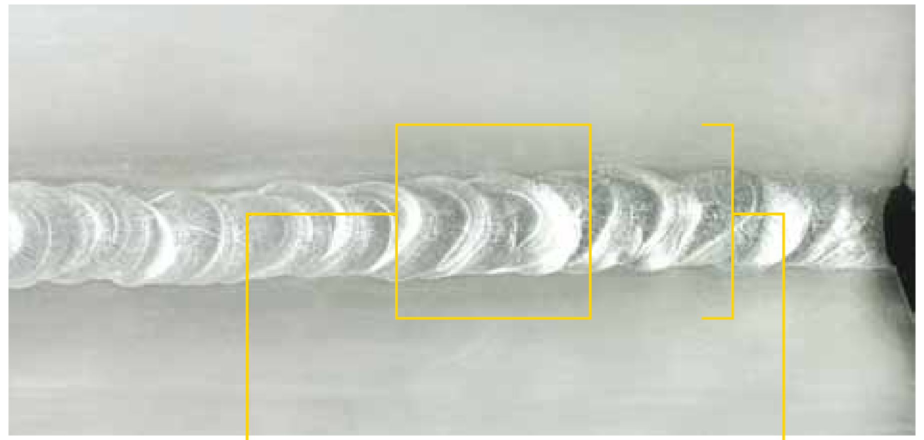
The section shows a concave reinforcement, which gives the best mechanical and corrosion resistance properties.

GTAW FILLET WELD IN HORIZONTAL POSITION (PB)

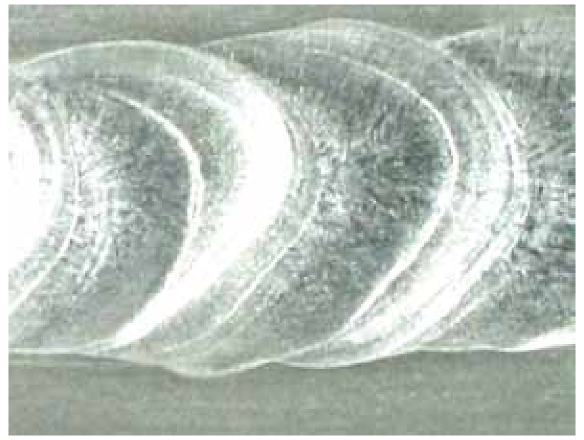
Good



Filler: 2.4 mm, 19.9 Si wire   *I*: 90 - 110 A   *v*: 3 - 10 cm/min
Gas: Pure Ar   *U*: 10 - 12 V
Observations: As-welded condition. Coarse rippling, thin surface oxides on the weld.



Cleaned weld (pickled).
Clean but coarse weld rippling.

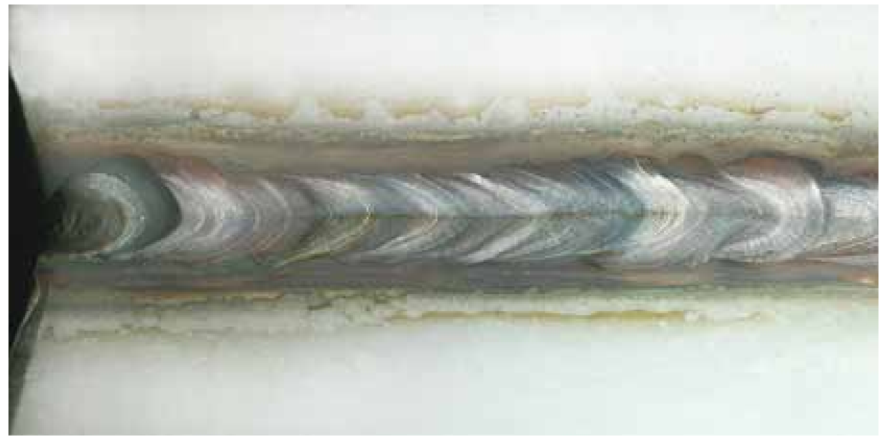


Close-up of the weld surface.

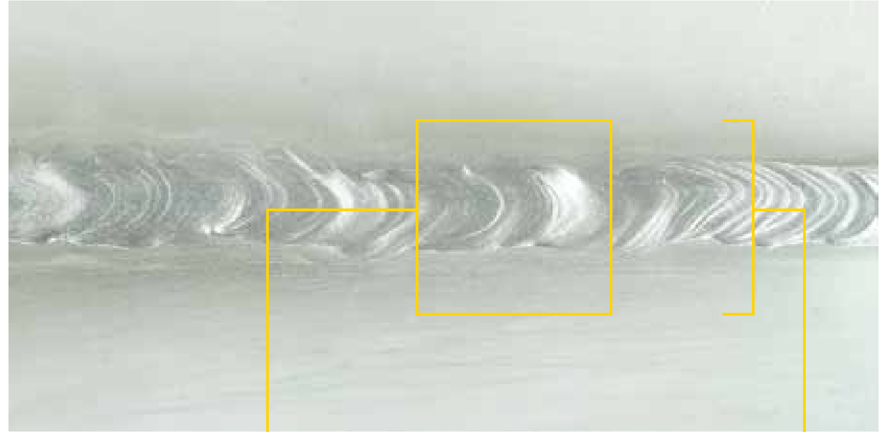
The section shows a concave weld.

GTAW FILLET WELD IN HORIZONTAL POSITION (PB)

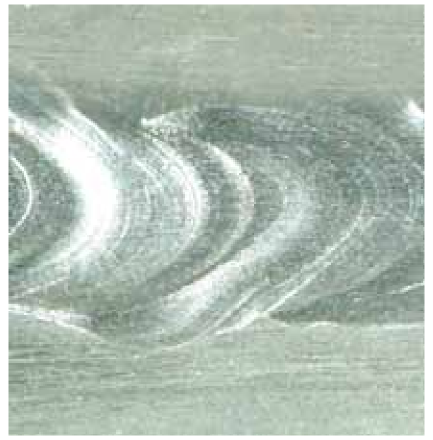
May be acceptable



Filler: 2.4 mm, 19.9 Si wire   *I*: 90 - 110 A   *v*: 3 - 10 cm/min
Gas: Pure Ar   *U*: 10 - 12 V
Observations: As-welded condition. Very coarse, irregular rippling, thin surface oxides on the parent material.



Cleaned weld (pickled).
Clean but irregular and coarse weld rippling.



Close-up of the weld surface.

The section shows a rather low and asymmetrical penetration form.

Superior: The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

Good: The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

May be acceptable: The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

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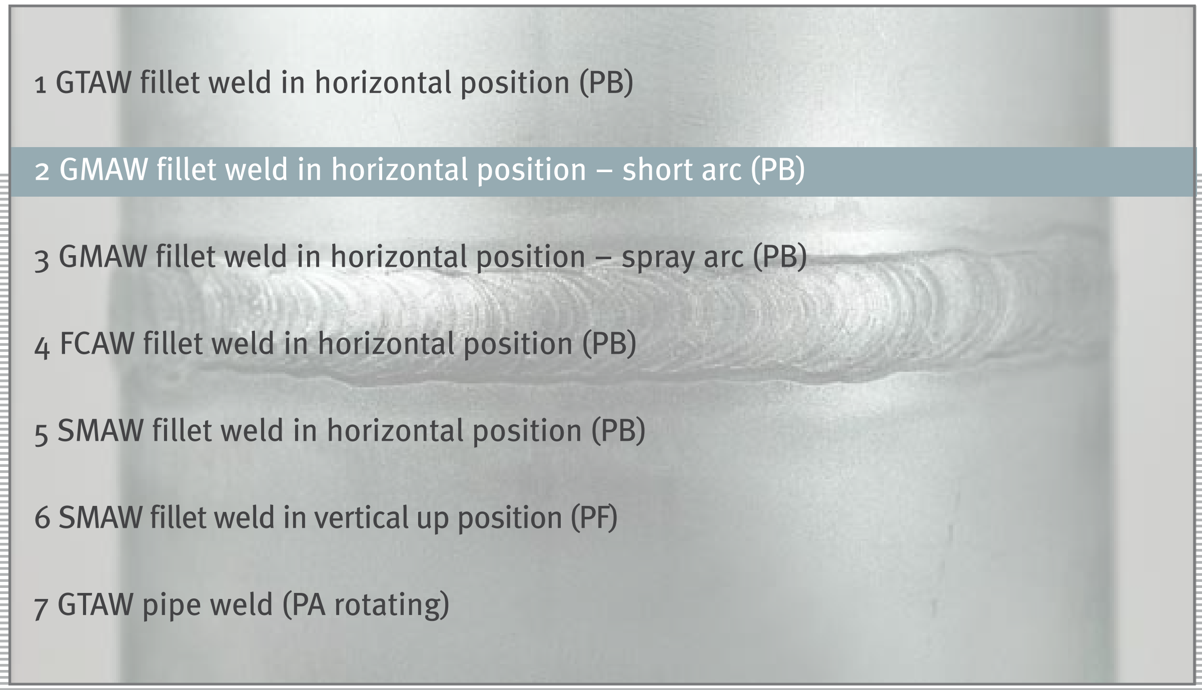

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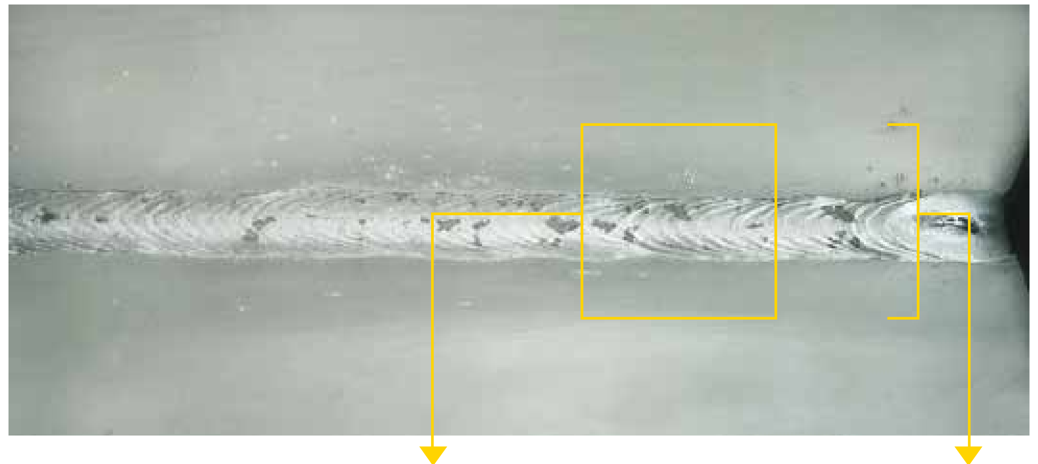
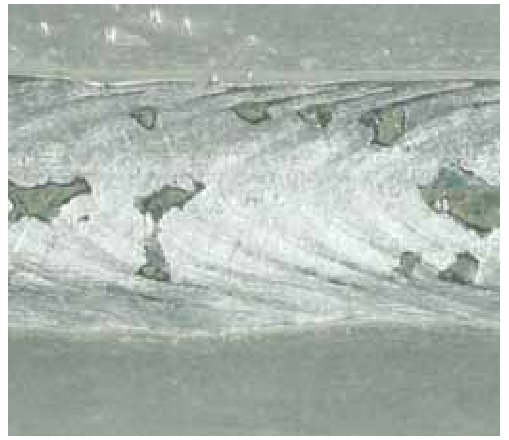
Filler: 1.0 mm, 19.9L Si wire   *I*: 140 - 170 A   *v*: 25 - 30 cm/min
Gas: 98 % Ar + 2 % O_2 *U*: 14 - 19 V
Observations: As-welded condition. Fine rippling, the bead has surface oxides and there is spatter on the parent material.

Cleaned weld (pickled). Pickling cannot remove this type of embedded surface slag.

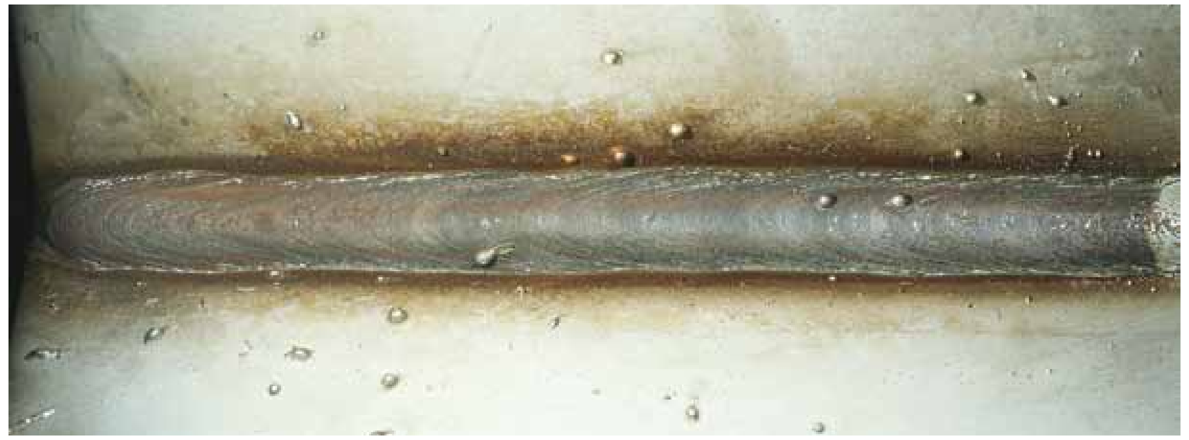




Close-up of the weld surface.

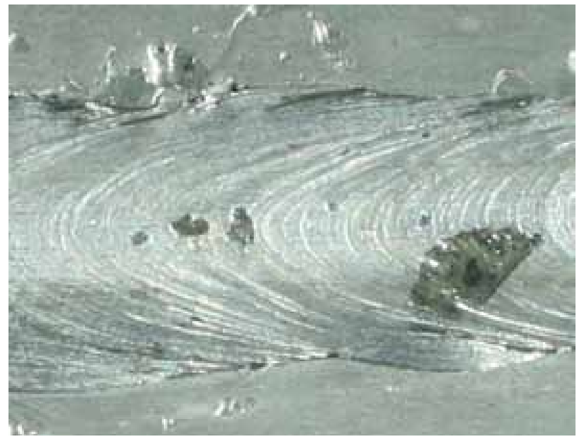
The section shows a rather convex reinforcement.

Good

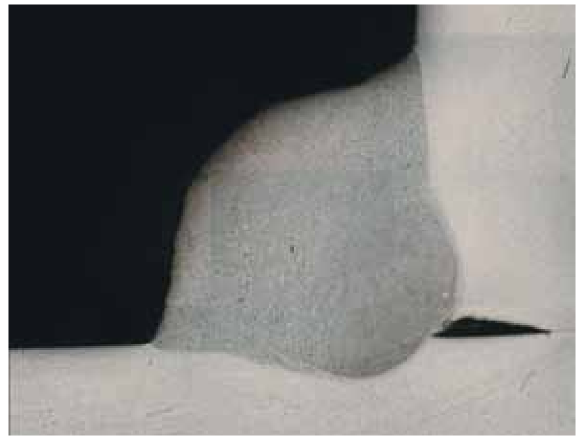


Filler: 1.0 mm, 19.9L Si wire   *I*: 140 - 170 A   *v*: 25 - 30 cm/min
Gas: 98 % Ar + 2 % O_2 *U*: 19 - 21 V
Observations: As-welded condition. Coarse rippling, the bead is irregular, has surface oxides and there is heavy spatter on the parent material due to too high voltage.

Cleaned weld (pickled). Pickling cannot remove this type of surface slag.

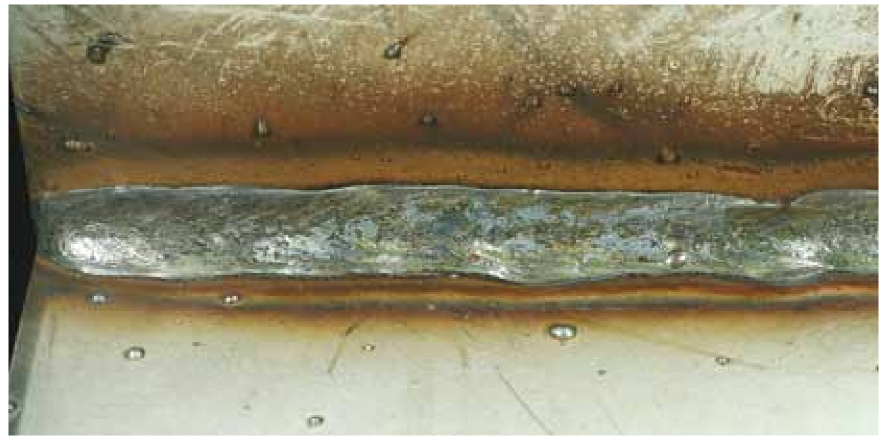


Close-up of the weld surface with surface slag.

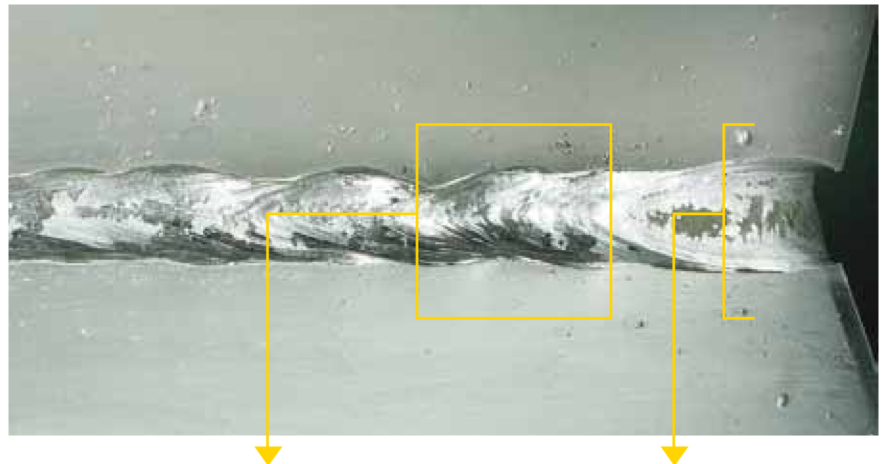


The section shows a convex weld. This is typical of this procedure.

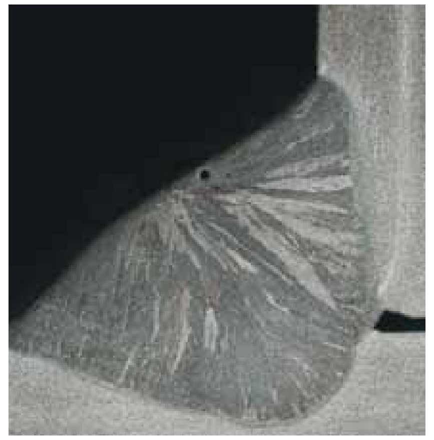
May be acceptable



Filler: 1.0 mm, 19.9L Si wire   *I*: 120 - 140 A   *v*: 12 - 16 cm/min
Gas: 98 % Ar + 2 % O_2 *U*: 19 - 21 V
Observations: As-welded condition. Coarse rippling, the bead is irregular, has surface oxides and there is heavy spatter on the parent material.



Cleaned weld (pickled). Pickling cannot remove this type of surface slag.



The section shows a slightly convex reinforcement. This geometrical form might reduce fatigue performance. Close to the weld surface, there is slight porosity. This is typical of this procedure.

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Superior: The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

Good: The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

May be acceptable: The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

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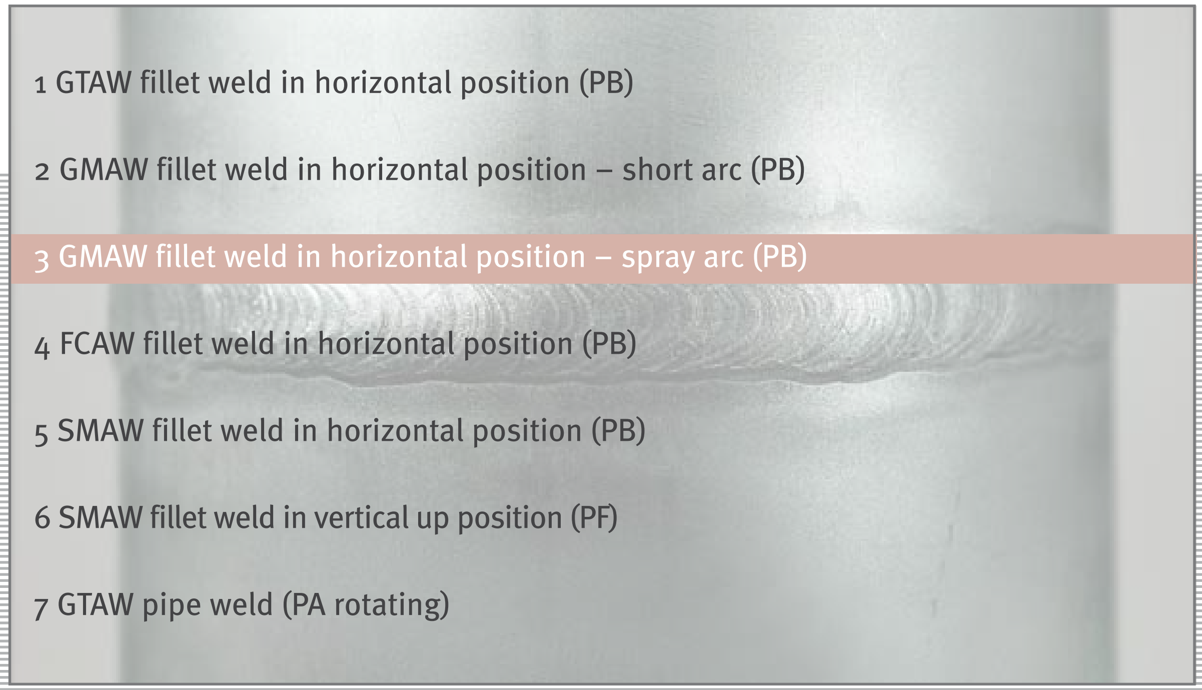

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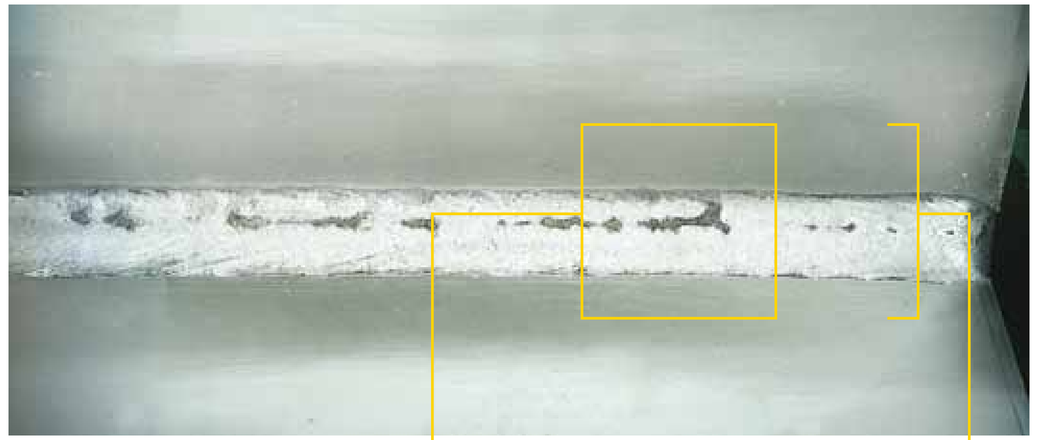
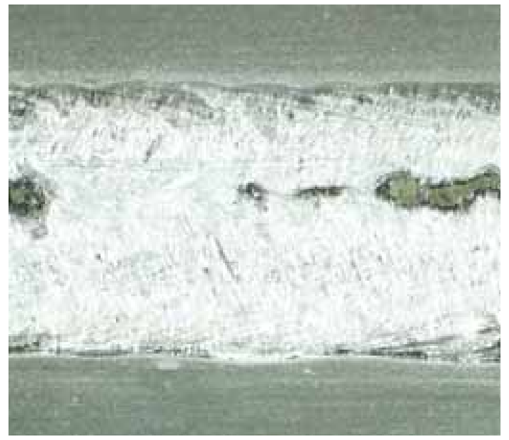
Filler: 1.0 mm, 19.9L Si wire   *I*: 180 - 200 A   *v*: 25 - 30 cm/min
Gas: 98 % Ar + 2 % O_2 *U*: 25 - 29 V
Observations: As-welded condition. The bead has surface oxides and slag.

Cleaned weld (pickled). Pickling cannot remove this type of embedded surface slag.





Close-up of the weld surface.

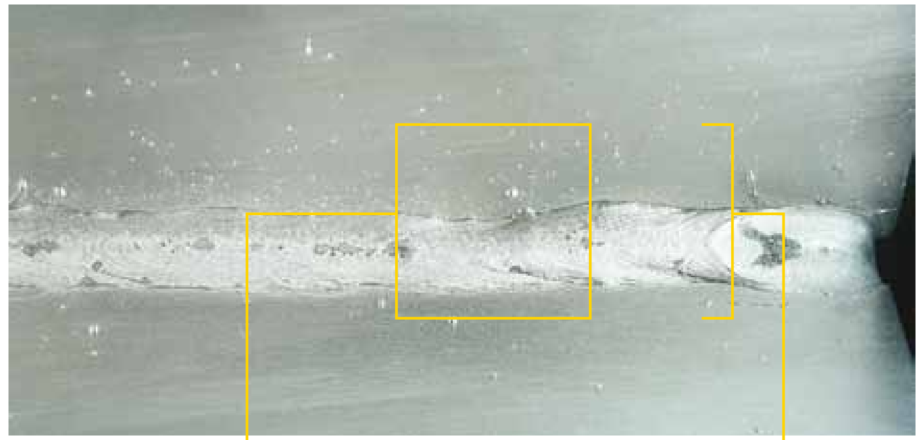
The section shows a slightly concave reinforcement with a low toe angle. Typical finger profile penetration is visible here.

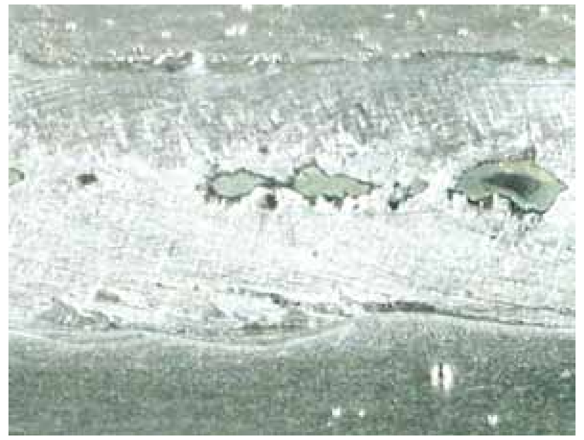
GMAW FILLET WELD IN HORIZONTAL POSITION – SPRAY ARC (PB)

Good

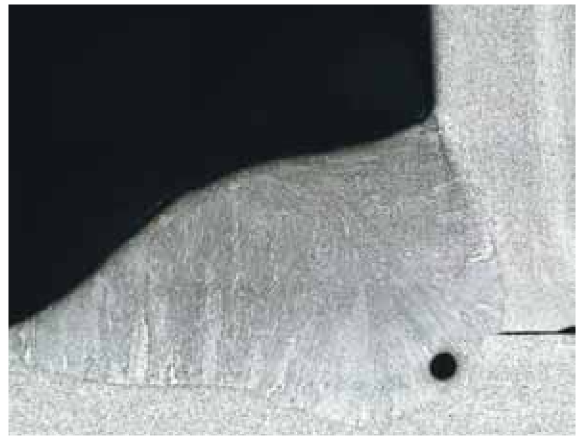
Filler: 1.0 mm 19.9L Si wire   *I*: 160 - 180 A   *v*: 25 - 30 cm/min
Gas: 98 % Ar + 2 % O_2 *U*: 23 - 25 V
Observations: As-welded condition. The bead is irregular, has surface oxides and there is spatter on the parent material. By using a higher voltage and smaller stick-out the amount of spatter might be reduced.

Cleaned weld (pickled). Pickling cannot remove this type of surface slag.





Close-up of the weld surface.

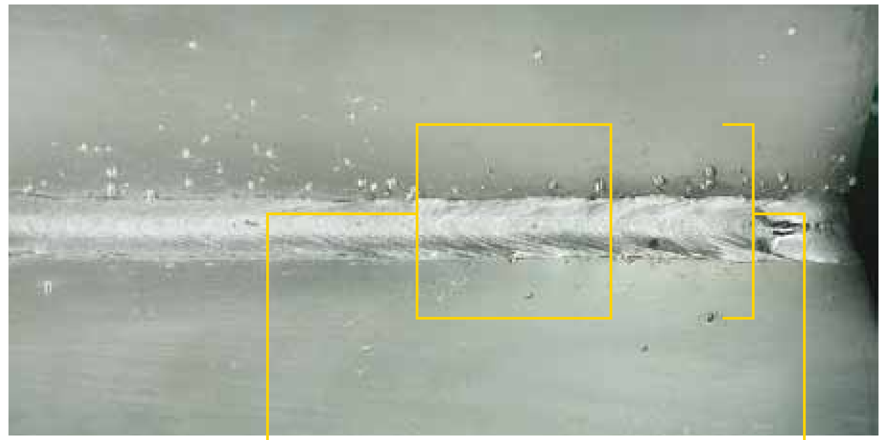


The section shows a rather asymmetrical and convex reinforcement. On the root side a typical porosity appears.

GMAW FILLET WELD IN HORIZONTAL POSITION – SPRAY ARC (PB)

May be acceptable

Filler: 1.0 mm, 19.9L Si wire   *I*: 180 - 200 A   *v*: 25 - 30 cm/min
Gas: 98 % Ar + 2 % O_2 *U*: 20 - 23 V
Observations: As-welded condition. The bead is irregular, has surface oxides and there is heavy spatter (due to low voltage) on the parent material and some on the weld metal.



Cleaned weld (pickled). Pickling cannot remove slag and spatter.

Close-up of the weld surface.

The section shows a convex reinforcement. The use of higher voltage would have reduced the convex profile. On the surface, a small amount of spatter appears. This is typical of this procedure.

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Superior: The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

Good: The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

May be acceptable: The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

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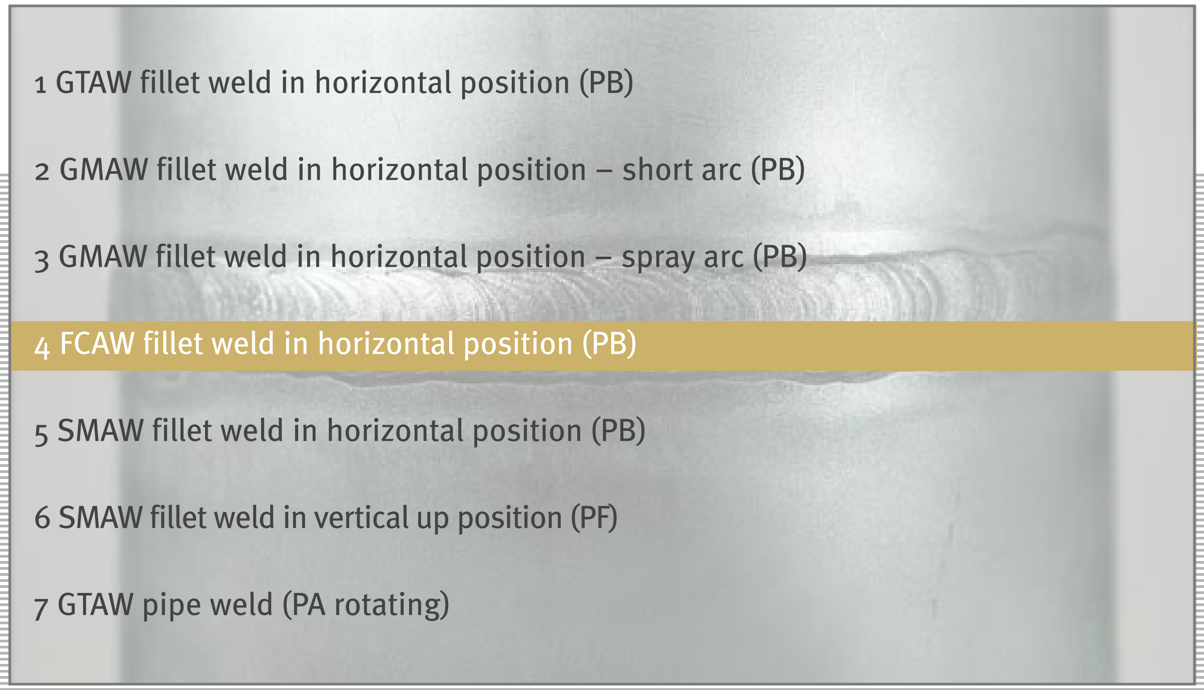

1 GTAW fillet weld in horizontal position (PB)

2 GMAW fillet weld in horizontal position – short arc (PB)

3 GMAW fillet weld in horizontal position – spray arc (PB)

4 FCAW fillet weld in horizontal position (PB)

5 SMAW fillet weld in horizontal position (PB)

6 SMAW fillet weld in vertical up position (PF)

7 GTAW pipe weld (PA rotating)

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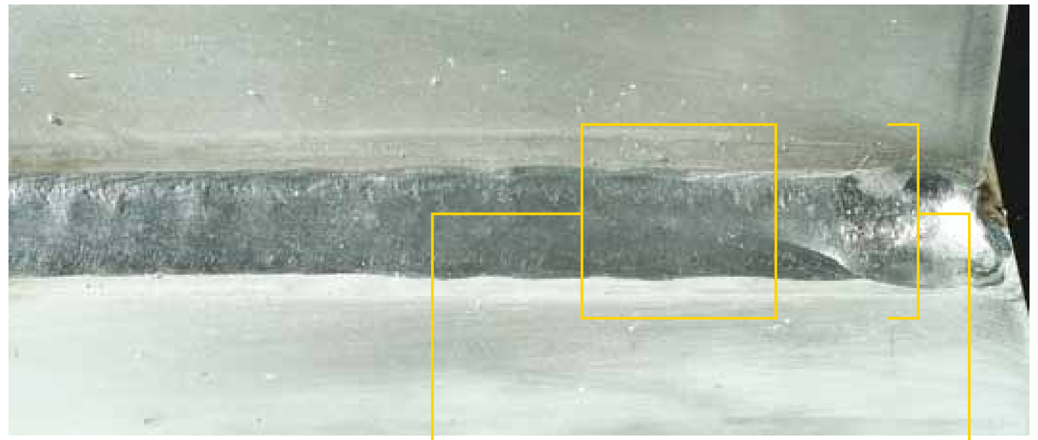
Filler: 1.2 mm, 19.9L wire — *I*: 190 - 210 A — *v*: 30 - 40 cm/min
Gas: 80 % Ar + 20 % CO_2 — *U*: 26 - 30 V
Observations: As-welded condition. Smooth surface with very fine rippling.



Cleaned weld with some spatter on the parent material (pickled).

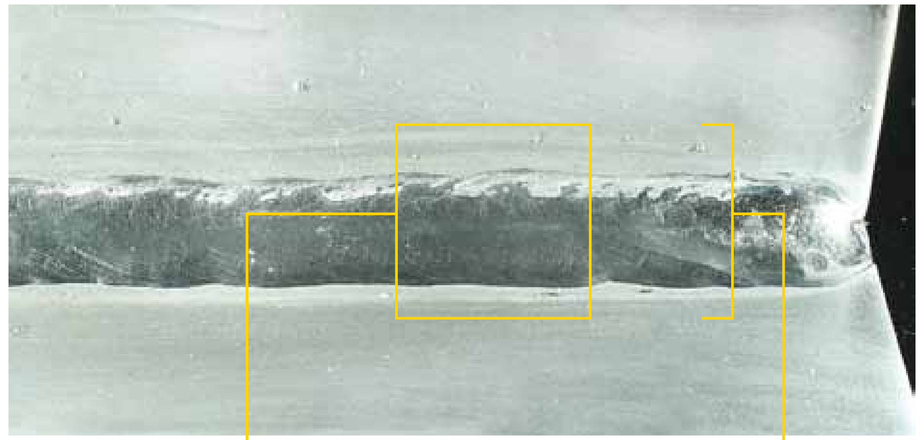
Close-up of the weld surface.

The section shows good concave/flat reinforcement.

FCAW FILLET WELD IN HORIZONTAL POSITION (PB)

Good

Filler: 1.2mm, 19.9L wire — *I*: 190 - 210 A — *v*: 35 - 40 cm/min
Gas: 80 % Ar + 20 % CO_2 — *U*: 26 - 30 V
Observations: As-welded condition. Smooth, fine rippling, the bead is slightly irregular.



Cleaned weld with some spatter on the parent material (pickled).

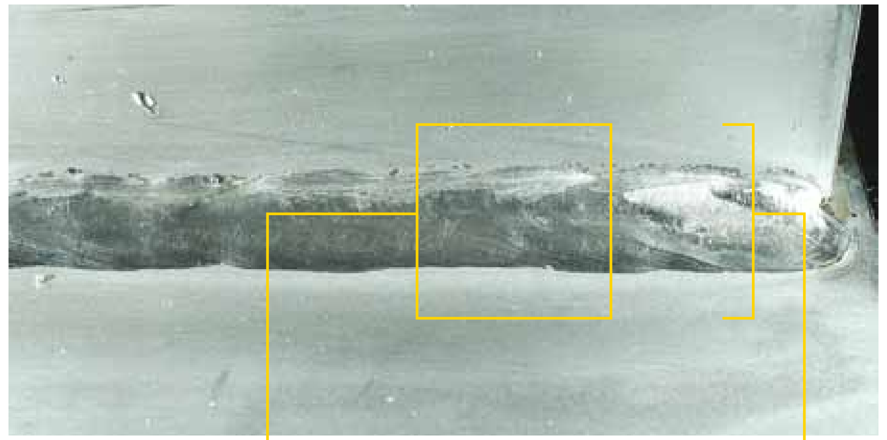
Close-up of the weld surface.

The section shows a rather convex/flat reinforcement.

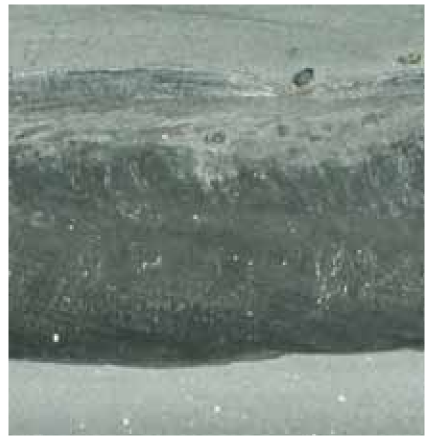
FCAW FILLET WELD IN HORIZONTAL POSITION (PB)

May be acceptable

Filler: 1.2 mm, 19.9L wire — *I*: 190 - 210 A — *v*: 35 - 40 cm/min
Gas: 80 % Ar + 20 % CO_2 — *U*: 26 - 30 V
Observations: As-welded condition. The bead is irregular and there is some spatter on the parent material. The reason for the irregular bead and spatter could be excessive stick-out and too great a torch angle.



Cleaned weld (pickled).



Close-up of the weld surface.

The section shows a relatively convex, asymmetrical reinforcement.

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Superior: The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

Good: The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

May be acceptable: The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

Shielded Metal Arc Welding (SMAW) or Manual Metal Arc (MMA), both here referred to as SMAW.

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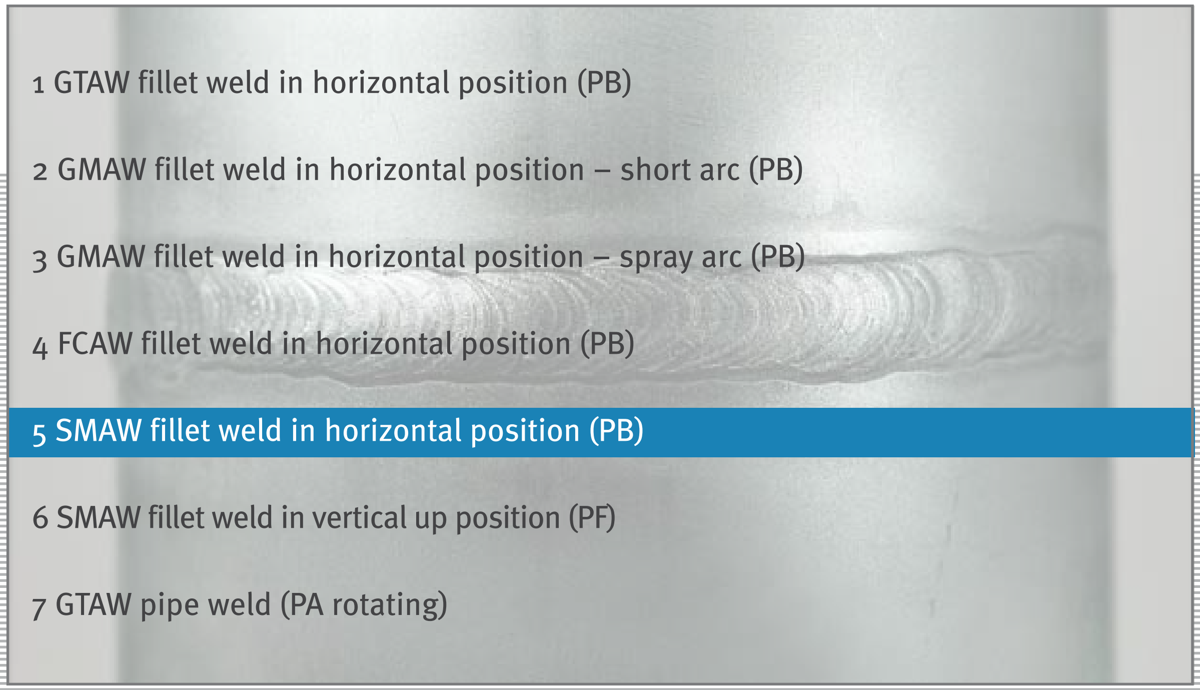

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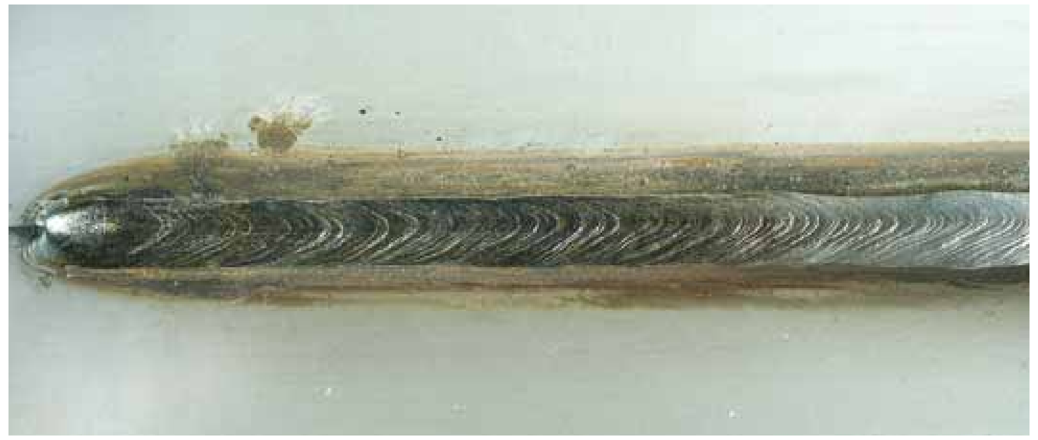
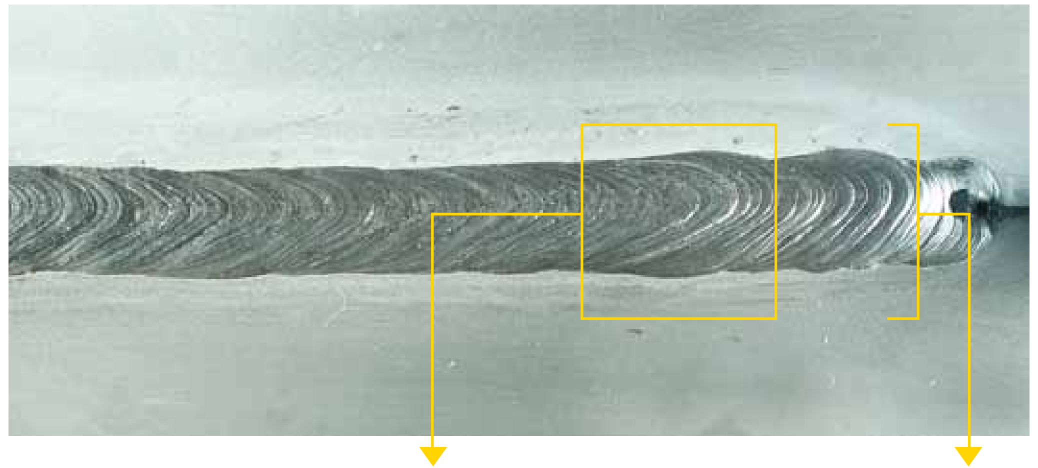
Superior

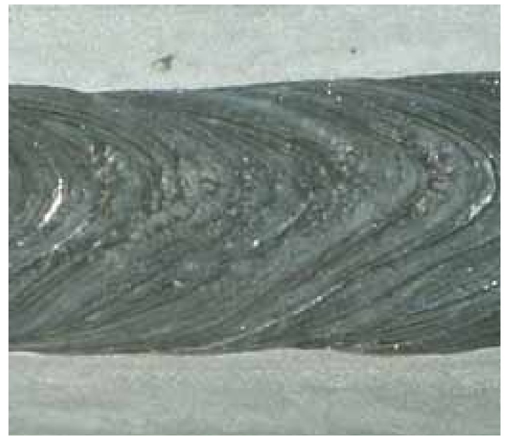


Filler: 3.25 mm, 19.9L rutile-acid coating *I*: 95 - 115 A *U*: 24 - 30 V *v*: 23 - 28 cm/min

Observations: As-welded condition. Typical rippling for SMAW. The bead is regular and has some surface oxides.



Cleaned weld (pickled)



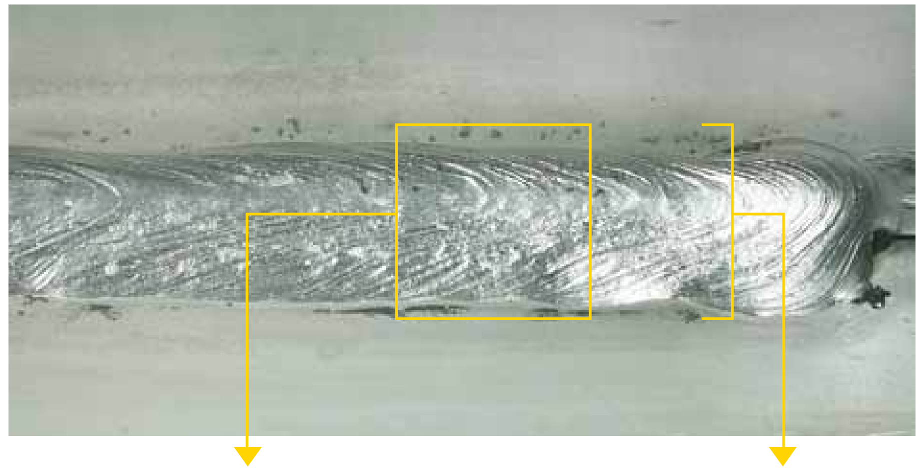
Close-up of the weld surface.

The section shows a thin, concave reinforcement. The reason could be a too high a speed.

Good

Filler: 3.25 mm, 19.9L rutile-acid coating *I*: 95 - 115 A *U*: 24 - 30 V *v*: 21 - 26 cm/min

Observations: As-welded condition. Coarse rippling, the bead has some spatter on the parent material.



Cleaned weld (pickled)

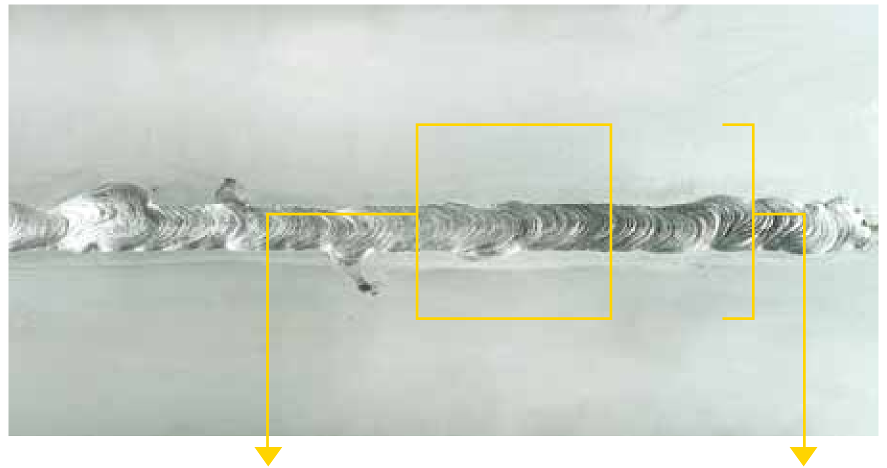
Close-up of the weld surface.

The section shows a convex/flat reinforcement.

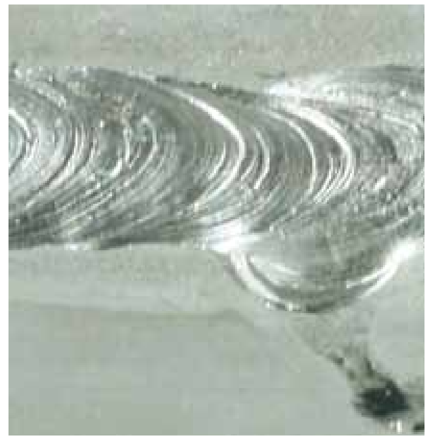
May be acceptable

Filler: 3.25 mm, 19.9L rutile-acid coating *I*: 80 - 100 A *U*: 24 - 30 V *v*: 21 - 28 cm/min

Observations: As-welded condition. Coarse rippling, the bead is irregular and has surface oxides. There is an ignition scar on the parent material and spatter.



Cleaned weld (pickled)



Close-up of the weld surface.

The section shows a slightly convex reinforcement with low penetration.
The reason could be too high a speed at the start of the weld.

Superior: The weld is technically acceptable in all but the most demanding environments, having a smooth surface with no or only fine rippling and a basically flat reinforcement.

Good: The weld is technically acceptable in most environments, but may require a mechanical finishing treatment to achieve a smoother surface.

May be acceptable: The weld may be technically acceptable in non-critical environments, especially if not visible and not exposed to a corrosive environment. It may require a mechanical finishing treatment to achieve a smoother surface.

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Shielded Metal Arc Welding (SMAW) or Manual Metal Arc (MMA), both here referred to as SMAW.

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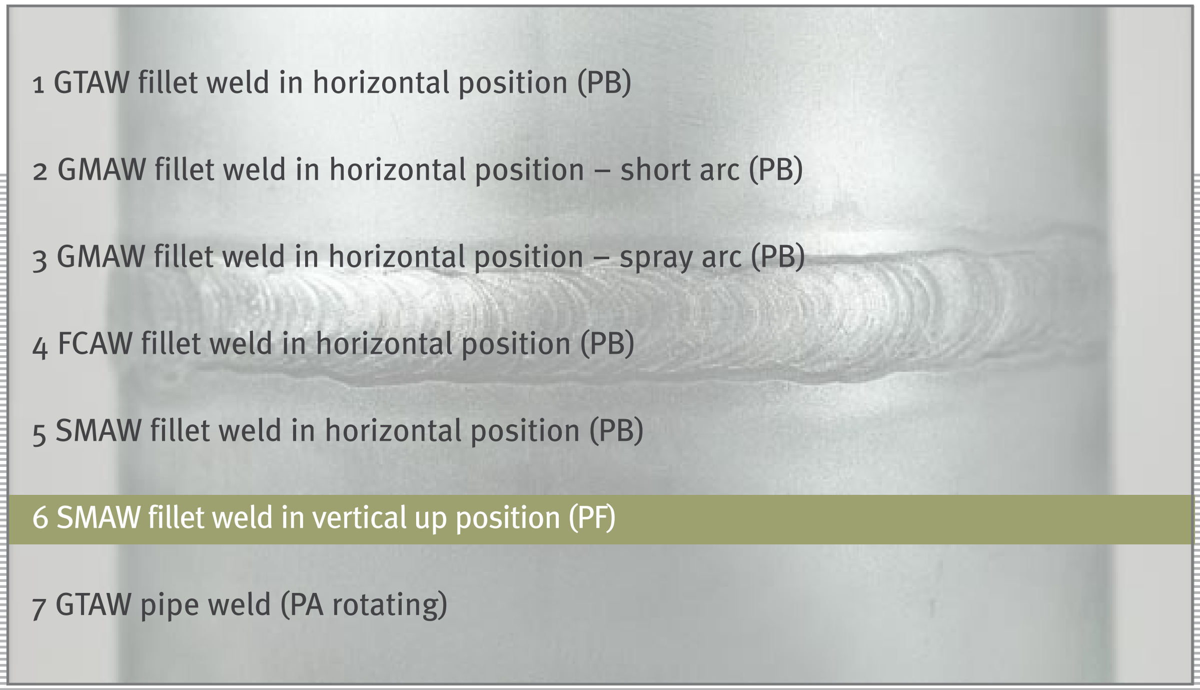

1 GTAW fillet weld in horizontal position (PB)

2 GMAW fillet weld in horizontal position – short arc (PB)

3 GMAW fillet weld in horizontal position – spray arc (PB)

4 FCAW fillet weld in horizontal position (PB)

5 SMAW fillet weld in horizontal position (PB)

6 SMAW fillet weld in vertical up position (PF)

7 GTAW pipe weld (PA rotating)

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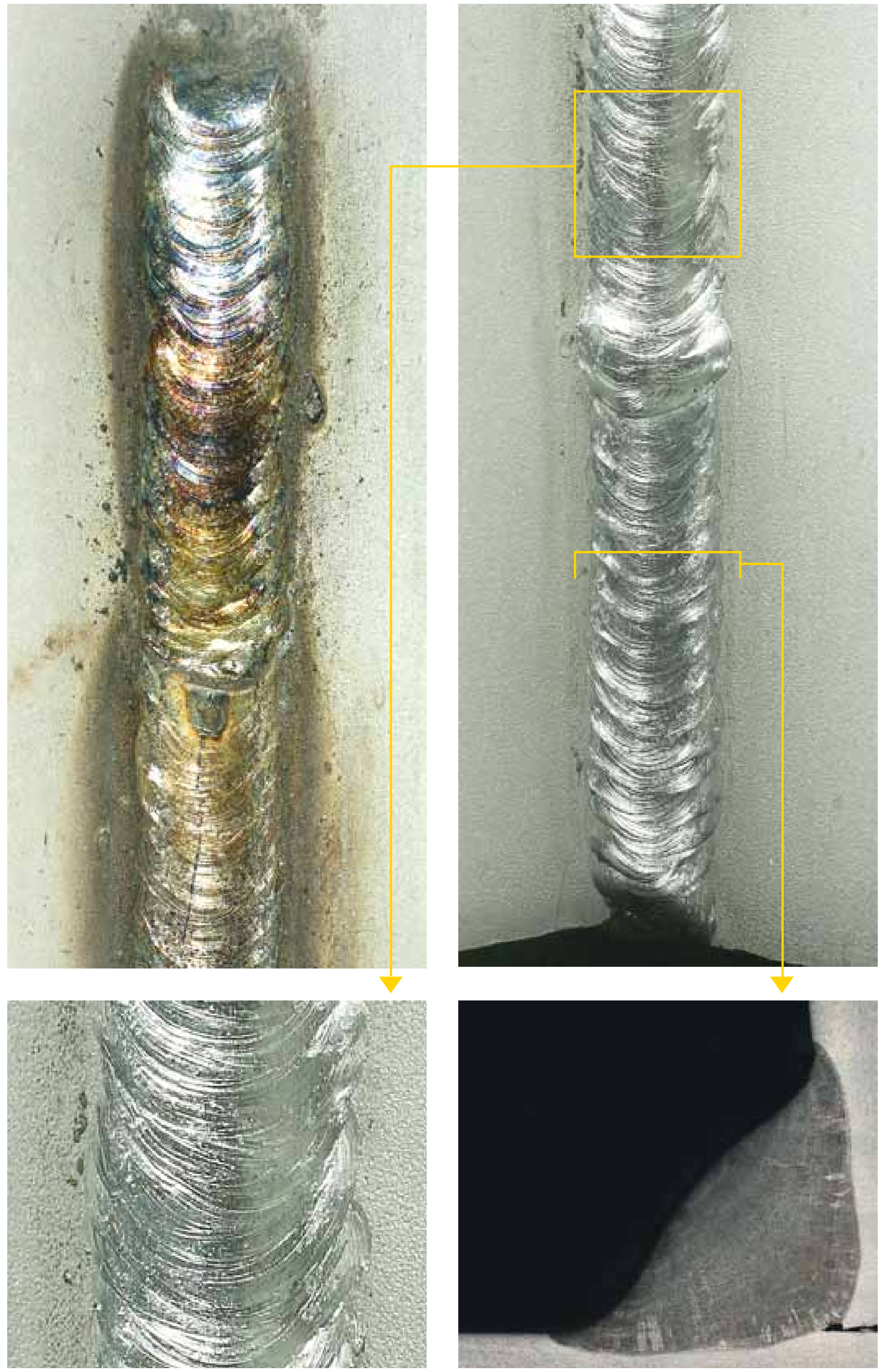
Superior



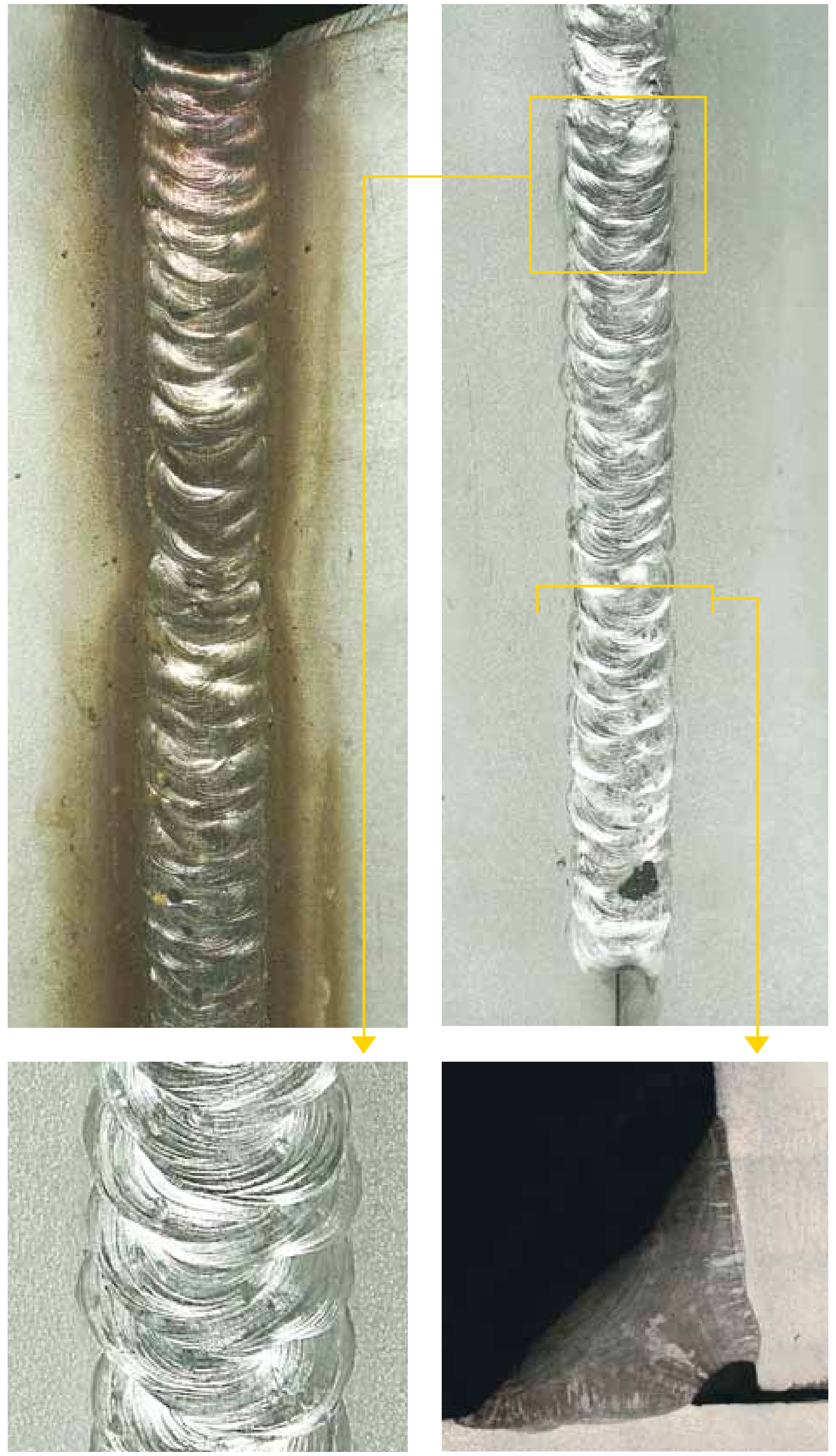
Filler: 2.5 mm,
19.9L rutile-acid
coating.
I: 60 - 70 A
U: 21 - 27 V

Observations:
As-welded condition,
the coarse rippling is
typical of this welding
position and
welding method.
The left photo shows
surface oxides.

Pickled surface (right)

The section shows a
rather convex
reinforcement.

Good



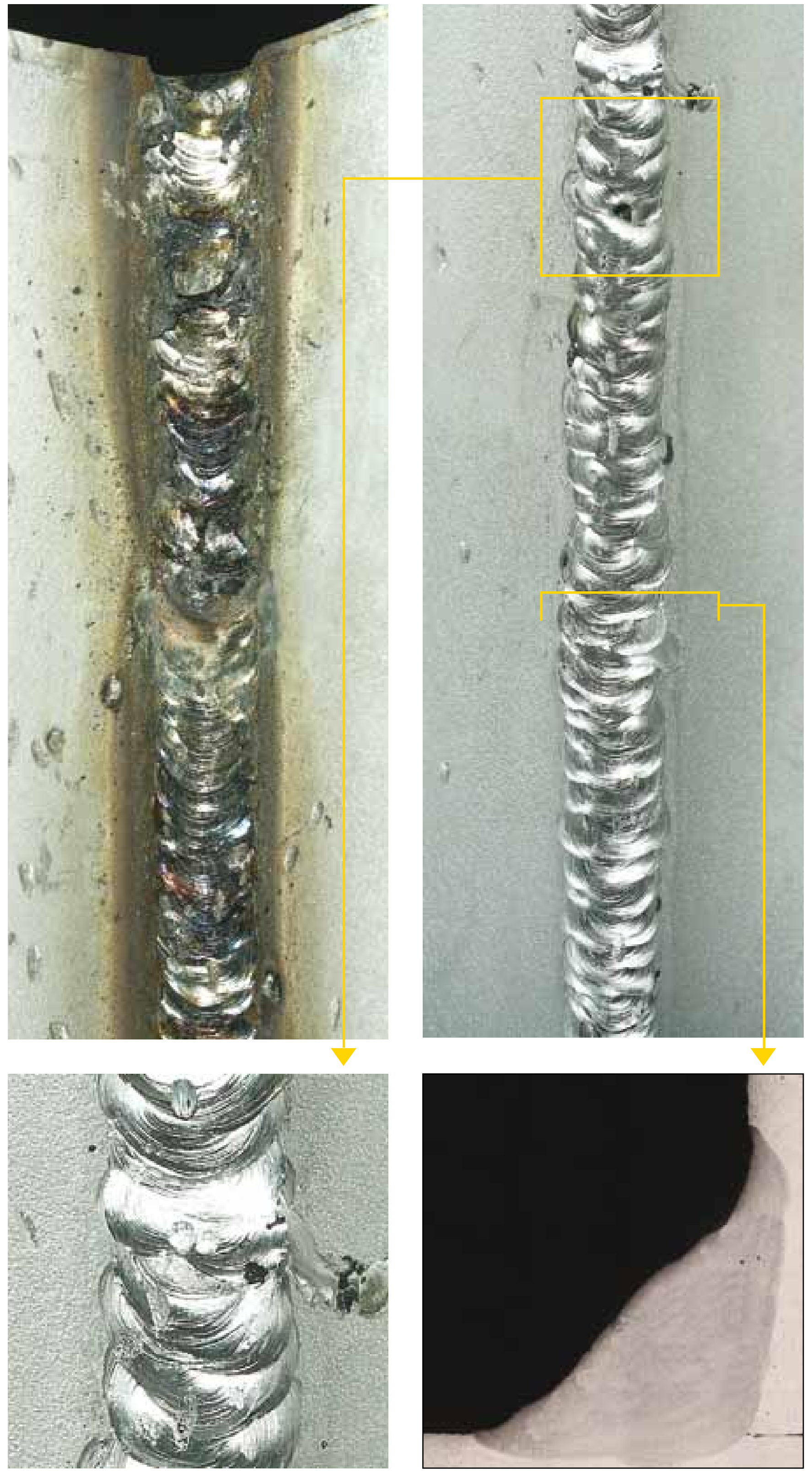
Filler: 2.5 mm,
19.9L rutile-acid
coating
I: 60 - 70 A
U: 21 - 27 V

Observations:
As-welded condition,
typical rippling.
The reason for the
coarse rippling is too
high a zigzag welding
speed.

Cleaned weld – pickled
(right)

The section shows
a flat reinforcement.
Penetration is imperfect
due to excessive
welding speed.

May be acceptable



Filler: 2.5 mm,
19.9L rutile-acid
coating
I: 60 - 70 A
U: 21 - 27 V

Observations:
As-welded condition,
very coarse rippling.
The bead is irregular
and there is heavy
spatter on the
parent material.
Too long an arc length
might be the reason
for the spatter.

Cleaned weld – pickled
(right)

The section shows a
relatively convex
reinforcement.

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Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas Welding (TIG), here referred to as GTAW.

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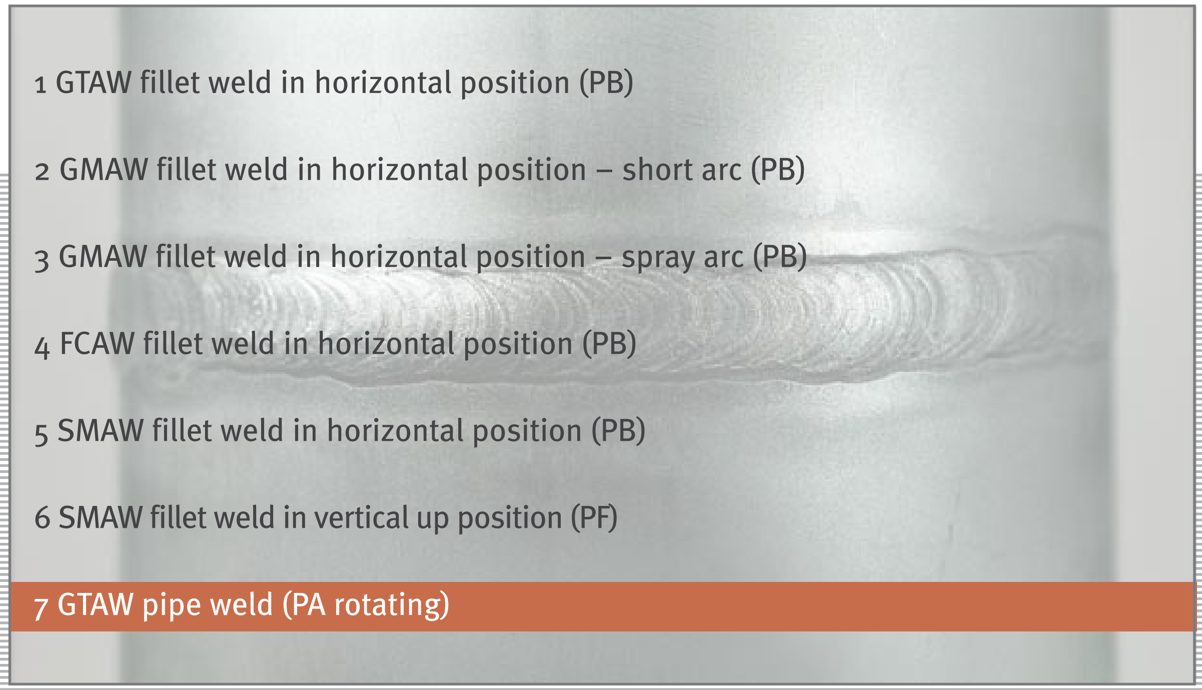

1 GTAW fillet weld in horizontal position (PB)

2 GMAW fillet weld in horizontal position – short arc (PB)

3 GMAW fillet weld in horizontal position – spray arc (PB)

4 FCAW fillet weld in horizontal position (PB)

5 SMAW fillet weld in horizontal position (PB)

6 SMAW fillet weld in vertical up position (PF)

7 GTAW pipe weld (PA rotating)

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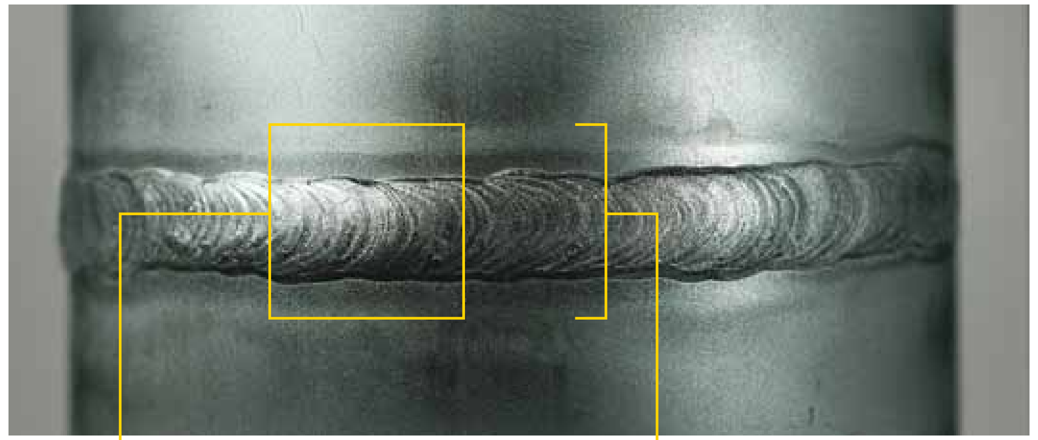
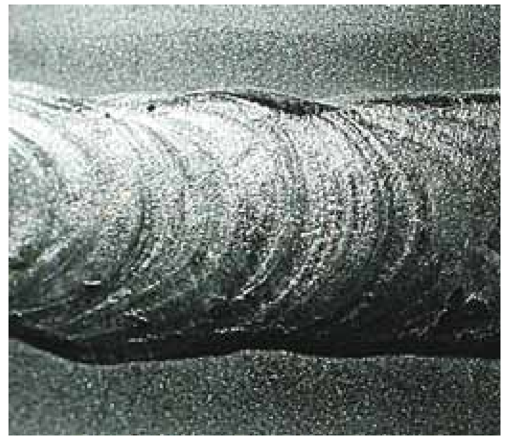
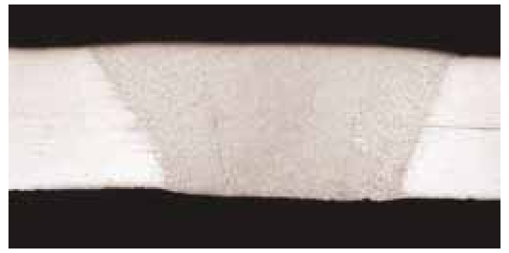
Filler: 1.6 mm, 19.9L Si wire *I*: 45 - 55 A *v*: 4 - 6 cm/min
Gas: Pure Ar *U*: 10 - 13 V
Observations: As-welded condition, very smooth, fine rippling with thin surface oxides.

Cleaned weld (pickled)



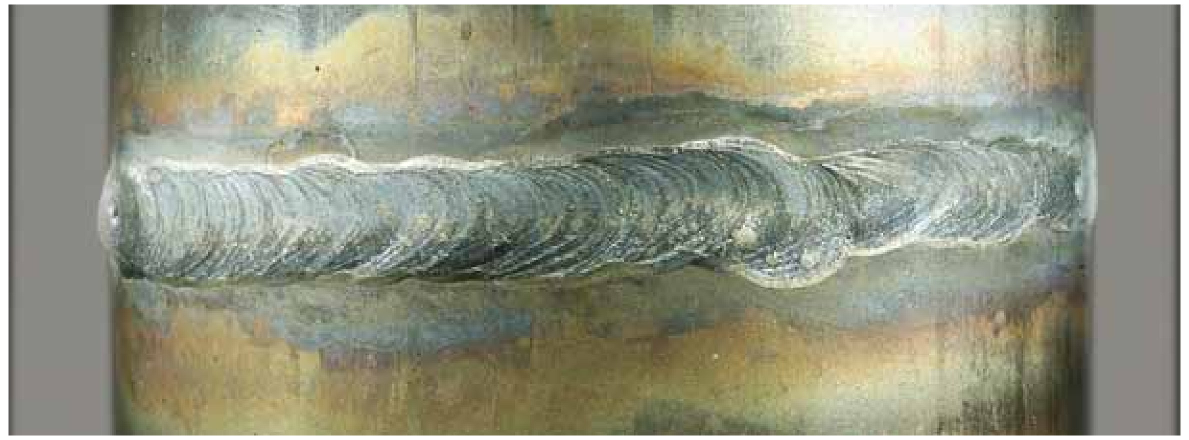


Close-up of the weld surface. Observe the slag on the upper area.



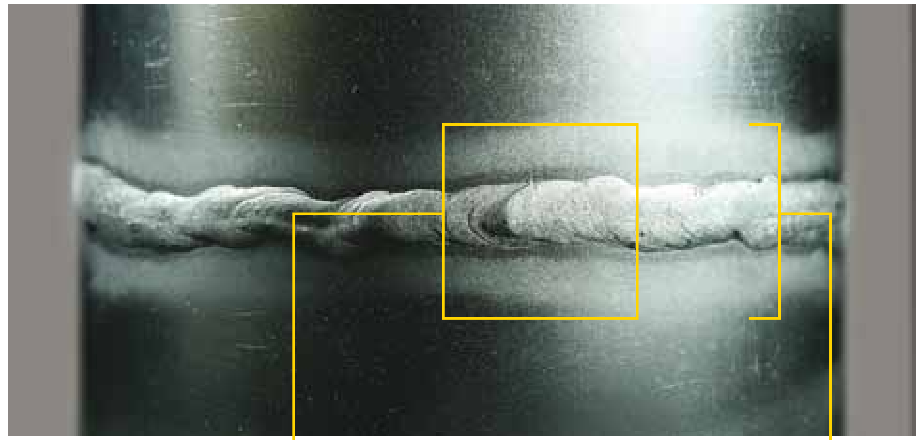
The section shows a weld with good geometrical form.

Good



Filler: 1.6 mm, 19.9L Si wire *I*: 45 - 55 A *v*: 4 - 6 cm/min
Gas: Pure Ar *U*: 10 - 13 V
Observations: As-welded condition, rather irregular bead due to variation in welding speed.

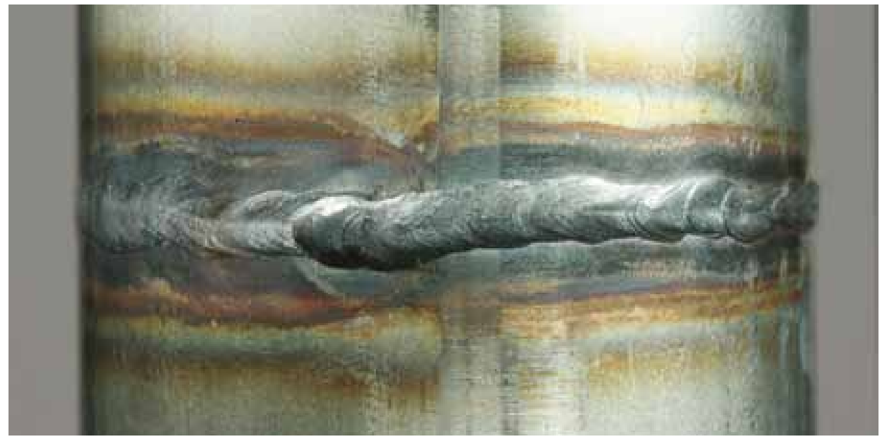
Cleaned weld (pickled)



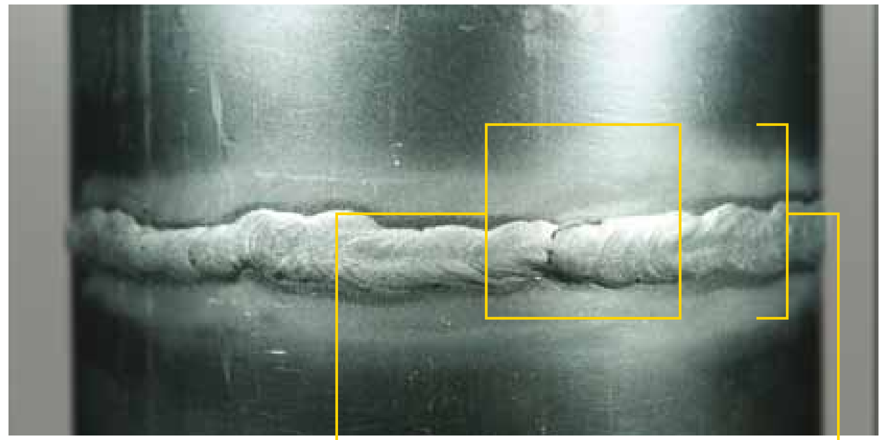
Close-up of the weld surface. Small slag particles can be observed.

The section shows a relatively large penetration resulting from a wide gap between the pipes.

May be acceptable

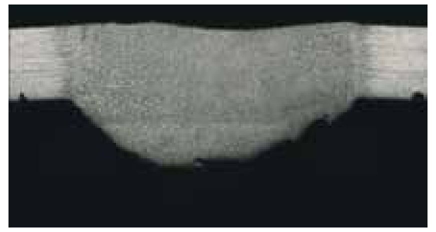


Filler: 1.6 mm, 19.9L Si wire *I*: 40 - 50 A *v*: 4 - 6 cm/min
Gas: Pure Ar *U*: 10 - 13 V
Observations: As-welded condition, irregular bead resulting from too low current.



Cleaned weld (pickled)

Close-up of the weld surface. Slag can be observed.



The section shows a weld performed without purging gas. The root penetration is too great and the root area has an irregular, spongy surface. The large penetration is due to the wide root gap.

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