Yan & Partners

FIELD GUIDE · 實務指南 · 2026 EDITION

Underwater welding & oxy-arc cutting

水下直流電弧焊接及電弧氧切割

Practical know-how from 25+ years of marine work in Hong Kong, in English and Traditional Chinese.
香港海事工程逾25年的實戰經驗，中英對照。

Yan & Partners Engineering Co., Ltd. · 恩泊利工程有限公司

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FOREWORD · 序言

Diving work is essential in a coastal city like Hong Kong. A commercial diver needs more than diving skills: they also need a working knowledge of construction and the trades around it, so training asks far more of them than most jobs do.

Training matters, but real skill is built on site. Few divers get to do every kind of task, so experience across the industry is uneven. We hope divers and contractors will keep sharing what they learn, to close those gaps and make the whole industry safer and more efficient.

Since 1999, Yan & Partners has put a great deal of time into underwater welding and cutting. This guide collects what we have learned in the field, as a free resource for everyone in the trade.

潛水作業是沿海城市不可或缺的專業工種。除了潛水技術，從業員還需要深入了解建築及相關行業的知識，因此專業潛水員的入職培訓要求遠高於其他行業。

培訓固然重要，但實務經驗才是專業技能的基石。並非每位潛水員都有機會接觸所有工種，因此業界的技能水平並不平均。我們期望同業透過交流、討論和回饋，分享各自的實務經驗，彌合知識差距，提升整體技術水平，令業界更安全、更有效率。

恩泊利（Yan & Partners）自1999年起在水下焊接及切割方面投入了大量時間，累積了寶貴的經驗。我們將這些實戰心得整理成這份指南，免費供業界參考。

BEFORE YOU START · 開始之前

Wet welding is normally used for temporary or emergency work, not permanent structures. Water carries heat away far faster and less evenly than air, which weakens the weld. Permanent structural welds need an approved procedure and a qualified welder (for example to AWS D3.6M), or dry habitat welding.

一般而言，水下濕式焊接多用於臨時或緊急工程，而非永久結構。水的散熱速度遠比空氣快而且不均勻，會令焊道強度減弱。永久結構的焊接需要經批核的焊接程序及合資格焊工（例如按 AWS D3.6M 標準），或採用乾式艙室焊接。

A Wet welding 水下濕式焊接 01–13

B Oxy-arc cutting 水下電弧氧切割 14–17

! Safety essentials 安全要點 —

PART A

Wet welding

水下濕式焊接

DC arc welding with coated electrodes · 直流電弧焊接

01 Choose fillet or lap-fillet joints

選用角焊或疊角焊

A fillet joint loses heat from the weld pool more slowly, so the diver can control the weld more easily, and test coupons show higher tensile strength.

角焊的熔池散熱較慢，潛水員較容易控制焊接，焊道切片的拉力測試強度亦較高。

02 Use DC, electrode negative (straight polarity)

使用直流電，焊鉗接負極（直流正接）

Connect the electrode holder to the negative terminal. The arc length stays steadier, arc blow is reduced, and the holder corrodes far less by electrolysis. Never use AC underwater.

焊鉗應連接直流焊機的負極。這樣電弧長度更穩定，偏弧現象減少，焊鉗亦較不易因電解而損耗。水下絕對不可使用交流電。

03 Keep beads narrow and the arc short

焊道要細，弧長要短

Hold the electrode close to the work. The flux coating burns to form a gas shield that protects the weld pool, but underwater the gas floats away quickly and the shield is weaker. A wide bead lets the pool collapse and spoils the weld; a short arc keeps the shield where it is needed.

焊條應貼近焊件。焊條藥皮燃燒時會產生氣幕保護熔池，但在水中氣體受浮力影響很快上升，保護效果減弱。焊道過闊會令熔池塌陷，影響焊道質素；短弧能讓氣幕集中保護熔池。

04 Use electrodes no thicker than 4.6 mm

焊條直徑不應大於 4.6 毫米

A thicker rod pushes more current through the same contact, which heats up and damages the holder. A wide bead or large pool cools unevenly, and if travel speed can't keep up, quality drops. Also check the output limit of your DC welding machine.

焊條越粗，同一接觸面要通過的電流越大，電阻發熱令焊鉗容易損壞。焊道過闊或熔池過大，冷卻不均，走焊速度跟不上便會影響質素。亦要考慮直流焊機的最大輸出功率。

05 Keep the welding lens small, well fitted and light-tight

焊接鏡片要小巧、貼合面罩、不可漏光

A compact lens that fits snugly on the mask is not pushed around by the current, so both hands stay steady for balance. No light may leak around the dark glass. Most underwater welding happens in near darkness: the sudden glare makes the pupils contract hard and can cause arc eye (flash burn) and temporary blindness.

鏡片細小並貼合面罩，才不會受水流衝擊，雙手可保持穩定平衡。除黑色鏡片外，絕不可有光線洩漏。水下焊接大多在黑暗中進行，強烈弧光會令瞳孔急劇收縮，可引致電光性眼炎及短暫失明。

06 Wear a full-face mask or helmet with a non-conductive regulator

使用全面罩或頭盔，配合不導電的呼吸調節器

You work very close to the arc, so exposed skin is easily burned. Metal in a live, conductive medium corrodes by electrolysis, shortening its life, and when the electrode comes near a metal regulator the diver can feel a strong shock.

水下焊接需要近距離觀察電弧，皮膚外露容易受傷。金屬在通電的介質中會發生電解，縮短器材壽命；焊條靠近金屬呼吸調節器時，潛水員更會感到強烈電擊。

07 Choose insulated rubber gloves a size larger

選用較大尺碼的絕緣膠手套

You must be able to hold the electrode holder easily. Tight gloves tire the hand quickly and the weld suffers. Check gloves for holes and tears before every dive.

潛水員要能輕鬆握持焊鉗。手套太緊會令手部很快疲勞，影響施工質素。每次下水前都要檢查手套有否破損。

08 Don't coil the welding leads

避免焊線打圈

Current running through a coiled lead builds a magnetic field that disturbs the arc (arc blow) and makes the current unstable. Run the leads as straight as you can.

電流通過打圈的焊線會產生磁場，干擾電弧（偏弧）並令電流不穩定。焊線應盡量拉直。

09 Use a holder with a full-length grip and a large contact area

焊鉗把手要夠長，接觸面要夠大

Like a pistol grip, an ergonomic handle lets you swing the holder easily and makes changing rods simpler. For cutting, the oxygen valve can be fitted neatly on the handle. Holding the torch head itself is neither comfortable nor efficient. A larger conductor also takes longer to be eaten away by electrolysis.

就像手槍把手，符合人體工學的設計能讓焊接時輕鬆擺動焊鉗，更換焊條亦更容易。進行水下切割時，更可把純氧閥門安裝在把手上。手持焊槍頭焊接既不輕鬆亦沒有效率。導體越大，被電解損耗所需的時間越長。

10 Wrap electrodes thinly and tightly, and seal the tip

焊條膠布要拉薄纏緊，連同焊條頭一併封好

Stretch the tape thin, wrap it tight with as little overlap as possible, and seal the rod end too. In the heat of the arc the flux and tape vaporise together; thick tape burns unevenly and hides the bead. Poorly wrapped rods absorb moisture in air, and the flux dissolves if they stay in water too long. A sealed tip keeps the flux dry until the last moment: just tap the tip lightly before striking the arc.

膠布應拉薄、纏緊，疊口越少越好，並連同焊條頭一併封好。在高溫電弧下，藥皮與膠布會一同氣化；膠布太厚會氣化不均，阻礙觀察焊道。焊條包得不好，在空氣中會受潮，在水中太久藥皮亦會溶解。封好焊條頭可保存藥皮直至施工前一刻，起弧前輕敲焊條頭便可開始焊接。

11 Flat position (平火): weld right to left, watching the joint ahead

平火：由右至左施焊，視線看著焊縫

With the holder in your right hand, weld from right to left and keep your eyes on the joint ahead, not the finished bead. Hold the electrode at less than 90° to the work, adjusting to your own technique. The arc light lets you see the joint and pool clearly, and rising gas doesn't block your view. If you drift off the joint, move forward 3–5 mm, then come back into the pool and build up. This cleans the joint, lets the pool penetrate properly, and gives a smoother, stronger bead. A good bead finishes with slag still on it.

右手持焊鉗，由焊件右方向左方施焊，視線看著前方的焊縫，而不是已完成的焊道。焊條與焊件角度小於 90 度，按個人技巧調整。透過弧光可清楚看到焊縫和熔池，不會被上升的氣體阻礙視線。走焊時若偏離焊縫，可先向前移 3–5 毫米，再退回熔池積焊，好處是清潔焊縫、令熔池正常滲透，焊道更平滑、強度更高。完成的焊道應有焊皮覆蓋。

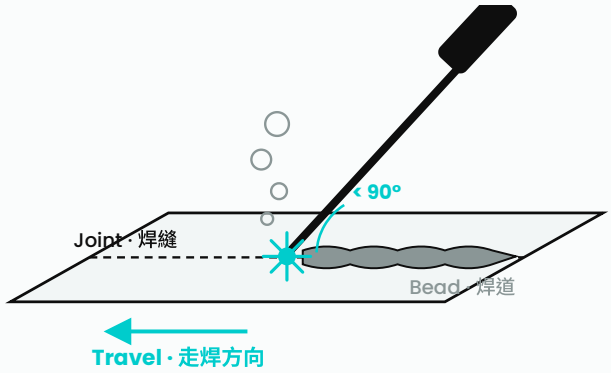


Fig. 1 — Flat position, right to left · 圖一：平火，由右至左

12 Vertical position (企火): narrow joints downward, wide joints upward

企火：窄焊縫由上向下，闊焊縫由下向上

Once the arc is struck, the flux gives off gas that keeps the pool stable, but underwater the gas rises. Tilt the electrode about 45° upward and weld downward, so the molten metal and slag cool under the gas shield. The bead should finish with slag on the surface, and your eyes should stay between the pool and the joint, clear of the rising gas. If the joint is too wide, turn the electrode to 90° and weave upward to fill it.

起弧後，焊藥產生的保護氣體可穩定熔池，但在水中氣體會向上浮。將焊條微微向上傾斜約 45 度，然後向下走焊，讓焊水和焊皮在氣膜遮蔽下一同冷卻，效果最好。完成的焊道表面應有焊皮。視線應集中在熔池與焊縫之間，不受上升氣體影響。若焊縫太闊，焊條要改為 90 度，由下向上織焊填補。

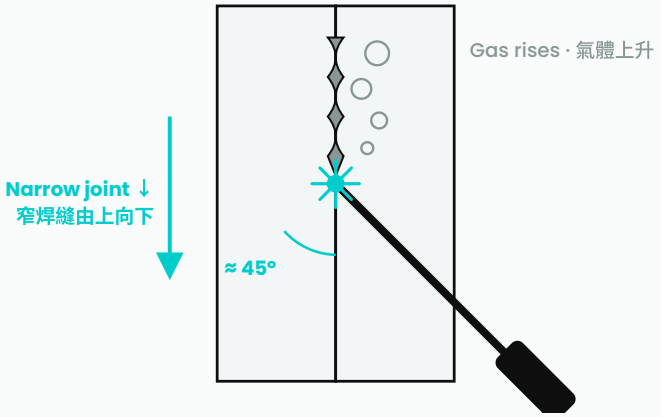


Fig. 2 — Vertical position, downhill for narrow joints · 圖二：企火，窄焊縫由上向下

13 Horizontal position (橫火)

橫火

Horizontal welding combines the techniques of the flat and vertical positions above.

橫火結合了平火和企火的技巧。

PART B

Oxy-arc cutting

水下電弧氧切割

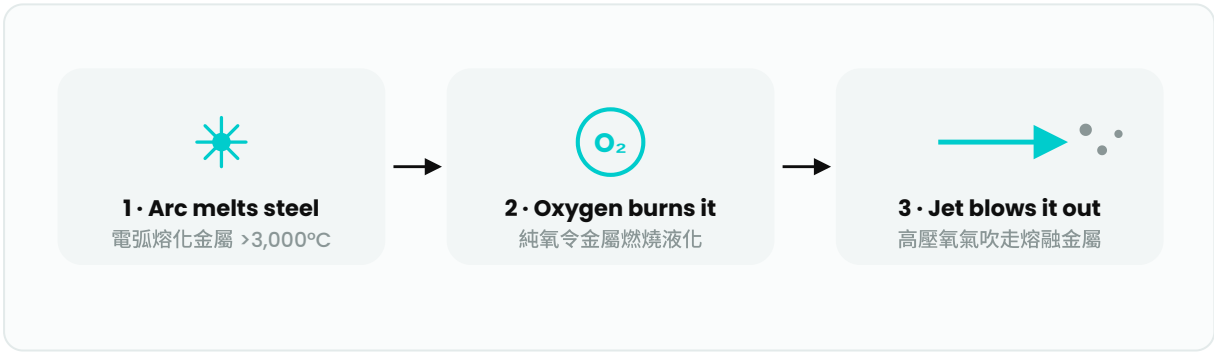
Cutting steel with an arc and pure oxygen · 以電弧及純氧切割鋼材

14 How underwater cutting works

水下切割的原理

An electric arc heats the steel to over 3,000 °C until the metal at the cut turns molten. A jet of pure oxygen through the hollow cutting rod then burns (oxidises) the hot metal. This reaction releases a great deal of extra heat and liquefies the metal completely, and the pressure of the oxygen jet blows it out of the cut, separating the piece.

切割電弧產生逾 3,000 度高溫，令切口的金屬熔化成糊狀。純氧經中空切割棒噴出，令高溫金屬燃燒（氧化），反應釋放大量額外熱能，使金屬完全液化；再利用高壓純氧的噴射力，把液化金屬從切口吹走，把工件切斷。



15 Designing a better welding and cutting handle
改良水下焊接手柄的設計要點

• Make the torch head from heat-resistant material.	槍頭要使用耐高溫物料。
• Make the handle from a material that won't crack or shatter.	把手要使用不易碎裂的物料。
• The head and handle should screw together and apart easily.	槍頭與把手之間要容易旋緊及鬆開。
• Size the handle so that, with the ball valve fitted, you can open and close it with one hand.	把手長度以安裝球閥後可單手開關為準。
• After connecting the welding lead, wrap a layer of ordinary tape before the 3M tape, so it is easy to replace later.	接駁焊接線後，先用普通膠布打底，再包 3M 膠布，方便日後更換。
• Never clamp the oxygen hose onto the cutting rod with a metal hose clip: it corrodes by electrolysis and is hard to pull off. A rubber band works better.	氧氣喉切勿用金屬喉碼鎖緊切割棒，容易電解而且難以拔出，用橡皮圈較為實際。

Our improved underwater welding handle
我們改良的水下焊接手柄
yanpartners.com/projects/underwater-welding-handle
Chinese · 中文：add ?lang=zh-hant

16 Cutting a caisson
沉箱切割法

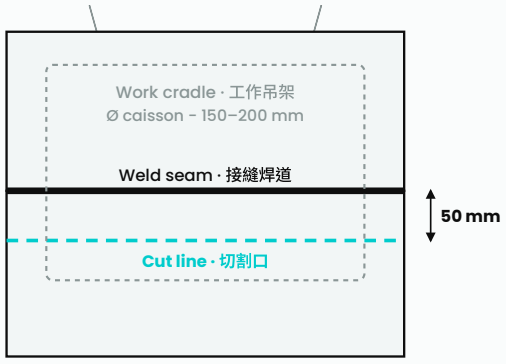


Fig. 3 — Cut 50 mm below the seam · 圖三：於焊道下 50 毫米切割

a Pre-fabricate a circular work cradle 150–200 mm smaller in diameter than the caisson.

預製圓形工作吊架，直徑比沉箱小 150–200 毫米。

b Tie the cutting rods and torch to the cradle so the diver can reach them easily.

將切割棒和焊槍繫在工作吊架上，方便潛水員取用。

c Once the cutting depth is set, have the cradle lowered to it. Find the weld seam between caisson segments and mark the cut line 50 mm below it. Over comms, have the cradle adjusted up or down to your most comfortable working height. Before striking the arc, touch the cut point with your left hand, aim at it and crack the oxygen valve open with one hand: the small flow purges seawater from the rod without blowing the oxygen hose off. When you feel bubbles leaving the rod, open the valve further, let the jet hit your left hand, then take the hand away and strike the arc. Cut at a steady speed, the rod at less than 90°, with a constant forward flicking motion. Listen: an even, steady sound is the best sign of a clean through-cut when you can't see the light.

確定切割深度後，控制吊架下降至該深度，找出沉箱之間的接縫焊道，把焊道下 50 毫米定為切割口。用通話器指示吊架上下微調，把切割姿勢調至最舒適的高度。起弧前用左手觸摸切割口，對準後單手輕微開啟純氧閥，以少量氧氣迫走切割棒內的海水，好處是不會把氧氣喉彈開。感覺到切割棒有氣泡逸出時才開大氣閥，移動切割棒讓氣流觸及左手，然後移開左手起弧切割。切割時保持均速，角度小於 90 度，並不停向前挑動。細心聆聽切割聲音是否一致，這是看不見光時判斷切道是否通透的最好方法。

d Stay at that comfortable height until the cut is finished. When changing rods, don't move: you can then feel the kerf and carry on. Keeping the cut 50 mm below the weld seam gives a flatter kerf that is easier to break, and saves rods and time.

保持最舒適的高度直至完成切割。更換切割棒時保持原位不動，便可摸到切割道並延續切割。切割道保持在焊道下 50 毫米，可得到較平直、較容易絞斷的切割道，並節省切割棒和時間。

FIELD TIP · 要訣

Don't stare at the arc spot. Look just ahead of it — the same trick as drawing a straight line with your eyes closed. Check behind the cut from time to time: visibility permitting (and with soil behind the wall), you will see a dull glow of flame about 100 mm long. If it stays steady, the cut is through and clean.

切割時眼睛不要盯著切割光點，而是看著切割點前方，這是「閉眼畫直線」的最好方法。同時不時觀察切割點後方：能見度許可的話（背面是泥時適用），會見到一段約 100 毫米的火舌暗光；若暗光平穩，該段切割道一定通透漂亮。

17 Cutting an I-beam
工字鐵切割法

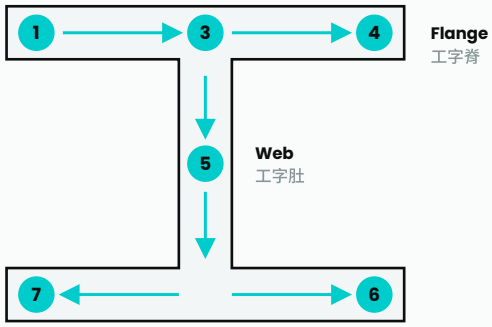


Fig. 4 — Cutting sequence · 圖四：切割次序

1	Start cutting at the flange, the rod at less than 90° (except for thick plate).	由工字脊開始切割，切割棒角度小於 90 度（厚料除外）。
2	Don't watch the arc spot; watch the glow on the far side of the flange. If it stays bright without stopping, the cut is through.	眼睛不要盯著切割光點，而是看工字背面的暗光。光度保持不熄，割道一定通透。
3	When the cut reaches about the middle of the flange, turn the rod to 90° and slow down. Keep watching the far side.	切割道到達脊的中間點時，把切割棒改為 90 度並放慢速度，眼睛仍然看著背面。
4	When you cut through at the web, flame shows through behind. Carry on and cut the other half of the flange.	切斷工字肚位置時，背面會透出火舌。繼續割斷另一半工字脊。
5	Close the oxygen valve, move to face the web, strike the arc where the flange cut meets the web, and cut the web.	關閉氧氣閥，移動身位面向工字肚，在脊切割道與工字肚交接處起弧，切割工字肚。
6	At the other flange, change the handle angle and cut half the flange from the inside out. Close the oxygen, move to face the other side, and continue the kerf to finish that flange.	切割至另一邊工字脊時，改變切割把手角度，由內向外切割半邊工字脊。完成後關閉氧氣閥，移動身位面向另一面，延續切割道割斷另一半工字脊。
7	Near the end, watch whether the beam may fall, or leave 25–50 mm (1–2 in) uncut as a safety hold.	將近完成時要留意工字是否會倒塌，或預留 1–2 吋不割斷作為保險。

SAFETY

Safety essentials

安全要點

Read these before every welding or cutting dive · 每次焊接或切割潛水前必讀

Surface safety switch

水面安全開關

Always work through a knife switch on the surface. The tender makes the circuit live only when the diver calls “make it hot”, and breaks it (“make it cold”) before every rod change.

必須經水面刀閘開關施工。只在潛水員要求「通電」時才接通電路，每次更換焊條前必須「斷電」。

Stay out of the circuit

身體不可進入電路

Keep the ground clamp close to the work and in front of you. Never put your body between the electrode and the ground.

接地鉗應靠近工件，並放在潛水員前方。身體切勿處於焊條與接地之間。

Watch for trapped gas

提防積聚氣體

Cutting releases hydrogen and oxygen that can collect in caissons, tanks, pipes and under plates, and explode. Vent enclosed spaces and never cut into a closed void.

切割會釋出氫氣和氧氣，可積聚在沉箱、水缸、管道及鋼板底部並引致爆炸。封閉空間必須通風，切勿切入密封空腔。

Check the kit every dive

每次下水前檢查裝備

Inspect leads, holder insulation, gloves and the regulator before each dive. Have a supervisor and a standby diver on every job.

每次下水前檢查焊線、焊鉗絕緣、手套及呼吸調節器。每項工作必須有潛水督導員及後備潛水員。

This guide shares field experience for trained commercial divers. It does not replace formal training, an approved welding procedure, a dive plan or the diving regulations that apply to your work.

本指南旨在分享實務經驗，供受過訓練的專業潛水員參考，不能取代正式培訓、經批核的焊接程序、潛水計劃或適用的潛水規例。