GOM Diving Safety Work Group

COMMITTEE WORK GROUP

JAN 2014

DISCLAIMER

This US GOM DSWG document is not meant to be all inclusive, and not every rule and regulation is contained herein. The US GOM DSWG does not issue policy or create regulations. The reader should consult additional resources and subject matter experts for more detailed information as required.

Underwater Burning

The GOM Diving Safety Workgroup is a US GOM focused, non-competitive and non-commercial group of oil and gas operators, transmission companies, commercial diving companies, supporting sub-contractors, organizations and industry stake holders. The group will provide a unified voice to promote and improve diving safety, through the following:

- identification and sharing of best practices
- identify and seek solutions to industry challenges and issues
- review and comment of existing and proposed standards and guidelines
- provide input to the regulators and industry associations

Purpose of Committee

This document has been prepared by the US GOM DSWG as guidance for:

Underwater Burning

Committee Chairman	Gary Kane
Executive Sponsor	Ted Roche

Committee Members (Names Only)	
Trevor Day	Paul Woodhall
David Gilbert	Jack Couch

The document is divided into seven sections:

- **Part 1: Executive Summary**

- **Part 2: Definition**
    - Defines the activity that is being evaluated and provides definitions from regulatory or industry groups that are associated with the activity.

- **Part 3: Regulatory and Industry Gap Analysis**
    - Identifies regulatory and industry association requirements to perform the activity or operation and provides a visual aid to determine the consistencies between these groups as it relates to the activity

- **Part 4: Past Incidents**
    - Identifies past near misses, incidents, and fatalities and provides causal factors and the root cause of the incident in order to provide supporting documentation for the hazard analysis in Part 5.

- **Part 5: Hazard Analysis**
    - Identifies the hazards of the activity or operation, Identifies the risks associated with the hazards, and provides specific mitigation considerations for each hazard to reduce or eliminate risk

- **Part 6: Drills and Preparation**
    - Provide a list of drills that should be performed to prepare the crew members for possible emergency situations

- **Part 7: Appendix**
    - Please do not alter the template, in order to maintain the consistency of the documents it relates to other committees, but please add additional documentation, reports, drawings, etc. in this section that may provide more depth or relevant information to the report.

Part 1: Executive Summary of Committee

Underwater burning is a high risk / critical diving activity that presents a potential for serious injury or fatality unless performed to a high standard by well-trained and competent personnel. The frequency of diver fatalities, injuries, incidents, and asset damage occurring while using underwater burning continues to be unacceptably high within the global diving industry.

This Committee was formed and the following guidance has been developed to assist with the management of this activity and provide control measures and guidance to ensure the safe execution of this operation.

When practical, eliminate underwater burning and cutting operations by developing a work scope that can be completed through the use of mechanical cutting or other intervention techniques. Alternative cutting methods may include, but are not limited to: hydraulic saws, shears, diamond wire, water jet cutting, hydraulic hand tools and explosives.

When it is not practical to eliminate underwater burning, sufficient safeguards and controls must be put in place to manage the risks of the cutting operations. Advance planning and a thorough risk assessment should be undertaken to identify potential risks and identify mitigations to keep the diver from being in harm's way. Venting requirements and positive identification of the material and surrounding conditions must be understood prior to beginning the burning operation.

Divers engaged in underwater burning need to be competent in the task. This competence is achieved through training, knowledge and experience. (See Appendix 1 for training recommendations)

Part 2: Definition

Oxygen-arc cutting is defined as the oxygen cutting process in which metal is severed by means of the chemical reaction of oxygen with the base metal at elevated temperatures. The heat of the arc brings the metal to its kindling temperature and then a high velocity jet of pure oxygen is directed through a tubular cutting electrode at the heated spot. The metal oxidizes and is blown away. The tip of the electrode, which is exposed to both heat and oxidation, is consumed in the process and needs to be replaced by the diver at regular intervals. (IMCA D 003)

Part 3: Regulatory and Industry GAP Analysis

The following documents were referenced in development of this Guidance or provide additional information and guidance on underwater Oxy-Arc cutting operations. The latest revision of each of these documents should be referenced when planning to use underwater burning.

- *IMCA D 003 Rev. 1, Guidelines for oxy-arc cutting*
- *ADCI – Consensus Standard Rev.6 - Section 5.31 "Welding and Burning"*
- *OGP Report No.471 - Oxy-arc underwater cutting Recommended Practice*
- *U.S. Navy Underwater Cutting and Welding Manual, Doc.# S0300-BB-MAN-010*
- *IMCA D 045, R 015 – The Safe Use of Electricity Underwater*

Item	Description of Item	IMCA	ADCI	USCG	OSHA	OGP	Comments
1	Permit Required	Yes	No	No	No	Yes	Underwater burning is a critical diving activity and should be managed by the Permit to Work process.
2	MOC Use	Yes	No	No	No	No	The decision to use or not to use underwater burning should be decided prior to the job; all cold cutting options should be considered as primary method. If circumstances change and UW burning becomes required, an MOC and associated risk assessment should be completed.
3	Site Specific HAZID	Yes	No	No	No	Yes	Should be required
4	JSEA/JSA	Yes	Yes	No	No	Yes	A JSEA is recommended for all diving activities, especially for UW burning.

Item	Description of Item	IMCA	ADCI	USCG	OSHA	OGP	Comments
5	Alternate Cutting	Yes	Yes	Yes	No	Yes	It is recommended that alternative cutting methods should always be used in lieu of UW burning.
6	Competency of the Supervisor	Yes	Yes	Yes	Yes	Yes	Recommend supervisor proven competency
7	Competency of the Diver	Yes	Yes	Yes	No	Yes	Recommend diver proven competency
8	Gas venting and entrapment	Yes	Yes	Yes	Yes	Yes	Specific drawings and diagrams should be developed prior to the job, experience and training should include proper venting techniques.
9	DC Output only	No	Yes	No	No	Yes	Only DC output welding machines should be used.
10	Welding Power Source	Yes	Yes	No	No	Yes	Power requirement matrix is attached as appendix.
11	Breaker or Knife Switch	Yes	Yes	Yes	No	Yes	Breakers are recommended
12	Diagrams of item to be burned	Yes	No	No	No	Yes	Site specific drawings and diagrams should be developed and reviewed prior to the job
13	No Through Water Ground	No	Yes	No	No	Yes	No through water grounding.
14	Ground Size	No	No	No	No	Yes	Ground lead size should be determined by project specific circumstances
15	Splices	No	No	No	No	Yes	Splices should be kept to a minimum
16	Continuity/ Polarity	Yes	No	No	No	Yes	Leads should be load tested and machine polarity verified.

Item	Description of Item	IMCA	ADCI	USCG	OSHA	OGP	Comments
17	Oxygen quality	No	No	No	No	Yes	Oxygen quality can affect burning performance
18	Oxygen cleaned hose	Yes	No	No	No	Yes	Proper hose selection and oxygen cleaning are essential to safe operation.
19	Oxygen Regulator	Yes	No	No	No	Yes	High flow regulator recommended.
20	Oxygen Pressure	Yes	No	No	No	Yes	Suggested manufacturer recommendations are included in Appendix
21	Torch	Yes	No	No	No	Yes	Standardize. Torch should be inspected, maintained and tested as per manufacturer recommendations.
22	Rod	Yes	No	No	No	No	Should be based on material to be cut, and project specific conditions
23	PPE	Yes	Yes	Yes	Yes	Yes	Proper PPE is required
24	Training for burning	No	No	No	No	Yes	Written and practical training are critical for safe burning operations, see appendix for recommendations.
25	Bell location	Yes	No	No	No	Yes	Should be addressed in HAZID, and diver awareness requirements
26	Cutting methods	Yes	No	No	No	No	Should be standardized through training class and HAZID
27	Flowcharts / Checklists	Yes	No	No	No	Yes	Example flowchart in Appendix

Item	Description of Item	IMCA	ADCI	USCG	OSHA	OGP	Comments
28	Equipment Cert and PMS	Yes	No	No	No	Yes	Preventive maintenance recommended
29	Specific Procedural Steps	Yes	No	No	No	Yes	Procedure and cut plan to be developed and reviewed prior to mobilization and during pre-dive briefing.
30	Specific Amp Setting	Yes	No	No	No	Yes	Suggested manufacturer recommendations are included in Appendix
31	Contractor Checklist	Yes	No	No	No	Yes	Should be required
32	Client Checklist	No	No	No	No	Yes	Should Be required

Part 4: Past Incidents

This section lists some of the documented injuries and fatalities over the past sixty years attributed to underwater oxy-arc burning. In most of these incidents the root cause of the injury or fatality was from an explosion caused from trapped hydrogen gas or hydrocarbons. The incidents listed below do not include the numerous un-reported incidents when a blow-back or explosion occurred, instances where the torch was blown out of the diver's hand or caused his ears to ring for several hours.

Year	Location	Details	Fatality	Injury
1947	USA, Hawaii	After the bombing of Pearl Harbor, it was estimated that the Navy and civilian divers spend about 20,000 hours underwater on major salvage operations lasting over two years. Two divers died on operations cutting into the wreck of the Arizona probably underwater oxy arc explosions	2	
1969	New Zealand	Cutting up the wreck of the ferry "Wahine" at the entrance to Wellington Harbor, underwater explosion	1	
1968	USA	Underwater Oxy Arc Explosion seriously injured but recovered after a year in hospital, never returned to diving. Second diver burning on a damaged conductor, improperly vented.		1
1970	UK	Diver killed in an explosion during salvage operations	1	
1977	USA	Salvage operations on the tanker "Sansitena" in Los Angeles harbor, diver had been in the water two hours conducting oxy-arc cutting operations, gas pocket, underwater explosion, reported as "diver stricken with bends when he surfaced after an underwater explosion"		1

Year	Location	Details	Fatality	Injury
1978	UK	Diver was killed in a burning explosion underneath a small barge or tanker.	1	
1980	Brazil	Oxy/arc torch not working, taken back to the bell for checking, flash fire, two divers died of burns	2	
1981	USA	Diver was oxy arc cutting well conductors in approximately 45 feet of water when an explosion occurred. The diver was found unconscious and tangled in his hose with his diver hat and harness off. He was brought to the surface unconscious.	1	
1984	UK	Diver was oxy-arc cutting, rendered unconscious by an explosion. Face plate blown in, ruptured eardrums, right side pneumothorax, rescued by bellman		1
1986	USA Illinois	Diver died in an explosion during a ship salvage operation on a sunken corn barge, possibly burned into a pocket of methane given off by the fermenting corn.	1	
1990	Singapore	Diver killed in an underwater explosion in an underwater pile cutting operation	1	
1991	USA	Chasing hangers after doing an inside burn off below the mud line resulted in underwater explosion, face plate blown in, drowned. The incident led to a brief and informal moratorium on inside burn offs and this incident was a major factor in the introduction of the 'T' type faceplate screw anchors”	1	
1993	USA	Diver cutting a window in the 10 ¾ inch casing. Surface personnel heard an explosion on the diver’s radio. The standby diver found him unconscious and his helmet off. The injured diver later died in the decompression chamber of cardiac arrest	1	
1993	Singapore	Diver died in an underwater explosion during a salvage operation on a shipwreck.	1	
1993	Honduras	Diver died while performing underwater cutting operations to raise a sunken coastal freighter.	1	
1999	UKCS	Diver died in oxy arc explosion. HSE prosecution, (See IMCA SF 07/01).	1	
1999	GOM	Diver died in underwater oxy arc explosion, improperly vented tank on a salvage operation.	1	
1999	USA, California	Welder diver, 'died in an industrial accident' at Los Angeles Harbor	1	
2001	GOM	Diver died in Mississippi river barge salvage job, oxy arc explosion	1	
2003	GOM	P & A job. Oxy Arc cutting, H2 build up, explosion, fatality. No proper drawings, insufficient venting. No JSA, MMS report, no personal details	1	
2004	GOM	Diver received 3rd degree burns, Broco BR 22 defective manufacturing plus bad technique		1
2004	GOM	Oxy Arc explosion, Ship's plate, diver unconscious/dizzy, 3 days off work. (See IMCA SF 05/04)		1
2004	GOM	Oxy Arc explosion, tank, salvage diver perforated both eardrums, 37 days off work. (See IMCA SF 05/04)		1
2005	Romania	Diver died in underwater burning during salvage of the 'Rostok' from the Danube	1	

Year	Location	Details	Fatality	Injury
2006	GOM	Underwater Oxy Arc explosion, knocked unconscious, facial lacerations, chipped tooth, sore ribs. 3 weeks off work		1
2007	Indonesia	Diver killed in an explosion cutting into the hull during salvage operations.	1	
2007	GOM	Diver was killed in explosion using a grinder to cut vent holes on a fallen structure deck plate, with hydrogen and hydro-carbon build up under the plate.	1	
2008	France	Diver was killed cutting up a sunken boat, underwater oxy/arc explosion	1	
2008	GOM	Diver had a bilateral traumatic pneumothorax following burning explosion.		1
2008	Philippines	2 divers injured cutting up wreck "Trapped air explosion knocked divers off their feet" Hospitalized with breathing difficulties, later released.		2
2009	Turkey	Salvage diving operation on the wreck of the ferry 'Hayak N', 1 diver killed and 1 diver injured in an underwater explosion during cutting sheet metal	1	1
2010	GOM	Post 'Katrina' - diver killed in underwater oxy-arc explosion.	1	
2011	Georgia	Two scuba divers were killed in an underwater explosion working on the salvage of the sunken Ukrainian ship, the explosion could have been caused by hydrogen accumulated inside the ship	2	
	GOM	Cutting up of the wreck of the "High Island III" - "There we were making gas dive after gas dive burning box after box of rods, cutting up a bent and twisted pile of the drilling derrick. The diver had rigged up to a big pile of I-beam and angle iron and was cutting it free of bottom. Diver says, "OK get up on the load it's free to the surface." and goes back to the bell to watch the load come up. As it clears bottom he sees what looks like a huge (20 to 30ft) cloud coming up under this pile of scrap (gas trapped in the scrap pile) The diver asks the supervisor, "What the heck is that?" the supervisor responded. "The bomb you were building."		
		Totals	**28**	**11**

Part 5: Hazard Analysis

Item	Hazard Identified	Risk Associated with Hazard	Mitigation Considerations
1	Electric Shock	Injury to topside or diver	• Ensure gear is in working order, good condition and set up by trained personnel. • Check all welding leads for damage and make necessary repairs, these repairs should be done by trained qualified personnel. • Repairs to welding cables should be made with waterproofing adhesive, wrap and tape (3M or similar) • Clean the knife switch and all electrical connections. • Ensure that the knife switch is kept dry to prevent electrocution to the operator. • Ensure the welding machine frame is grounded
2	Electric shock	Injury to diver	• AC power shall not be used for underwater cutting and welding due to the extreme danger involved with AC current underwater. • The diver should wear at a minimum: a wetsuit jacket, booties, and rubber gloves with leather or Kevlar outer glove. • Establish a ground to the work from the welding machine (positive terminal), make sure the ground clamp is attached to an area cleaned of rust or marine growth. • The Diver should never get between the torch and the ground or work; he could become part of the circuit.
3	Electric Shock	Injury to diver	• A diver is at risk from severe electrical shock when performing a cutting or welding operation while only partially immersed in water. (e.g. splash zone or habitat). • The diver should wear full rubber wet suit, insulated gloves and booties if working partially submerged. • Proper ground placement (to keep diver out of circuit) is critical to preventing electrocution.
4	Electric Shock	Injury to diver	• Do not touch the helmet with the electrode or any un-insulated part of the electrode holder or torch. • Do not touch the work with the metal helmet or any metallic part of the diver's dress.
5	Electric Shock	Injury to diver	• When burning is stopped, signal MAKE IT COLD before changing electrodes. This must always be done. Keep the torch in cutting position until the supervisor acknowledges MAKE IT COLD. • This safety precaution is recommended regardless of the electrode type or current setting

Item	Hazard Identified	Risk Associated with Hazard	Mitigation Considerations
6	Electric Shock	Injury to the diver	• Use of through-water ground is discouraged; the ground clamp placement should not position the diver between the torch and the ground.
7	Electric shock	Damage to Equipment	• Use of through water ground discouraged; damage to vessel's hull or facility from electrolysis.
8	Electric Shock	Injury to the diver	• Verify correct polarity of the torch by using the bucket test, place electrode and ground in bucket of seawater and make the torch "hot", if the polarity is correct (Straight Polarity) a small stream of bubbles will come from the rod tip
9	Electric Shock – Knife Switch	Injury to diver or topside personel	• It is extremely important to mount the knife switch correctly. The switch must be positively acting, rigidly mounted, and located so that it cannot be accidentally knocked or vibrated closed. Should the switch fall, the circuit would be broken. • Electric hazard in dive control should be mitigated by careful placement and correct mounting of knife switch.
10	Explosion	Injury to diver	• Underwater burning creates hydrogen/ oxygen mixtures that are highly explosive. All closed compartments, enclosed space, structures or pipelines should be flooded or purged with water and vented. If unsure about the condition of the compartment or pipe the vent holes should be cold cut. • Ensure that gases cannot be trapped by providing a vent hole at its highest point. • The diver should keep his face plate and soft tissue areas of the body (larynx and chest) away from the direct line of the cut; an explosion can act as a shape charge and focus the power of the explosion to whatever is in front of it.
11	Explosion	Injury to the diver	• Explosions have caused pneumothorax and then Arterial Gas Embolism on various incidents, therefore a DDC should be immediately available on all UW cutting jobs regardless of depth
12	Explosion	Injury to the diver	• Escaping hydrocarbons can accumulate at the work-site; do not burn if hydrocarbons are present. • Never burn into a space containing an unknown or explosive substance, always drill or saw your vent.

Item	Hazard Identified	Risk Associated with Hazard	Mitigation Considerations
13	Explosion	Injury to the diver	• Grinding is considered a hot process due to the spark generated by the grinding disk. • Do not use grinding to vent if there is the possibility of hydrogen /gas/hydrocarbon pockets on the back side of the object being cut.
14	Explosion	Injury to the diver	• Below mud-line cutting, cutting on pipelines with weight coating or cutting against a grout backing have a tendency to build up large quantities of trapped gases. • It is recommended to remove weight coating and when burning below the mud-line the backside of the material being cut should be jetted to vent the gas. • When possible vent with inert gas or air. • Always know what is behind the material being cut. There may be; hydrocarbon solid, liquid, or gas, air, concrete, mud, voids due to scantling shape (cross section) which could produce gas pockets with the potential for explosions.
15	Explosion	Injury to the diver	• Cutting on sheet piles can trap gas in pockets of the knuckles. Be sure to have area in vicinity of these knuckles properly vented.
16	Explosion	Injury to diver	• BEFORE commencing any burning operations, the Diving Supervisor and divers who will do the work should meet with company representative and physically identify the pipeline, conductor or riser to be worked on. • The dive supervisor should verify with the diver in the water the agreed upon procedure/cut plan is being followed prior to beginning the UW burn. • The initial penetration should be drilled or saw cut. • Before cutting on any pipeline it should be opened to the surface, vented to atmosphere, flushed with seawater and flooded. If there is any doubt about the pipelines internal condition it should NOT be cut

Item	Hazard Identified	Risk Associated with Hazard	Mitigation Considerations
17	Explosion or fire	Injury to diver	• Do not operate the torch with the spark arrestor removed. Doing so may cause injury to the diver and damage to the torch. • Do not burn the rod down to within 1-2 inches of the torch, this can cause damage to the collet, washer or spark arrestor, it also makes removing the rod stub extremely difficult. • NITROX should not be used on dives where oxy-arc cutting is performed. Higher oxygen concentrations in the free flow or exhaust could lead to explosions.
18	Fire	Injury to topside	• Prior to hooking up Oxygen to the torch ensure the bottles are secured in a rack to prevent them from falling over. • Ensure that valve outlet, regulator and all fittings are free from grease, dirt and other foreign matter. • Ensure O2 equipment is properly hooked up, check for and repair any leaks • Have properly trained fire watches with in-date fire-fighting equipment.
19	Fire	Injury to topside	• Hydrocarbons ignite almost spontaneously in the presence of oxygen. Never allow oxygen-carrying components to come in contact with oil or grease.
20	Fire	Injury to topside	• Due to the flammability and toxicity of fumes from waterproofing compounds, waterproofing must be conducted in a well-ventilated space, clear of any open flames or spark producing machinery. NEVER take a burning lead or torch into the bell.
21	Differential Pressure (Delta P)	Injury to diver	• Delta-P can exist on platform members if they were welded topside before the platform was installed, likewise a pipeline that is open ended on the surface is only under a single atmosphere. • Be aware of body position, when possible verify zero pressure (flood pipeline), use “tattletales” and diffusers to check for or prevent Delta-P. • Keep body, hoses, tool lanyards and clothing away from any area of Delta-P, the in-rush of water may pull in these items and drag a diver into harm’s way. • If Delta-P is present, stay back and verify item has equalized (e.g. flooded) and inform topside

Item	Hazard Identified	Risk Associated with Hazard	Mitigation Considerations
22	Burn	Injury to diver or topside	• Wear proper PPE when burning, report all burns no matter how minor since burns can easily become infected
23	Burn	Damage to umbilical	• Molten slag or sharp metal can damage the diver's hose, umbilical management is important.
24	Welding flash burn	Eye injury to topsides personnel and diver	• When testing the burning gear on deck insures the tenders are wearing proper PPE including: Rubber gloves and welding hood with #8 lens minimum. • Divers should wear a burning lens on their helmets when burning in clear water, #4 lens is usually sufficient.
25	Chemical Burn	Injury to the diver	• Distillate or petroleum products can cause chemical burns to unprotected skin, divers should consider wearing dry suits and apply a dermal protective gel to exposed areas to prevent irritation
26	Bell Contamination	Injury to diver	• Combustion by-product, oxygen or hydrogen bubbles, and hydrocarbons must not enter the bell atmosphere. Be sure the bell is in an area below cuts/vents, be aware of currents. • Evaluate the use of a hyper-gas hydrocarbon monitor in bells during salvage / burning operations. • Increase the required Oxygen content monitoring in the bell checks. • The burning lead/ torch should never be brought up into the bell.
27	Crush or Pinch points	Injury to diver	• Be aware of body placement, anticipate stored energy and stay out of line of fire, consider the use of hold-backs, anchors, chains or come-a-longs to prevent objects from sudden movement after they are cut. • Pipelines or platform members may shift or break free without warning, always verify the diver has safe spot to be out of line of fire before beginning the cut. • Umbilical management is important at all times while burning to prevent potential for entrapment or hose damage from falling steel.
28	Trapped Diver	Diver	• Be aware of body placement, anticipate and dictate material being cut. Ensure standby diver is qualified and always ready
29	Low Visibility	Diver	• Ensure qualified divers are used in low visibility operations, do not make guesses and always verify before cutting. • Take adequate time for the diver to assess the situation and discuss potential hazards with topsides.

Item	Hazard Identified	Risk Associated with Hazard	Mitigation Considerations
30	Cuts and Punctures	Topside and Diver	• Wear proper PPE, Kevlar gloves (over the rubber ones) and chaps
31	Diving Equipment Damage	Topside and diver	• Burning equipment high amperage cables and oxygen hoses should not be run in any cable tray (or similar) that is in any way connected to diving system electrical power, hydraulic, or gas services.
32	Rigging Equipment	Crane / Winch cable damage	• Insure rigging components are not causing grounding, this could damage the wire rope and cause rigging failure
33	Rigging Equipment	Nylon strap damage	• Insure that nylon slings stay clear of hot areas and molten slag. Nylon straps are not to be used on sharp edges.

Part 6: Drills and Preparation (specific to Underwater Oxygen-arc cutting)

Item	Drill Name	Describe Drill
1	Electrocution Drill	Perform drills on how to handle a topside man down due to electrocution - remove the electrical hazard first.
2	Unconscious diver recovery drill	Perform drill to simulate the recovery of a unconscious diver – assume diver has been in an oxy-arc explosion.
3	Injured diver recovery drill	Perform drill to simulate the recovery of a conscious yet injured diver (Cut Leg, broken arm, strained back)

Part 7: Appendix

Item	Appendix Item	Description of Item
1	Recommendation	UW Burning - Training and Competency Recommendations
2	Diagrams	Shows proper and improper venting techniques
		Shows venting pipelines with over-bends
		Shows proper burning gear set up (welding machine, knife switch, O2 , torch and ground)
		Shows correct knife switch set up
		Shows proper ground clamp placement
		Shows drag method of cutting
3	Photographs	Flammable residue in a pipeline
		Internal Stiffener Rings Inside of Members
		Torch damage from burning rod up into collet
4	Flowchart	Flowchart example from IMCA D 003
5	IMCA Safety Flashes	Excerpt from IMCA Safety Flash 07-01
		Excerpt from IMCA Safety Flash 10-03
		Excerpt from IMCA Safety Flash 05-04
6	Amperage and O2 Matrix	Welding machine and O2 PSI settings for steel & exothermic rods.
7	Broco	BR22 Leak test procedure

Appendix 1 : UW Burning - Training and Competency Recommendations

Divers engaged in underwater burning need to be trained and competent in the task. This competency is achieved through training, knowledge and experience. Diving Companies should perform in-house qualifications for their supervisors and divers to verify their competency and make these available to the client for review. The training criteria may vary on a case by case basis and this document does not intend to set specific training, experience or competency requirements.

Recommended training requirements may include the following:

- Formal dive school classroom instruction
- Formal dive school instruction for equipment set up
- Formal dive school dry (topside) and in-water instruction with various rods, materials, and visibility conditions.
- Company in-house classroom training and in-water qualifications
- Pre-job “task-specific” qualifications with material mock-ups
- Supervisor led training and mentorship based on diver’s experience

Recommended items to be included in the UW burning training should include, but are not limited to the following:

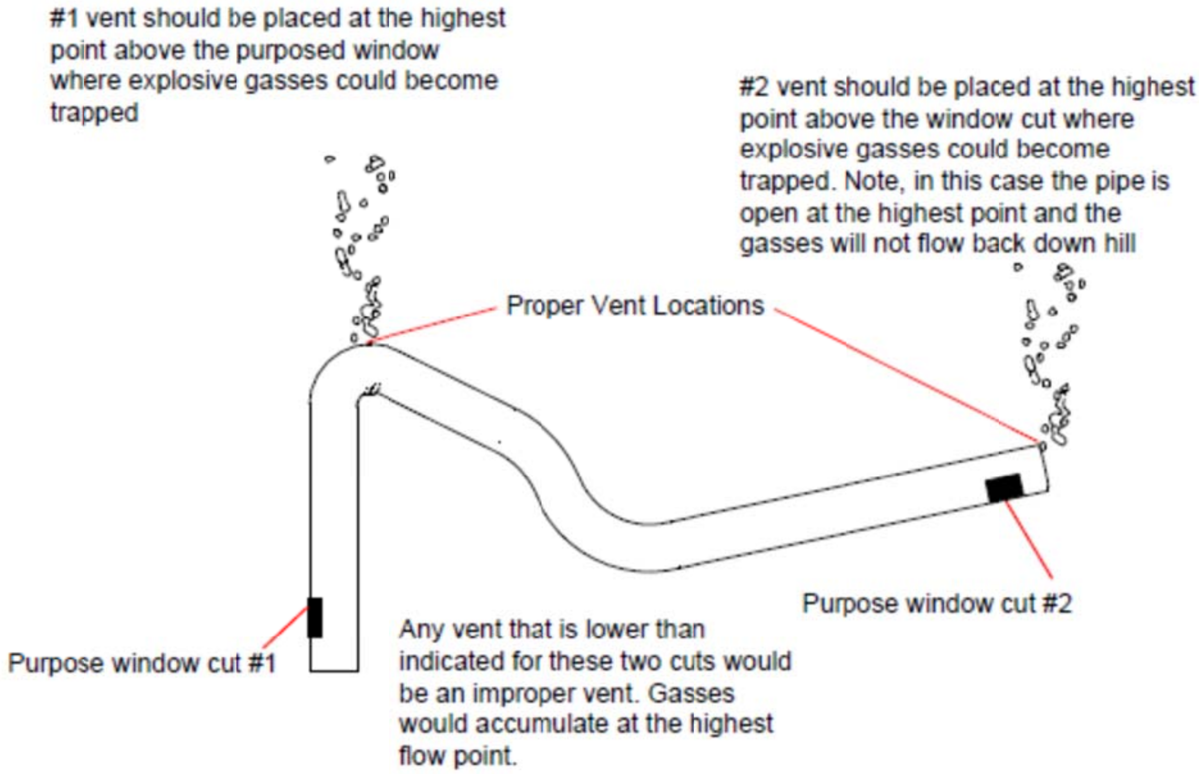
- Evaluation of alternative cutting methods
- Risk identification and mitigation
- Management of Change process
- Oxy-arc UW burning theory
- Equipment selection and set-up
- Venting
- Grounding
- Stored energy
- Differential Pressure
- Hydrocarbons sources
- Simultaneous Operations
- Cutting Rods and techniques

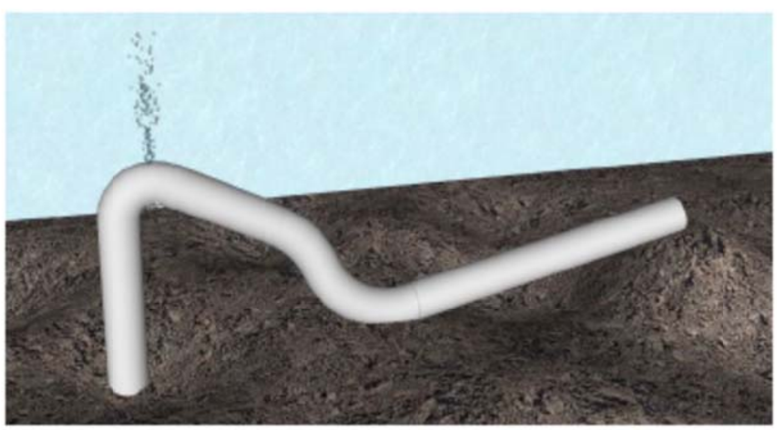
Experience level and competency are extremely important in the qualification process; these can be documented through log books, in house performance reviews, and written and practical testing.

The diver qualifications should be matched to the hazards associated with and the complexity of the specific burning operation/task.

Appendix 2 : Diagrams

Proper and Improper Venting Hole Locations



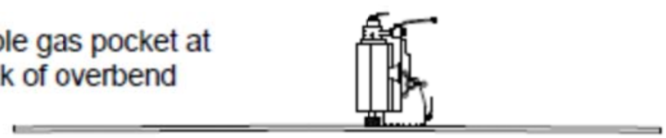


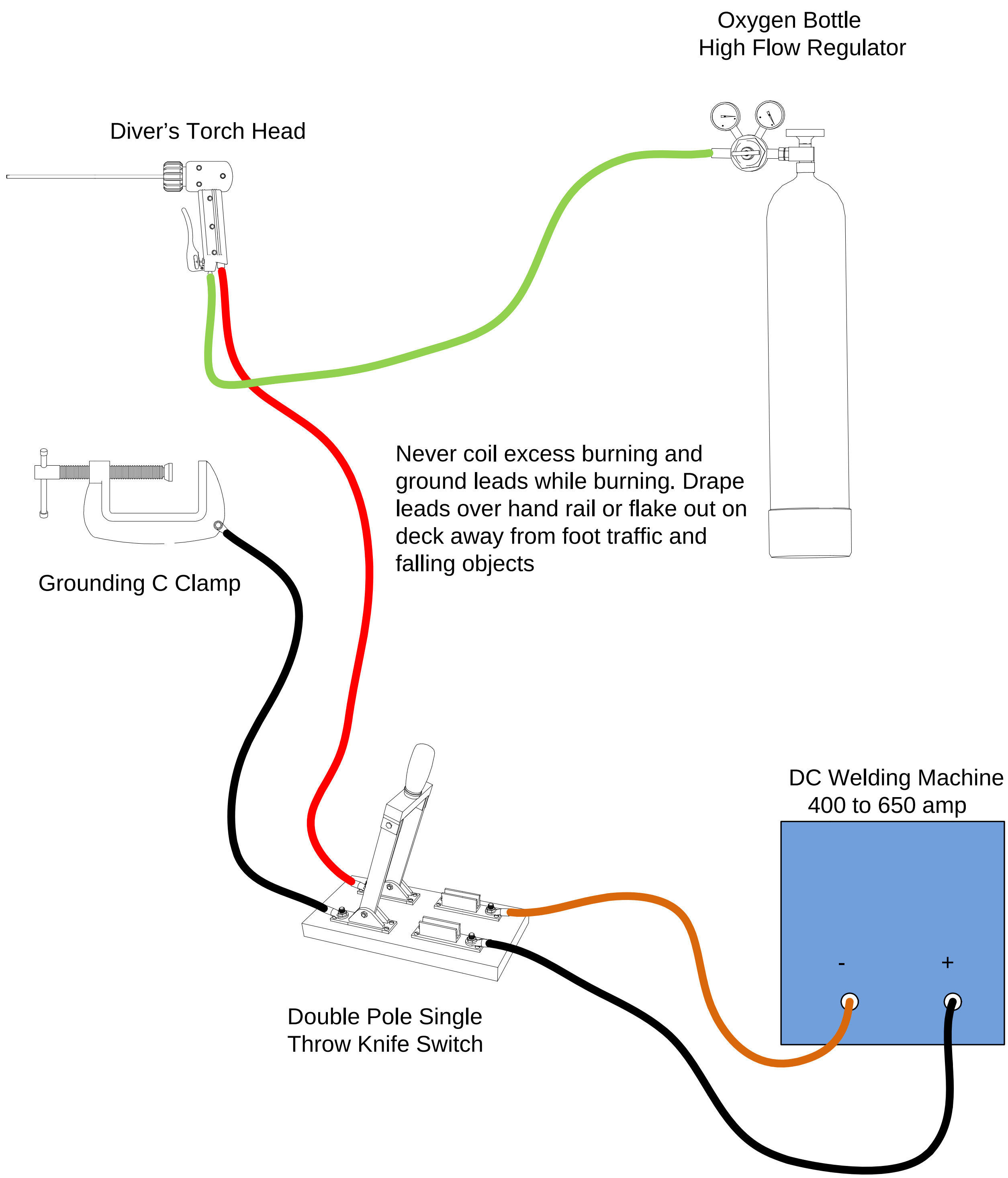
Venting Pipelines with Overbends

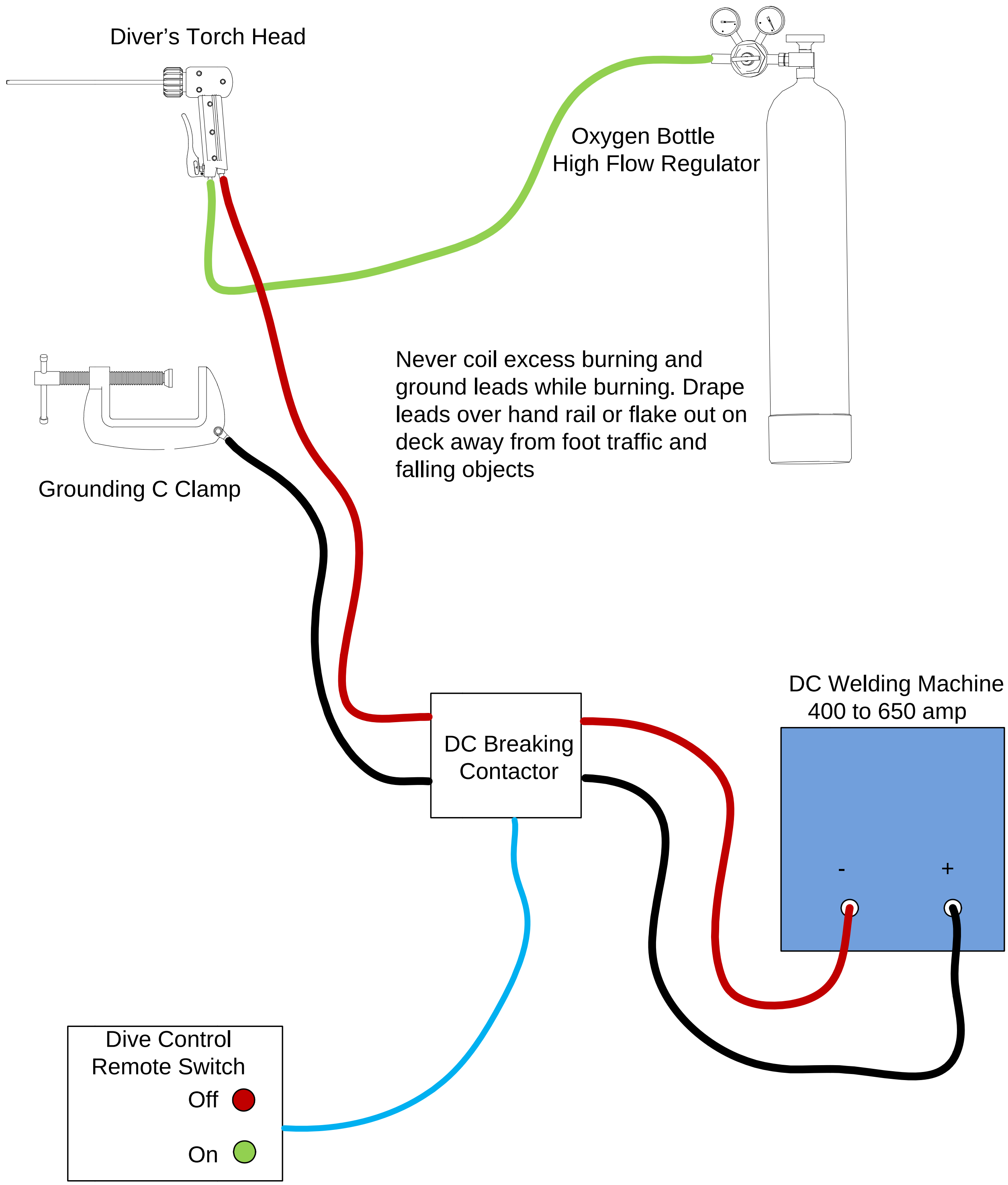
Pipelines that have a visual overbend, even if they have been pigged, should have the vent hole drilled or sawed.

Pipe with overbend, and hydraulic drill installed to vent at this location

Possible gas pocket at peak of overbend

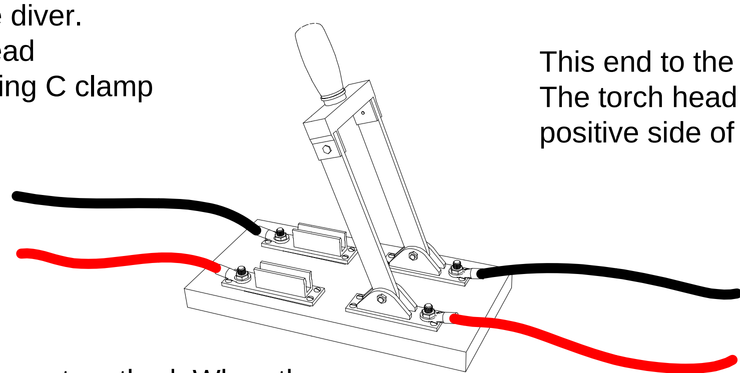



Oxygen Bottle
High Flow Regulator
Diver's Torch Head
Never coil excess burning and ground leads while burning. Drape leads over hand rail or flake out on deck away from foot traffic and falling objects
Grounding C Clamp
DC Welding Machine
400 to 650 amp
-
+
Double Pole Single Throw Knife Switch


Diver's Torch Head
Oxygen Bottle
High Flow Regulator
Grounding C Clamp
Never coil excess burning and ground leads while burning. Drape leads over hand rail or flake out on deck away from foot traffic and falling objects
DC Welding Machine
400 to 650 amp
DC Breaking Contactor
-
+
Dive Control
Remote Switch
Off
On

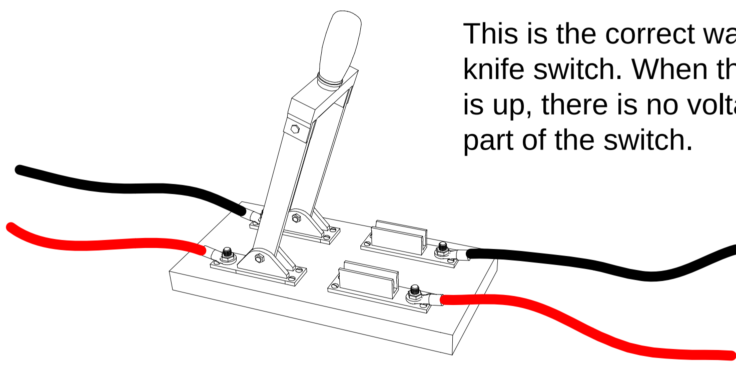
This end toward the diver.
RED to the torch head
Black to the grounding C clamp

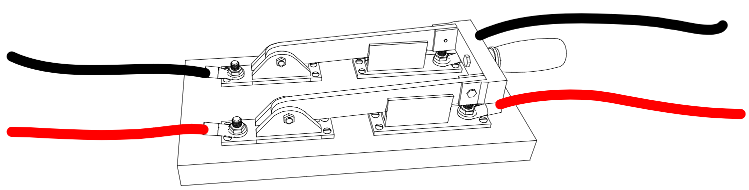
This end to the welding machine.
The torch head is connected to the positive side of the machine. (RED)



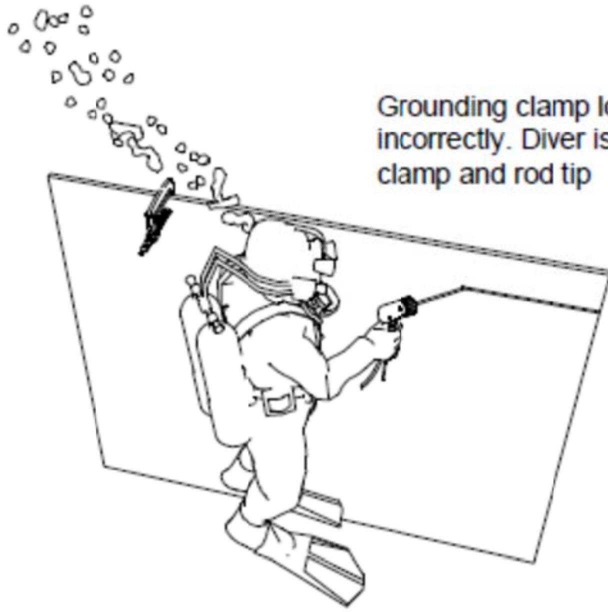
This is the incorrect method. When the knife switch handle is up, the full voltage of the welding machine is at the handle of the knife switch.

This is the correct way to connect the knife switch. When the switch handle is up, there is no voltage on the knife part of the switch.

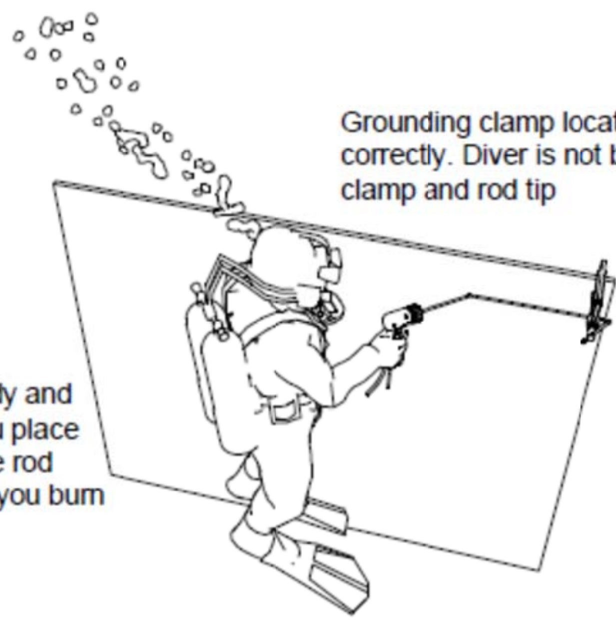




When starting to burn, look carefull at the placement of the grounding clamp. Make sure your body is not position between the ground clamp and the tip of the rod.



Grounding clamp located incorrectly. Diver is between clamp and rod tip



Grounding clamp located correctly. Diver is not between clamp and rod tip

DRAG METHOD

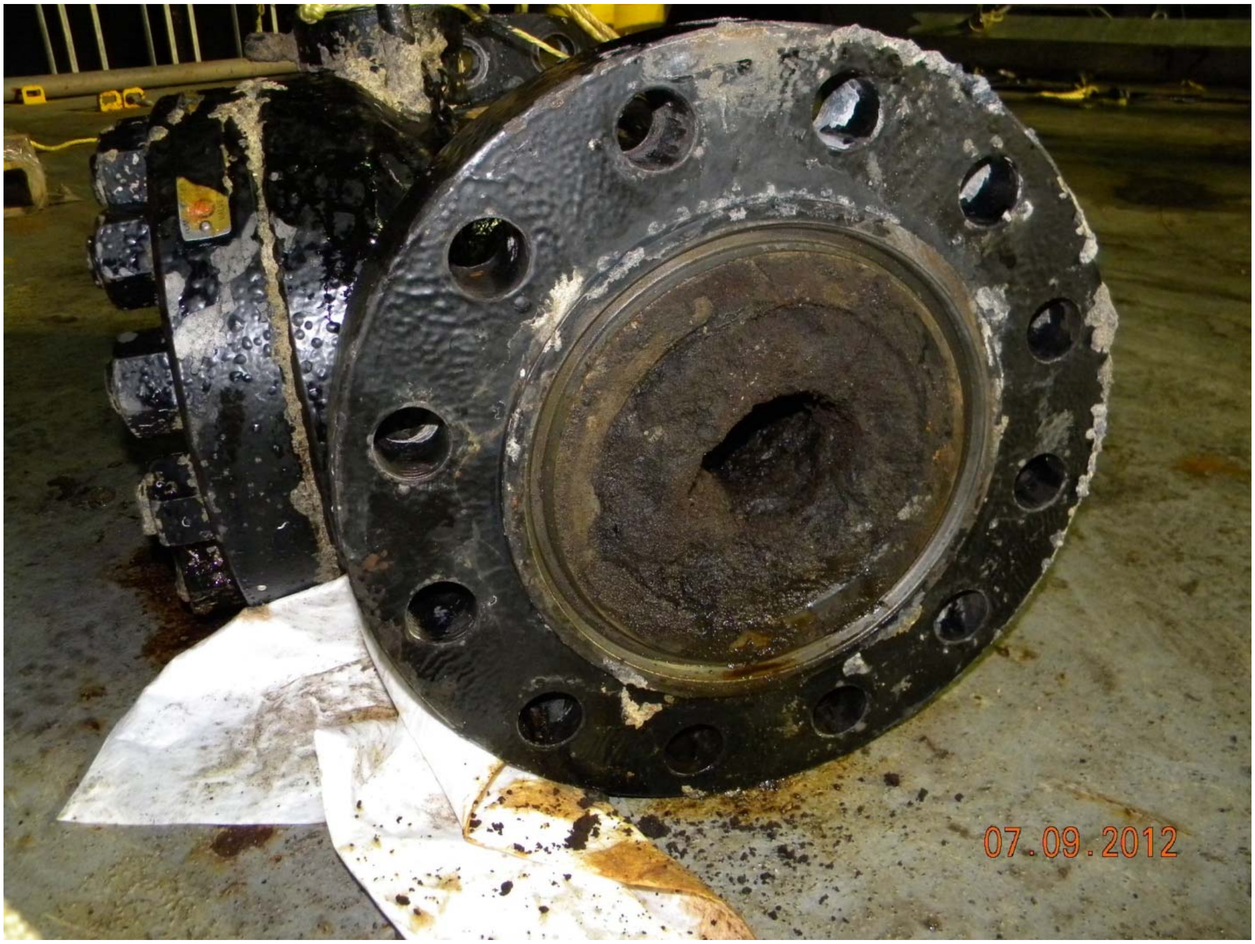
The drag method keep your body and face from in front of the cut. You place yourself to the side and drag the rod towards you. This requires that you burn by feel not by sight.

WARNING: Cutting on sheet piles is not recommended.

- Cutting on sheet piles can trap gas in pockets of the knuckles.
- Be sure to have area in vicinity of these knuckles properly vented.
- Below mud-line cutting has a tendency to build up large quantities of trapped gases.
- Cutting against a grout backing has a tendency to build up large quantities of trapped gases.
- It is recommended the backside of the material being cut should be jetted to vent the gas.
- When possible vent with inert gas or air.
- Always know what is behind the material being cut.

Alternative cutting methods are recommended.

Appendix 3 : Photographs



This pipeline was flushed and the plan was to burn it, this image shows the amount of extremely flammable residue that had built up over the years of service. Thankfully the decision was made to use alternative cutting methods.

Internal Stiffener Rings Inside of Members

Internal stiffener rings found inside of VD and skid beam members on this platform. If a member is at an angle gas could be trapped on the topside of the pipe even though it appears to be open ended. This member was cut with a diamond wire saw and gas of some sort did escape. Burning below one of these stiffeners would be a bad day.

During diver training session, we had a diver who wanted to burn the rod all the way to the torch. He did this several times requiring the burning torch to be sent to the surface to remove the rod with needle nose pliers. This is one habit we work on to stop, as it's dangerous and wastes time when the burning torch gets sent topside to remove a short stub. The third time he burnt the rod too short, the torch blew up (no injury to the diver, except scared him). The torch outer housing was fine, but the spark arrestor screen was vaporized, and the oxygen hose/fittings between the torch and the oxygen valve vaporized.

Appendix 4 : Flowchart example from IMCA D 003

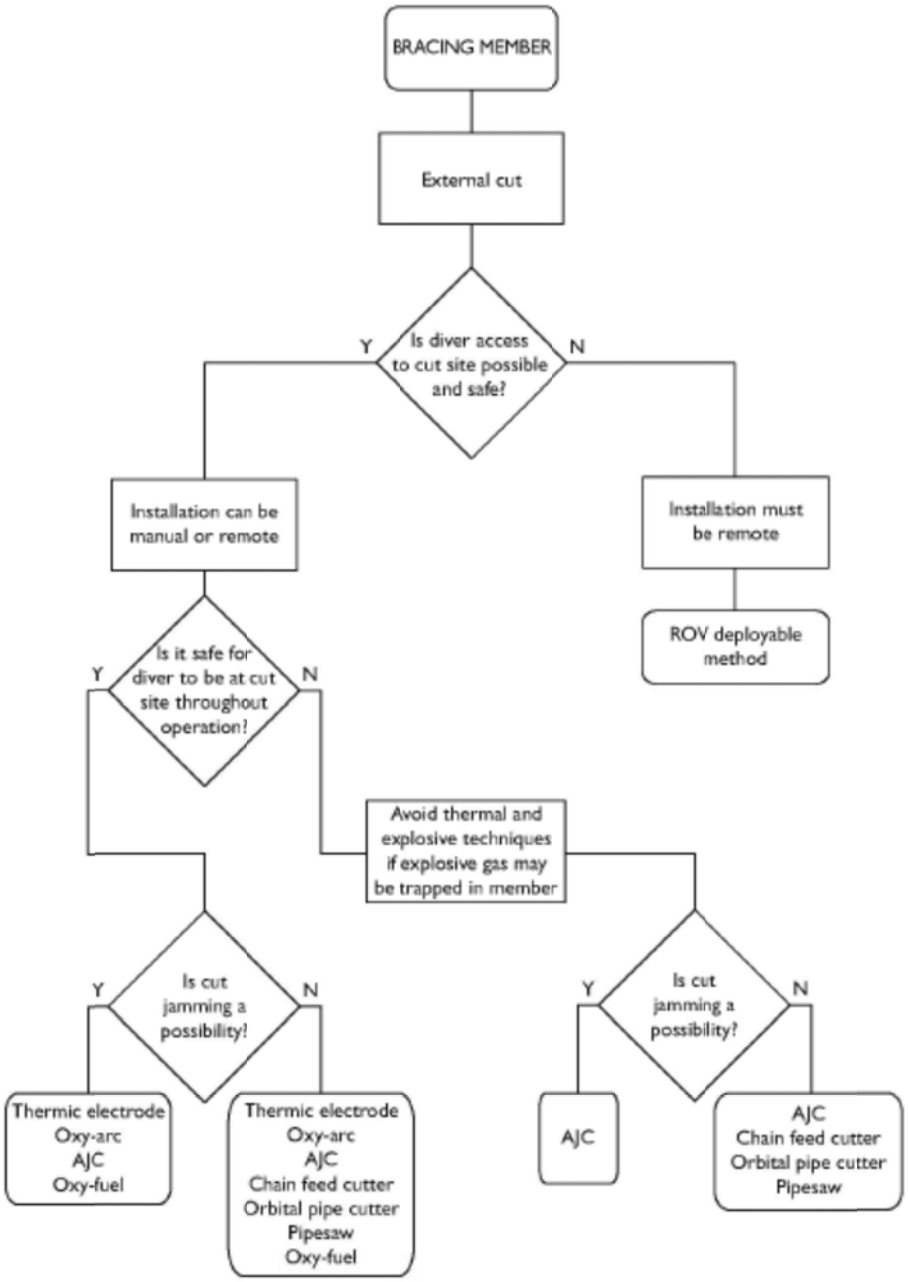


Figure 3 – Bracing member cutting flow chart

Appendix 5 : IMCA Safety Flashes

Excerpt from IMCA Safety Flash 07-01

5 Oxy-Arc Cutting

The investigation into a diver fatality on a subsea structure involving oxy-arc cutting has identified that the most likely cause of the explosion was that gas trapped in a cavity above the diver was ignited by a spark. The gas was likely to have been generated during the oxy-arc cut on the spool directly below the cavity.

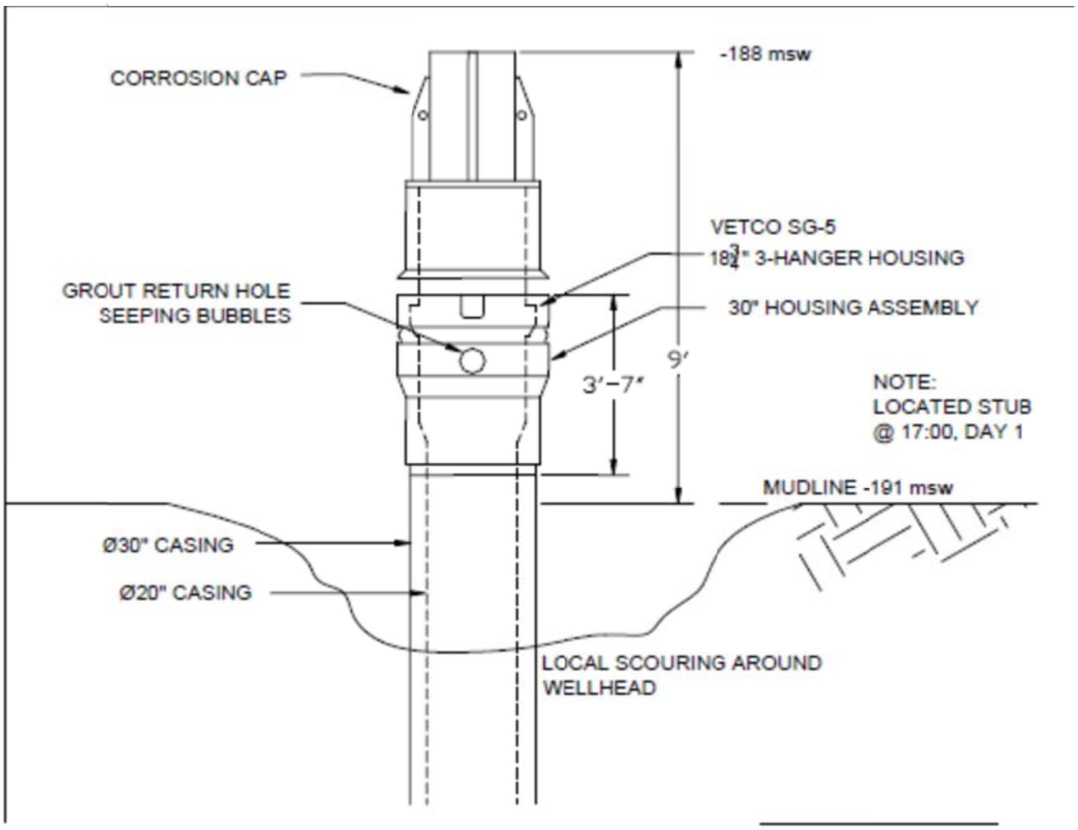
The company involved has issued the following instructions to its personnel regarding subsea oxy-arc cutting:

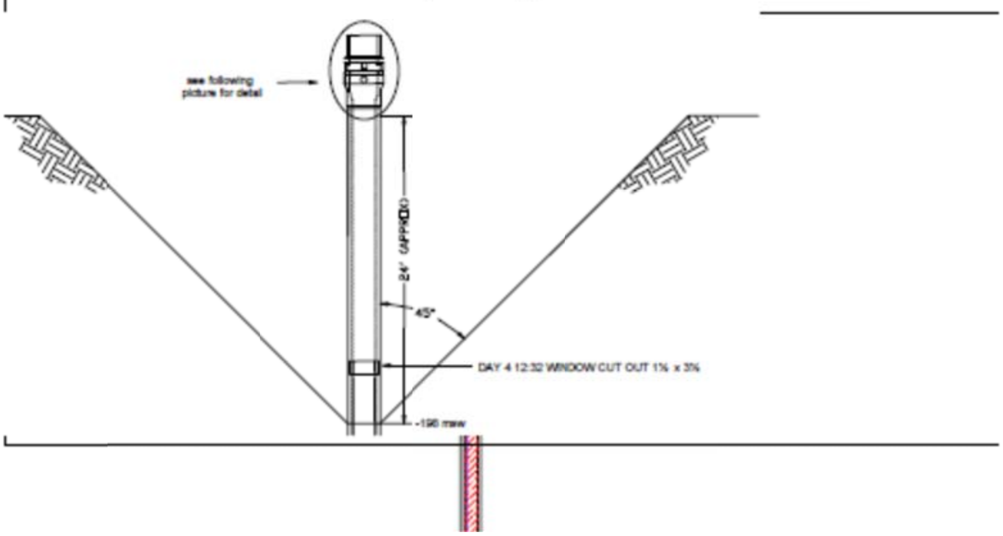
- Oxy-arc cutting should only be used if there are no practical alternatives;
- Any oxy-arc cutting operation needs the approval of the relevant manager for that operation and a specific task plan and risk assessment covering the detail of the particular task need to be in place;
- Supervisors should ensure all hazards have been identified, the risk properly assessed and that control are clearly specified, communicated and in place prior to work commencing;
- Divers who use oxy-arc equipment should be trained in its use;
- Divers who are to carry out oxy-arc cutting should be fully aware of and understand the risks and risk control methods to be adopted;
- Supervisors and oxy-arc equipment operators need to ensure that there is no possibility of gas entrapment, creating a potential explosion hazard, prior to striking an arc;
- Supervisors and oxy-arc equipment operators need to ensure that any potential location where gas could be trapped is completely vented before striking the arc. This will probably require creation of a vent hole. Flushing the cavity with air is not likely to be sufficient;
- Oxy-arc equipment operators should not energize the Broco rod unless oxygen is flowing through the rod. Hydrogen from electrolytic action can otherwise build up in the rod, creating an explosion hazard.

Excerpt from IMCA Safety Flash 07-01

3 Diver Fatality – Underwater Explosion

A member has advised of a recent fatality, involving an experienced diver, which occurred during underwater cutting operations as part of a well stub removal project. The site conditions and sequence of events are summarized in the diagrams below.





Excerpt from IMCA Safety Flash 10-03 – Continued.

The company's subsequent investigation has noted the following findings:

- Site conditions had proved to be different from those represented in the end-customer's drawing, in terms of the wellhead connector assembly, bubbling gas and lack of grout between annuli;
- Generic procedures had been produced for what had been considered a 'standard' or 'routine' well stub removal;
- The job safety analysis (JSA) had focused on excavation as the primary risk;
- A 'can do/will do' attitude can be prevalent among dive teams and in the wider industry, which may have caused some resistance to halt operations;
- The project manager only had limited involvement in this operation;
- The on-site procedure, developed by a widely experienced team of diving superintendent, supervisor and diver, proved to be not adequate to avoid the fatality.

The company has noted the following actions:

- It has instigated a 'formal request for information' procedure for retrieval of additional information from customers;
- It has reiterated that salvage and burning jobs are never routine and are potentially hazardous. It has noted the need for detailed procedures and project risk assessments to be prepared, as per its project management procedures;
- It has noted the need for project management procedures to include formal job handover procedures and project risk assessments;
- It has pointed out the need for formal project risk assessments and work site job safety analyses (JSAs) to identify all potential risks before commencement of operations;
- It is aiming for a better implementation of its 'safety stand-down' system through reinforcement training, in accordance with its management-of-change procedures, to bring about a 'can do/will do **safely**' culture embraced by all employees;
- Again in relation to a better implementation of its management-of-change procedures, the company has noted that, whenever appropriate, project managers, senior and/or onshore management and the customer are to be involved in and to approve all significant changes to procedures.

Excerpt from IMCA Safety Flash 05-04

7 Underwater Explosions

We have received reports from members of four separate incidents of underwater explosions occurring when oxy-arc cutting techniques have been in use:

1. A diver was making corner holes in the ships shell plate using ultrathermic cutting rods to mark the area that had to be cut out. The rod did not ignite and the diver was forced to tap a number of times with the rod on the cutting spot. Every time he tapped, an amount of oxygen must have been escaped from the rod and eventually the mixture in the gas pocket reached its lowest explosion level value. When the rod ignited, the heat, together with hydrogen, reached the gas pocket, which was followed by an explosion. The diver was hit by the pressure wave of the explosion and became dizzy/ unconscious for a short period. The standby diver guided the victim out of the wreck. The diver went into the decompression chamber and was then taken to the hospital for observation. He had some chest pain but was able to resume working after three days.
2. Salvage divers were cutting an access hole into a tank for lifting slings to be installed. The hole had to be burned from the inside to the outside. Before starting with the cutting, the remaining oil and air pockets were removed by a pump. After checking that there were no visible residues of oil the diver started to cut a hole in the tank. Within approximately five seconds an explosion took place. The standby diver immediately started to retrieve the umbilical and the supervisor kept talking to the injured diver. The injured diver managed to climb the dive ladder himself. When the injured diver was on deck the paramedic examined him and he was then taken to hospital. Both of the diver's eardrums had been perforated and he had a sore throat and nose and chest pain. The diver could not resume his work for 37 days.
3. During cutting work in a double bottom on a salvage job while cutting the bottom plating in longitudinal direction, a diver tried to cut a small hole in the tank to avoid gas pockets building up under the tank top. When the cutting rod had initially gone through the tank top plating, the diver had reported some suction into the hole. While he drew the cutting-rod back, an explosion occurred. The diver was able to come to the surface without any problem or assistance of the stand by diver. After the decompression, the diver medic diagnosed a perforation of both eardrums.
4. The fourth incident occurred during the cutting of tank wall plating. The intention was to flush the tank for a couple of hours using an air hose before and during the actual cutting. The diver wanted to cut a small hole in the tank wall, just beside a hole made by his predecessor, to connect a thin rope to keep the air hose in place. Before resuming cutting, the diver felt with his hand inside the hole to check for a gas-pocket and everything seemed to be okay. Within a few seconds of starting cutting, he saw a fire inside the tank and an explosion followed. The diver was able to come to the surface without any problem or assistance of the stand by diver and was transferred to a nearby rig for medical treatment. The medic diagnosed perforation of both eardrums.

5.

Excerpt from IMCA Safety Flash 05-04- Continued.

Oxy-arc cutting involves the use of large quantities of oxygen and generates hydrogen during the process. When the proportion of hydrogen to oxygen reaches a certain level, an explosive mixture is formed, which will ignite when the arc, or a spark, reaches it. Reminders of the following factors known to cause an explosion during oxy-arc cutting have been identified by those involved with these incidents:

- Gas pockets – gas pockets are formed when the shape of a structure is such that bubbles of gas are trapped on their way to the surface and allowed to accumulate in sufficient quantity;
- Blow backs – blow backs are spontaneous explosions of varying intensity which appear to be generated at the cutting point. A research project was carried out on the oxy-arc cutting technique at depth. It showed that there is enough hydrogen produced, during the time between making the rod 'hot' and striking the arc, to cause an explosion. During the research an interval of four seconds was shown to be long enough to produce sufficient hydrogen to cause a serious explosion, even in half-used rod;
- Explosive or flammable substances – depending on the substance involved, various gases or fumes can be released during cutting which can contribute to the mechanism of blow back. For instance: hydrocarbons inside a pipe, paint or bitumastic coatings, and some light alloy materials.

Actions instigated by those involved include specifying the use of hard helmets such as the super-lite for use during operations of this type and cold-cutting-drilling of holes to flush enclosed spaces prior to commencing hot work.
Particular recommendations arising from these incidents have included the following.

It is recommended that detailed risk assessments are carried out before underwater cutting operations commence, specifically when there may be a potential of gas entrapment and/or residual traces of hydrocarbons (such as in double bottom tanks/fuel tanks of vessels). Risk management measures such as diver awareness, for example divers should be familiar with IMCA D 003 (Oxy-Arc Cutting Operations Underwater), use of cold cutting techniques and flushing void spaces with inert gasses such as nitrogen.

The use of Arc Air Rods could also be considered in some cases. Whenever carrying out potentially hazardous operations such as those described in the text, it is imperative that diving supervisors and diving personnel are competent in terms of the skills required by the operation and the identification and management of hazards associated with the operation.

Appendix 6 : Amperage and O2 Matrix

Exothermic Rods Amperage & Oxygen Settings

Oxygen and Amperage setting for exothermic rods. All Oxygen settings should be figured at the torch. Exothermic Rods require 90 PSI at the torch. You must add 5 to 10 PSI for every 100 foot of host for hose loss

Exothermic rods require 150 AMPS at the rod

Length of Power Cable	Amperage settings for Cable Size		
Feet	**#1/O**	**#2/O**	**#3/O**
150	155	152	150
200	157	154	152
250	159	156	154
300	161	158	156
350	163	160	158
400	165	162	160
450	167	164	162
500	169	166	164

- The increase in amperage compensates for resistance losses. For greater lead lengths, add 2 amperes per fifty feet to settings.

Note: These pressures and amperage settings may differ from actual settings required depending on hose/cable lengths, diameter and conditions.

Tubular Steel Rods Amperage and Oxygen Settings

Oxygen and Amperage settings for tubular steel rods, flux coated. All Oxygen settings should be figured at the torch. You must add 5 to 10 PSI for every 100 feet of hose, for hose loss.

It will take 300 amps at the torch head to consume a tubular steel rod

650 AMP Welding Machine at 1800 RPM for Settings of 350 to 575:

Thickness of Metal	Oxygen settings over Bottom PSI	Amperage
5/8", 1/2"	70-80	350-390
3/4"	90-100	370-380
1"	90-100	380-390
1-1/4"	100-125	425-450
1-1/2"	125-150	460-480
1-3/4"	150-170	490-510
1-7/8"	150-170	510-525
2"	170	525-550

Note: These pressures and amperage settings may differ from actual settings required depending on hose/cable lengths, diameter and conditions.

Appendix 7 : BR22 Cutting Torch-Leak Test Procedure

1. Connect the torch to its Oxygen Supply, (contaminant free compressed air or other clean non-combustible gas will also work)
2. Set the regulator pressure to 130 PSI. (normal operating pressure is 90 PSI, 130 is for testing purposed only)
3. Seal off head of the torch
4. Replace the collet washer with a welding collet washer (solid rubber disk). Put a rod stub of full cutting rod in the torch and tighten normally (do not attempt to tighten nut without a rod in place as it will bend the tabs of the collet.)
5. Once the head is sealed, place the torch in a bucket of water, pressurize the torch and pull the torch lever to insure the entire torch is pressurized
6. Keep the lever depressed underwater for at least 30 seconds and look for bubbles. If there are bubbles coming from the torch it should be repaired prior to use. (There will be small bubbles initially as the water displaced any entrapped air in the torch, disregard these initial bubbles.)
7. Remove the torch from the water and point plug away from personnel or property and remove the nut slowly.
8. If torch has leaks repair as required and retest.
9. Remove the solid washer and replaced with normal collet washer.