
# WELDING TECHNIQUES FOR PIPELINE MANUAL WELDING

BY LAURENT BAUDOUIN AND ROBERT BISCHOF

**Welding onshore pipelines is a common operational practice involving girth welds from pipe to pipe. This process predominantly utilizes un-alloyed and low-alloyed steels, where the application of Shielded Metal Arc Welding (SMAW) with cellulosic electrodes remains prevalent. While voestalpine Böhler Welding offers an extensive range of semi-mechanized welding solutions, this article focuses on the intricacies of manual welding.**

**Our assortment of manual arc welding electrodes includes types featuring cellulosic coatings for highly efficient vertical-down welding, as well as basic low-hydrogen varieties with vertical-down or vertical-up operability.**

# WELDING TECHNIQUES FOR PIPELINE MANUAL WELDING

This comprehensive range caters to normal strength pipeline steel grades up to API X60/EN L415MB, high tensile grades up to API X100/ENL690MB, standard stainless-steel grades, duplex and super duplex stainless steel, nickel-based alloy 625, and CRA clad pipes alloy 316L, 625, and 825.

Among the basic electrode types, FOX EV (vertical-up) and BVD (vertical-down) stand out for their exceptional mechanical properties, boasting high CTOD values and ease of handling. Cellulosic electrodes are renowned for delivering excellent impact values and optimal operability even in challenging weather conditions. Rigorously tested for HIC and SSCC, they are suitable for use in sour applications

The FOX EV types are available in DrySystem™, eliminating the need for pre-use re-drying. Noteworthy within the basic stick electrode family, BVD types, designed and developed with precision, offer exceptional striking characteristics, and prevent start porosity. With a deposition rate 80–100% higher than vertical-up welding, these electrodes come in a can, eliminating the necessity for pre-use re-drying.

Subsequent pages will provide insights into a specific selection guide for our electrodes, along with troubleshooting and handling tips.

Pipeline Project: Südschiene, Austria 2010
Böhler FOX CEL 80-P

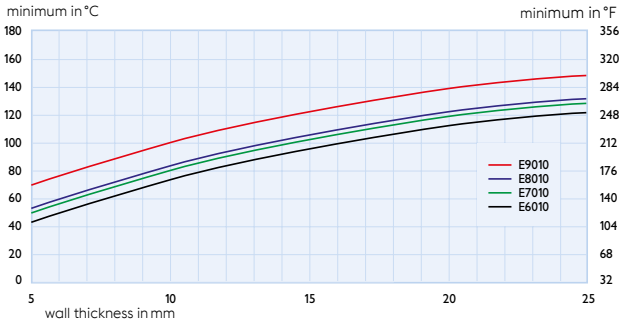
# WELDING TECHNIQUES CELLULOSIC ELECTRODES

The utilization of cellulosic electrodes for highly efficient vertical-down welding in pipeline welding poses a potential risk in the form of Hydrogen Assisted Cracking (HAC). The process involves the generation of a gas shield containing hydrogen during welding with cellulosic electrodes. While this gas shield facilitates deeper penetration and high deposition rates, meticulous attention must be given to preheating and interpass temperatures to mitigate the risk of HAC.

### Preheating and interpass temperature

To mitigate the risk of hydrogen-induced cracking, it is imperative to implement preheating measures before initiating welding and maintain an interpass temperature during the welding of individual beads. Considering the often-challenging site conditions, a recommended general preheating temperature of 150 °C (300 °F) is advised. This guideline is applicable to all wall thicknesses up to 25 mm (1") and weld metals up to class E9010 (FOX CEL 90). It is important to note that lower preheat and interpass temperatures are acceptable when dealing with the welding of thin-walled pipes.

The diagram below illustrates the minimum required preheat temperatures, which are contingent upon wall thickness and the type of electrode used. These temperature specifications are applicable to both preheating and interpass conditions.

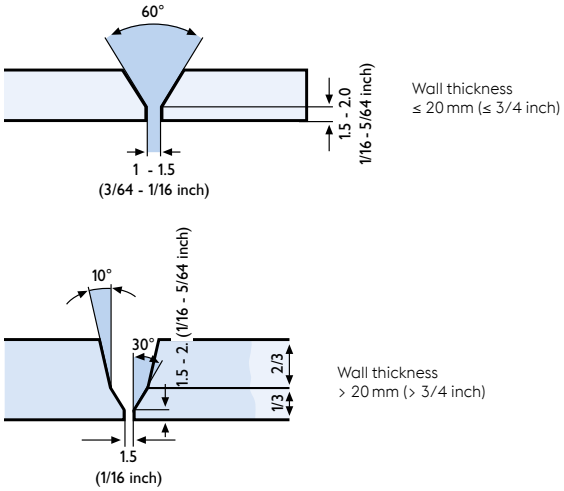



### Welding machines

Operation of cellulosic electrodes is exclusive to direct current. Welding machines used for this purpose must possess a dropping characteristic and a high open circuit voltage to ensure optimal performance.

For joint preparation, the following recommendations are suggested

### Recommended joint preparation



### Welding technique Stringer bead or root pass

The root pass stands as a pivotal element in pipe welding, demanding impeccable penetration. It is essential to carefully select the electrode diameter, travel speed, and amperage to align with the pipe diameter and wall thickness. Recommendations for electrode diameter based on pipe dimensions are as follows:

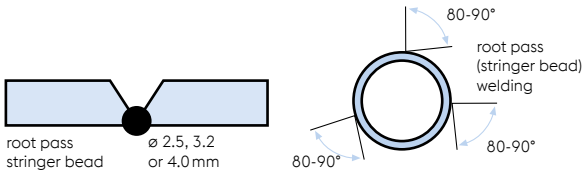
- For pipe diameters up to approximately 250 mm (10") and wall thickness up to 8 mm (5/16"), it is advised to use 3.2 mm (1/8") diameter electrodes.
- For larger sizes, employing 4 mm (5/32") diameter electrodes is recommended.

The welding process should be executed in a vertical-down direction, with the electrode maintaining good contact with both beveled plate edges. This approach ensures optimal fusion and penetration during the critical root pass, contributing to the overall integrity of the pipe weld.

| Electrode Diameter | | |
|---|---|---|
| 2.5 mm | (3/32“) | 50 - 80 A |
| 3.2 mm | (1/8“) | 80 - 100 A |
| 4.0 mm | (5/32“) | 120 - 150 A |

Line-up clamps are to be removed only upon completion of the root pass over the full circumference. In the case of welding larger diameter pipes, it is advisable to wait until the hot pass is finished before removing the line-up clamps.

During the execution of the hot pass, it is essential not to move the pipes to mitigate the risk of crack formation. This precaution ensures the stability of the welding process and contributes to the overall integrity of the weld joint.

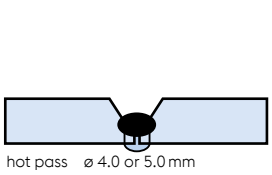


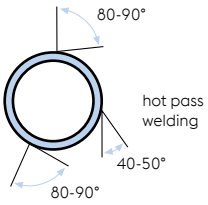
## Hot pass

To prevent lateral slag inclusions, which may manifest as "waggon tracks" in weld radiographs, it is crucial to perform slight grinding of the stringer bead. This practice helps to eliminate any potential defects and ensures the integrity of the weld.
Commonly used electrode sizes for this purpose include:

| Electrode Diameter | | |
|---|---|---|
| 3.2 mm | (1/8“) | 80 - 130 A |
| 4.0 mm | (5/32“) | 150 - 180 A |
| 5.0 mm | (3/16“) | 170 - 210 A |

Utilizing a relatively high welding current is advantageous as it promotes good penetration, allowing any remaining slag inclusions to re-melt and float to the surface. This approach also ensures thorough annealing of the root pass. It is recommended to weld the hot pass immediately after the deposition of the stringer bead, with no more than a 10-minute delay. This practice is particularly crucial for high-strength line pipe grades, helping to prevent under bead cracking in the base material. Maintaining this sequence and timing is essential for achieving optimal weld quality and integrity.




## Filler layers

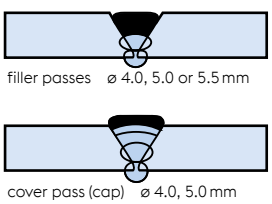
For filler pass welding on positive (+) polarity, achieving sufficiently flat and defect-free beads without undercut or slag inclusions can be ensured.

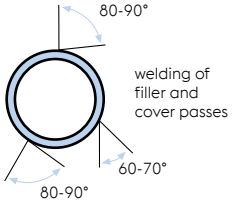
To achieve optimal results, employ a slight circular or stepping motion when applying the electrode, particularly in positions 12 to 2 o'clock, 12 to 10 o'clock, 4 to 6 o'clock, and 8 to 6 o'clock. For all other positions, utilize a weaving motion with a maximum width of two times the electrode diameter (2xØ). Adhering to these guidelines enhances the quality and appearance of the filler pass welds.

| Electrode Diameter | | |
|---|---|---|
| 3.2 mm | (1/8“) | 80 - 130 A |
| 4.0 mm | (5/32“) | 100 - 180 A |
| 5.0 mm | (3/16“) | 140 - 210 A |

**Cover pass (cap)**

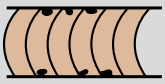
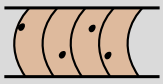
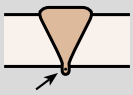
The cover passes are executed using a slight weaving motion of the electrode. It is important to ensure that the weld does not overlap the groove edge by more than 1.5 mm (1/16''). When applied correctly, the cover pass results in a weld reinforcement of approximately 1 to 2 mm (1/16''). This precision in execution contributes to the desired weld profile and overall quality of the weld joint.

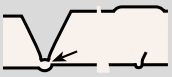
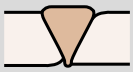
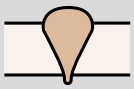
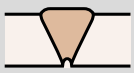
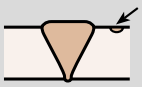



Pipeline Project: Südschiene, 2010 in Austria
Böhler FOX CEL 80-P

# TROUBLE SHOOTING

| Trouble shooting | Defects | Causes | How to avoid defects |
|---|---|---|---|
|  | Porosity<br>visible on the surface | » excessive and uncontrolled weaving<br>» base metal overheated (increased risk in thin wall pipe)<br>» moisture content of electrode coating too low | » weaving not to exceed 2 x electrode dia.<br>» choose electrode dia. and amperage as a function of pipe wall thickness<br>» keep electrodes in closed containers |
|  | Pinholes<br>not visible on the surface | » delayed deoxidation process in weld deposit<br>» moisture content in electrode<br>» coating too low or too high | » avoid excessive upsetting of metal deposited<br>» see chapter „storage“ |
|  | Piping or hollow beat almost exclusively in the reinforcement of stringer bead - therefore, practically no reduction of cross section | » root gap too narrow: degas-sing hindered by excessive dilution<br>» chemical composition of base metal: high Al levels usually favour piping formation | » root gap width not less than 1 mm<br>» the optimum root gap width of 1.5 mm should be observed for 0.040% Al steels in partic-ular. If trouble continues, use smaller electrode dia. |
|  | Slag inclusions generally occur-ing in groove faces and in stringer bead area (waggon tracks) | » insufficient cleaning in between passes<br>» stringer bead poorly ground<br>» incorrect electrode manipulation<br>» amperage too low | » clean each layer with rotary wire brush<br>» grind stringer bead sufficiently before applying hot pass<br>» improve electrode manipulation<br>» increase amperage |
|  | Lack of fusion (cold laps) | » insufficient melting of groove faces<br>» amperage too low<br>» groove faces contaminated and/or oxidized | » choose amperage to match electrode dia. and welding position<br>» clean groove faces properly |

| Trouble shooting | Defects | Causes | How to avoid defects |
|---|---|---|---|
|  | Underbead cracks almost exclusively in the hardened HAZ | » combined action of hydrogen, stresses, hardened structure | » preheat pipe material to favour hydrogen effusion, increase of heat input is also advantageous<br>» avoid moving pipe string<br>» considerable hardening is to be expected during welding of the stringer bead, therefore the hot pass must be applied immediately after its completion |
|  | Cracks caused by mechanical stresses usually in the stringer bead region | » moving of pipes during welding of stringer bead and/or before applying hot pass<br>» edge offset too large, resulting in reduced root cross section and incrceased risk of crack formation | » avoid moving pipe particularly during welding of stringer bead<br>» refer to relevant standards and specifications for maximum offset which, however, should be kept to a minimum |
|  | Undercut<br>in the region of stringer bead and cover passes | » amperage too high<br>» incorrect manipulation | » selection of correct amperage to match electrode size |
|  | Excess reinforcement | » Incorrect manipulation | » select amperage to match joint width<br>» allowance for desired cap layer weld reinforcement is to be made already when applying last filler pass (e.g. by additional layers or grinding of filler layers that are too high) |
|  | Sagging stringer bead | » amperage too high<br>» poor joint preparation, root gap<br>» too large | » select correct amperage to match joint<br>» preparation for stringer bead |
|  | Striking marks | » striking right or left of the joint causes local hardening – risk of hardening cracks | » strike arc in the groove |

# WELDING TECHNIQUES BASIC ELECTRODES FOR VERTICAL-DOWN WELDING

Vertical down BVD types stand out prominently within the basic stick electrode family. Their exceptional striking characteristics and ability to prevent start porosity are attributed to a specific design and development process. With a deposition rate significantly higher—ranging between 80% to 100%—than that of vertical up welding, these electrodes offer enhanced efficiency and productivity.

Moreover, their packaging in a can eliminates the need for pre-use re-drying, further simplifying the welding process and ensuring optimal performance straight out of the packaging. These features make Vertical down BVD types a standout choice for welding applications where high-quality results and streamlined operations are paramount.

**Combined technology with cellulosic and basic electrodes**

When utilizing basic vertical-down electrodes (BVD) for root passes, there is flexibility in the choice of electrodes for the root pass itself. Root passes can be effectively welded using either cellulosic or basic vertical-up electrodes.

In cases where root passes are welded with cellulosic electrodes in the vertical-down position, it is advisable to continue the consistency in electrode choice for the subsequent hot passes. Therefore, the preference is to weld hot passes with cellulosic electrodes as well. This ensures a seamless welding process and maintains uniformity in the characteristics of the weld throughout its different passes.

**Preheating and interpass temperature**

The interpass temperature plays a significant role in influencing the metallurgical processes occurring during solidification and cooling, thereby impacting the mechanical properties of the basic vertical down weld metal. To maintain optimal results, it is recommended to keep the interpass temperature within the range of 100 °C to 200 °C (210 °F to 392 °F) throughout the welding process.

It is important to note that joint preparation, preheating, and interpass considerations for cellulosic electrodes should align with the guidelines provided in the section for Cellulosic electrodes. Adhering to these specifications ensures consistency and enhances the overall quality of the welding process.

**Welding machines**

Indeed, basic vertical-down electrodes are designed to operate exclusively on direct current (DC). To ensure optimal performance, it is imperative that welding machines used with these electrodes possess specific characteristics. Specifically, the welding machines should feature a dropping characteristic and maintain a high open circuit voltage.
The dropping characteristic is essential for facilitating smooth and controlled welding operations. High open circuit voltage ensures effective arc initiation and stability when using basic vertical-down electrodes. These machine attributes contribute to the overall efficiency and success of the welding process.

**Handling guideline for using of Böhler Basic Vertical Down Electrodes**

FOX BVD electrodes are equipped with an active striking end, emphasizing the importance of initiating the arc effectively. To prevent the occurrence of starting porosity, it is recommended not to restart these electrodes once the welding process has commenced. This guidance is aimed at ensuring a seamless and high-quality welding operation, as restarting the electrode can introduce complications such as porosity, which may negatively impact the integrity of the weld.

The proper technique for striking the arc with FOX BVD electrodes is crucial for achieving a high-quality weld. Follow these guidelines:

- **Strike Arc Only in the Groove:**
  Initiate the arc specifically within the groove to ensure proper welding conditions.
- **Maintain a Short Arc During Start:**
  Keep a short arc during the start and avoid raising the arc length. A long arc can result in porosity.
- **Avoid Using the Same Starting Technique as Vertical Up Types:**
  Do not use the same starting technique as with basic vertical up types. Always start on the end crater from the last run and avoid starting in front and going back.
- **Electrode Angle:**
  Maintain an electrode angle of 80-90° in positions from 12-1 and 5-6, and 60-80° in all other positions. A too flat angle in the top position can lead to increased spattering.
- **Influence of Welding Machine Characteristics:**
  The number of spatters can be influenced by the welding machine characteristics. If available, slightly adjust the arc force button on the machine.
- **Avoid Starting Together at 12 O'clock Position (Staggering starts)**
  Never start together at the 12 o'clock position, as this is typically done with cellulosic types. Turbulences during starting can lead to porosity with basic types. Stop at the 6 o'clock position.
- **Use Maximum Recommended Amperage:**
  In positions from 12 to ~ 4 o'clock as indicated on the label of the tin, use the maximum recommended amperage. Only reduce the amps in the overhead position. Too low amperage can result in lack of fusion and slag inclusion.

Indeed, protecting the welding station against wind is crucial, and basic types are known to be more sensitive to wind compared to cellulosic types. Wind can significantly impact the appearance of porosity in the weld. Here are some additional pieces of advice on handling to ensure optimal welding conditions. It is essential to enclose the welding area, especially around the pipe, to shield it from the effects of wind. This includes closing the tent securely, ensuring minimal air movement around the welding site. Address potential wind entry points, including the bottom of the tent. Ensure a secure closure to prevent wind from disrupting the welding process.

### Filler passes

These passes are executed with 3.2 mm, 4.0 mm and 4.5 mm dia. electrodes, depending upon pipe thickness.

| Electrode Diameter | | |
|---|---|---|
| 3.2 mm | (1/8“) | 110 - 160 A |
| 4.0 mm | (5/32“) | 180 - 210 A |
| 4.5 mm | (3/16“) | 200 - 240 A |

The use of high amperage is essential to ensure sufficient penetration and maintain satisfactory process economy during welding. Additionally, incorporating a slight weaving motion is always recommended, as this helps prevent short-circuiting of the arc and contributes to a more controlled and stable welding process.
For welding heavy-wall pipes, it is advisable to deposit two to three beads side by side. Before applying the next bead, it is crucial to remove all slag, ensuring the integrity of the weld. Keeping the arc as short as possible further enhances control and precision during the welding operation, contributing to the overall quality of the weld joint.

### Cap Layer

The cap is deposited with a slight weaving technique, with a maximum weave of twice the electrode diameter.
Recommended amperages:

| Electrode Diameter | | |
|---|---|---|
| 3.2 mm | (1/8“) | 110 - 160 A |
| 4.0 mm | (5/32“) | 180 - 210 A |

**Storage of basic electrodes**

Storage and handling conditions are critical factors in maintaining the quality of basic electrodes. Here are guidelines for handling based on storage conditions:

- **Sealed Cans:** Basic electrodes stored in sealed cans do not require rebaking. The sealed environment helps preserve their quality.
- **Opened Cans:** Once a can has been opened, electrodes can be used for up to 8 hours. Beyond this time frame, rebaking may be necessary to maintain optimal performance.
- **Unsealed or Damaged Cans:** If electrodes are taken from unsealed, damaged cans, or those stored openly for more than 8 hours, it is recommended to rebake them. The rebaking process should be carried out at a temperature between 300 - 350 °C (570 - 660 °F) for a minimum of two hours and a maximum of ten hours.
- **High Humidity Conditions:** In environments with a relative air humidity of more than 70%, it is advisable to use heated quivers to store electrodes before use. Maintain a temperature range of 120 - 200 °C (248 - 400 °F) to mitigate the impact of high humidity on electrode performance.

Adhering to these storage and handling guidelines ensures the electrodes retain their quality and integrity, leading to successful welding outcomes.

# SUMMARY: CELLULOSIC AND BASIC VERTICAL DOWN (BVD) ELECTRODES

Cellulosic and Basic Vertical Down (BVD) electrodes play crucial roles in welding applications, each with distinct characteristics and recommended techniques. Cellulosic electrodes, known for deep penetration and high deposition rates, are suitable for various pipe welding scenarios. However, their sensitivity to wind and specific handling requirements necessitates careful consideration.
On the other hand, Basic Vertical Down (BVD) electrodes excel in providing exceptional striking characteristics and avoiding start porosity. The deposition rate with BVD types surpasses that of vertical up welding, enhancing efficiency. Welders should pay attention to striking techniques, electrode angles, and the impact of wind conditions on the welding station.
Common recommendations for both types include the importance of proper storage and handling. Opened electrode cans have specific usage timelines, and rebaking may be required in certain storage conditions.

In conclusion, choosing the right electrode type depends on the specific welding requirements and conditions. By following the recommended techniques and handling guidelines, welders can achieve optimal results, ensuring weld integrity and overall quality.

## LAURENT BAUDOUIN

GLOBAL INDUSTRY KEY ACCOUNT MANAGER PIPELINE

With a rich background spanning 24 years in the welding industry, I have garnered diverse experience, dedicating nearly 17 years to various roles in pipeline welding services. My journey evolved from a field welding engineer to the position of R&D Welding Manager. Currently, I hold the position of Global Key Account Pipeline Manager, overseeing crucial accounts on a global scale.
My primary focus is to leverage my extensive pipeline welding expertise in supporting our global sales teams for this product range. I derive great satisfaction from visiting key customers, aiming to gather valuable feedback.
By seamlessly integrating our unparalleled portfolio components into welding solutions and applying our unique metallurgical and application know-how, my objective is to deploy effective value-selling skills in identifying and engaging potential customers.

## ROBERT BISCHOF

GLOBAL APPLICATION WELDING SOLUTIONS

I have been working for voestalpine Böhler Welding since 1976.
My job is to provide the best technical support to our customers. I look after customers all over the world and try to provide them with the best and fastest solutions. I also give seminars and lectures for the Welding Academy, sharing my knowledge and experience. In addition, I carry out pipeline investigations and advise our customers on welding parameters and application solutions.

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We are a leader in the welding industry with over 100 years of experience, more than 50 subsidiaries and more than 4,000 distribution partners around the world. Our extensive product portfolio and welding expertise combined with our global presence guarantees we are close when you need us. Having a profound understanding of your needs enables us to solve your demanding challenges with Full Welding Solutions - perfectly synchronized and as unique as your company.

böhler welding by voestalpine · utp by voestalpine · fontargen brazing by voestalpine

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