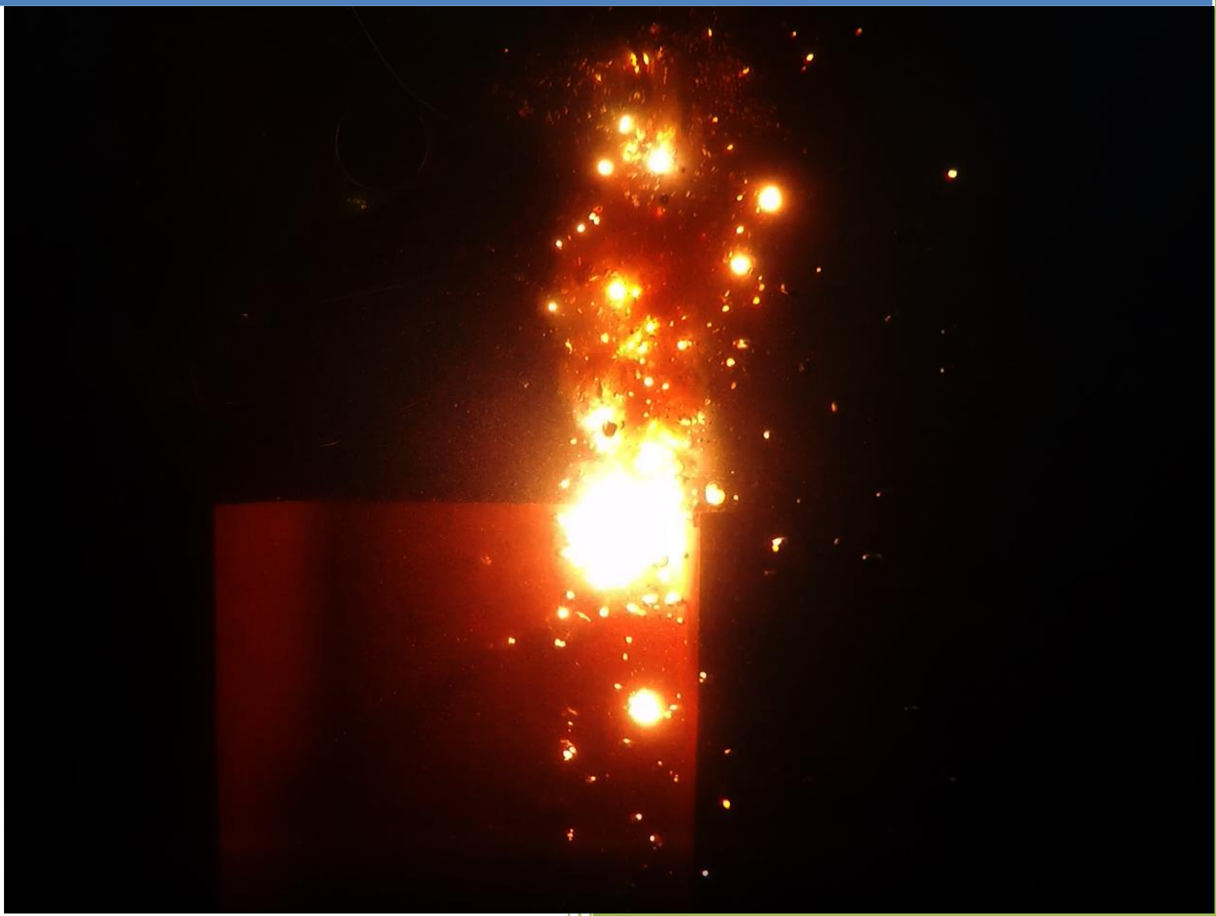
2019

Explosiveness of the underwater residual cutting gasses
Part 1
Fresh water



FRANCIS HERMANS
Retired Commercial Diver
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This study was made possible thanks to the collaboration and the technical assistance of the OCTO DIVING Company

Abstract

This document describes the various tests that have been carried out in fresh water to check the flammability and / or explosiveness of the residual gases produced during cutting with exothermic electrodes. The results obtained show that, contrary to what is generally thought, the gases rising to the surface contained a relatively low percentage of hydrogen which was well below the lower limit of flammability. At first glance, and subject to further study, it seems that the origin of the rare explosions under water related to exothermic cutting in fresh water is not due to an excess of hydrogen but rather to a combustible gas from another source.

Introduction

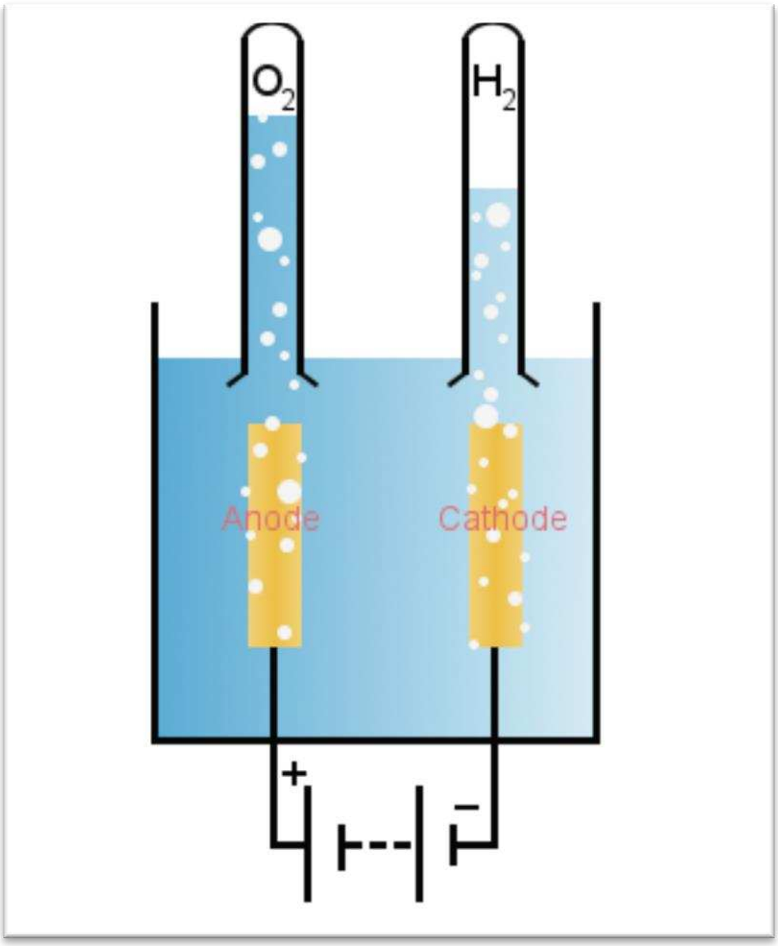
Why this study?
Underwater electric cutting is a technique dating back to 1923.
It has enabled a great deal of work to be done which would not have been possible without this process. Unfortunately, underwater cutting is also the cause of many serious and/or fatal accidents, one of the main causes being related to underwater explosions.
For a large number of accidents, it is known that the origin of the explosion was due to the presence in a confined area of hydrocarbon-based gas. On the other hand, for those whose origin is uncertain or unknown, there is usually a tendency to incriminate hydrogen.
If it is undeniable that a hydrogen / oxygen mixture is an extremely dangerous gas composition, it is necessary for it to become really explosive at surface or under water that the percentages of these two gases is between two well-defined limits of values, the lower explosive limit (LEL) and the upper explosive limit (UEL).
According to our various underwater cutting manuals, this LEL (which for an H_2 / O_2 mixture is 3.9% hydrogen) would be reached very quickly and exceeded, but is this indeed the case?
Very little concrete information on this subject is currently available.
There is the information provided in a video published by the ADCI[1] which informs us in a rather general way that the bubbles produced during the cutting consist of 70 to 90% hydrogen, but when asked for details on how its results have been obtained, the many emails sent to this association remained unanswered.
Similarly, an IMCA[2] document indicates that research on the topic of hydrogen production was conducted following an incident. But here, too, many requests for further information have gone unanswered for a long time, if only a small email indicating that this document was confidential and could not be shared.
Being a little sceptical about the values mentioned in the video, I then began to do an in-depth search on the web and thanks to this I was able to find three documents[3, 4, 5] mentioning the results of analyses that had been done on the residual gases generated during electrical cutting in salt water.
To my great surprise, the average percentage of hydrogen found during these analyses was well below the lower explosive limit of hydrogen, but especially far from the values mentioned in the video.

How was it possible to have such a big difference in measurement?
So I asked myself whether these analyses were a good reflection of the conditions that are encountered in the field, and so I tried to find answers about how hydrogen is produced under water.
The only thing I knew about it, was that this gas was produced on one hand by electrolysis of water and on the other by thermolysis but since my knowledge of chemistry is rather rudimentary it did not allow me to fully grasp the subject and I therefore tried to get answers from competent people, that is to say, chemists who had published papers related to hydrogen.
So I contacted a number of engineers (2), professor (5) and doctor (3) in chemistry and submitted some specific questions, but only four of them were kind enough to answer me, by stating however that they could not help me.
Finding that no help would come from this group of specialists, I finally decided that the only way to get answers to my questions would be to conduct a series of tests in the water and therefore set a message in an FB group to find a dive company that could help me.
Only one, OCTO Diving manifested itself spontaneously and it is thanks to her that the tests presented below could be realized.

Little reminder

How is hydrogen produced under water?
Hydrogen can be produced in two ways when cutting under water, by electrolysis and by thermolysis.
If we look at the many videos available on the web dealing with the electrolysis of water, we can see that when an electric current passes between two electrodes (anode and cathode) of inert metal it will then "crack" (dissociate) the hydrogen and the oxygen atoms present in the water molecules and we will then see a flow of bubbles appear around each electrode.
Hydrogen bubbles will appear around the cathode (electrode connected to the negative pole), while the oxygen bubbles will be generated around the anode (electrode connected to the positive pole).
Since each molecule of water (H_2O) consists of two hydrogen atoms but only one oxygen atom, the amount of hydrogen produced will be twice the amount of oxygen.

Fig 1: Water electrolysis description[6]



Underwater, the cutting process is almost the same.
The torch equipped with the cutting electrode made of copper and other alloys is connected to the negative pole and thus it will react like the cathode of our example and produce bubbles of hydrogen as soon as the electric current is sent into the circuit. On the other hand, and contrary to the tests carried out in the laboratory, under water, the earth clamp is generally connected to an oxidable metal (steel) and in this case very little or no oxygen bubbles at all will appear on the anode side because the oxygen will tend to oxidize and dissolve the metal.
What will greatly influence the flow of hydrogen by electrolysis is the nature of the water in which the diver will cut that is to say fresh water or sea water.
Fresh water generally contains less than one percent of salt and because of this is significantly less conductive of electric current than sea water which greatly reduces electrolysis.

The other way of producing hydrogen takes place by thermolysis or, more simply said, by the vaporization of water. Indeed, if water is brought into contact with a very high heat source, it will then cause the breaking (cracking) of water molecules into oxygen and hydrogen atoms.
The process is relatively simple and can be explained as follows:
When the incandescent slag is ejected from the kerf by the jet of oxygen, it will as soon as it comes into contact with the water be almost instantly wrapped by a film of water vapour (Leidenfrost effect[7]).

Fig 2: Formation of gas bubbles[8]

Inside this gas bubble, the water molecules that are trapped between the incandescent nucleus and the vapour membrane will be cracked within a few milliseconds which will have the effect of separating the H_2 and O_2 atoms.
The oxygen will then immediately begin to oxidize and form a crust around the slag while the hydrogen will dilate the membrane to its breaking point and thus be able to escape to the surface in the form of a small gas bubble. During a few microseconds, the surface of the slag will again be in contact with water, until a new film is created.

Then, the same cycle is resumed for a few seconds until the temperature of the slag no longer allows the chemical reaction.

Fig 3: Description of a gas bubble

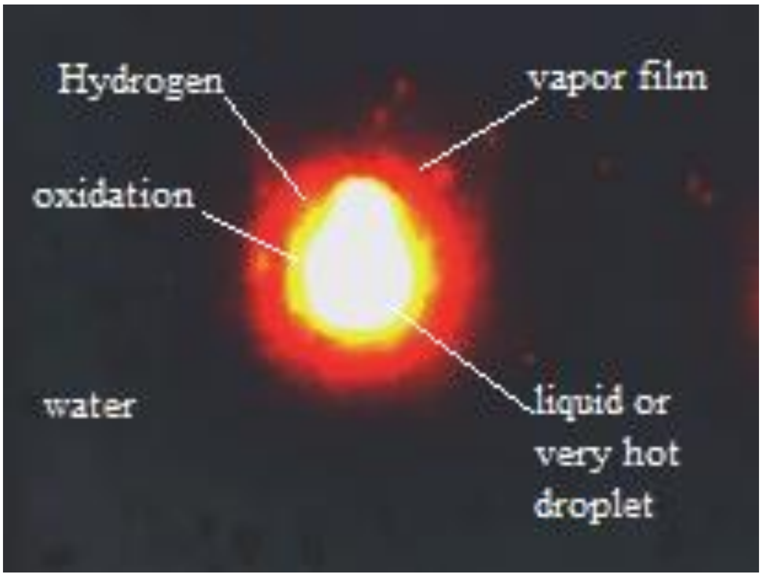


Fig 4: Final slag products

Tests description

Date of the tests
- April 20, 2019

Place
- Water tank of OCTO Diving

Depth
- 3,5 m

Visibility
- Good to poor

Metal piece
- HEA 200

Welding group
- Inverter 400 SX Lincoln

Exothermic electrodes
- Broco

Welding rods
- Barracuda

Diver
- Francis Hermans

Gas recovery system

The residual gases were recovered at the surface via a HDPE pipe Ø 300 in which a recess had been cut in its lower part in order to introduce the steel profile.
To limit the possible effects of an underwater explosion various vents were made in the upper part of the tube at 5 cm below the water level which allowed limiting the volume of gas partially immersed at 2.5 l.
At the same time, these vents also made it possible to evacuate the excess gas towards the outside of the tube, while keeping a slight overpressure (3.5 gr) into the bag.

Fig 5: Gas recovery tube description

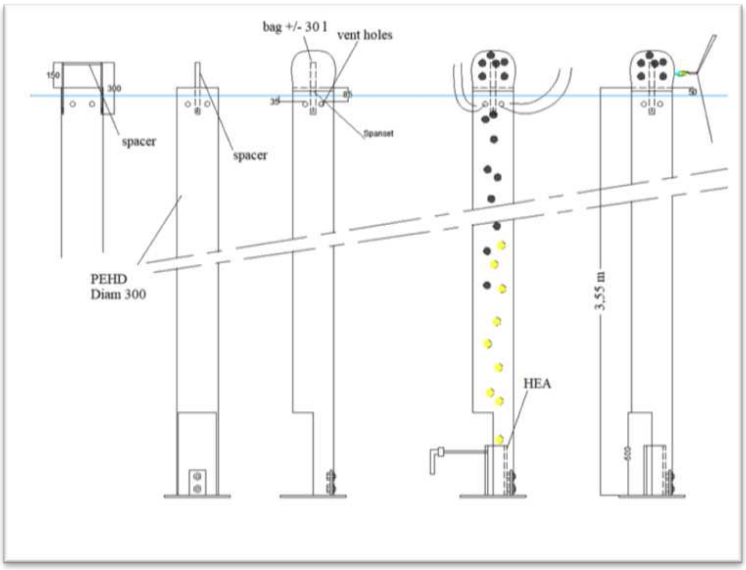


Fig 6: Gas recovery tube

The various tests were conducted in order to answer the following questions.

- Does exothermic cutting in fresh water generate an electrolysis effect?
- Is gas produced at the earth clamp (positive terminal) during reverse polarity cutting?
- Does reverse polarity (+ at torch) produce an electrolysis effect?
- Is the gas produced at the negative terminal actually hydrogen?
- What is the rate at which hydrogen is formed?
- Does the inflammation of pure hydrogen have an explosive effect?
- Are the residual gases generated by “hot” cutting flammable?
- Are the residual gases generated by “hot” cutting explosive?
- Are the residual gases generated by “hot” cutting in straight polarity explosive?
- Does the H_2 % increase with the cutting time?
- Are the residual gases generated by “hot” cutting in straight polarity at 200 Amps explosive?
- Are the residual gases generated by “hot” cutting in reverse polarity explosive?
- Are the residual gases generated by “cold” cutting explosive?
- Are residual gases generated by cutting in a concrete block explosive?
- Are the residual gases generated by welding in straight polarity flammable / explosive?
- What is the residual percentage of oxygen after “hot” cutting?
- What is the residual percentage of oxygen after “cold” cutting?
- What is the residual percentage of oxygen after cutting in a concrete block?
- Do the gases generated by the vaporisation of water in contact with hot steel contain hydrogen?
- Do the gases generated by the slag contain hydrogen?
- What is the flow of hydrogen generated by the slag droplets?

Does exothermic cutting in fresh water generate an electrolysis effect?

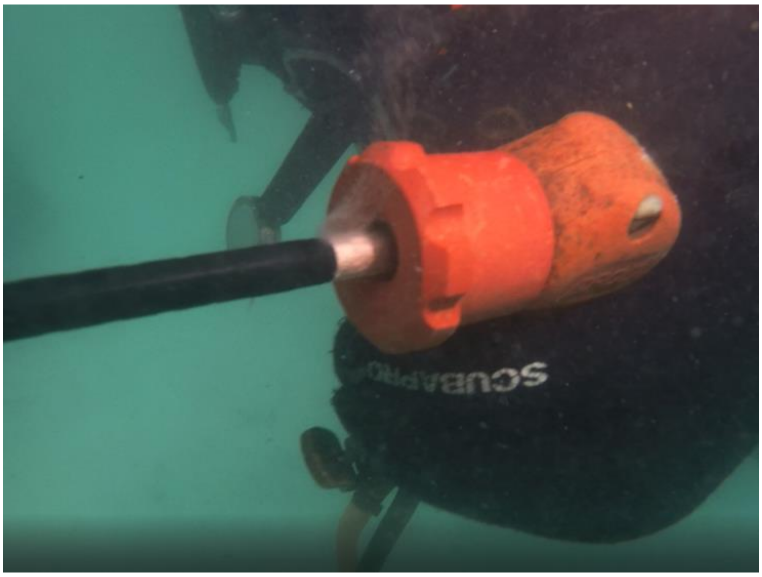
Test n ° 1:

- Connect the earth clamp to the positive pole
- Set the current at 150 Amperes
- Approach the electrode to the piece to be cut
- Check for the presence or absence of electrolysis

Result: A low electrolysis flow is observed in front of the electrode as well as around the non-isolated part entering the cutting torch.

Fig 7: Electrolysis in front of the rod

Fig 8: Electrolysis at the back of the rod



Is oxygen produced at the earth clamp (positive terminal) during cutting?

Test n ° 2

- Connect the earth clamp to the positive pole
- Set the current at 150 Amperes
- Approach the electrode to the piece to be cut
- Check whether gas bubbles are created around the workpiece and / or the earth clamp

Result: In contrast to laboratory electrolysis experiments, no oxygen or chlorine bubbles were observed during the test.

Fig 9: Absence of oxygen bubbles

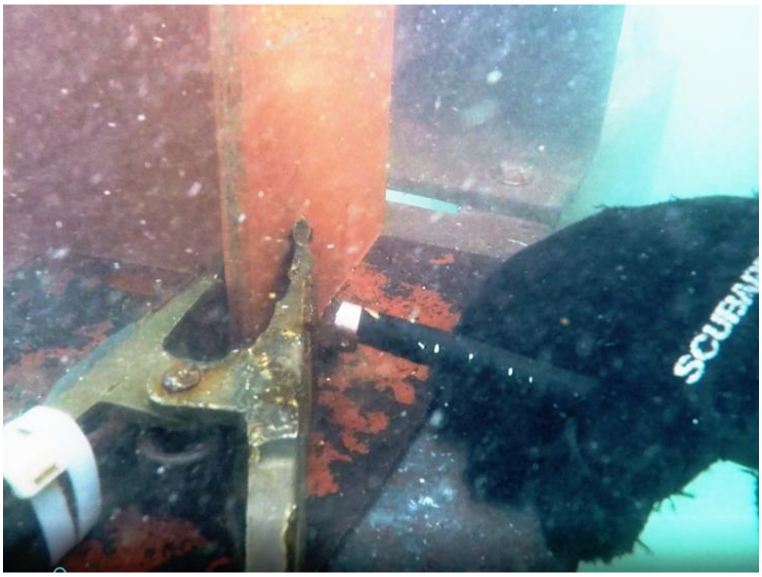
Does reverse polarity (+ at torch) produce an electrolysis effect?

Test n ° 3:

- Connect the earth clamp to the negative pole
- Set the current at 150 Amperes
- Approach the electrode to the piece to be cut
- Check for the presence or absence of electrolysis

Result: No electrolysis flow is observed in front of the electrode as well as around the non-isolated part entering the cutting torch.

Fig 10: Absence of electrolysis



Is the gas produced at the negative terminal actually hydrogen?

Test n° 4:

- Equip an electrode tip with a spacer device to prevent the formation of an electric arc
- Connect the earth clamp to the positive pole
- Set the current at 150 Amperes
- Approach the electrode tip to the metal piece
- Recover about 2 ml of gas
- Make a flammability test on the surface

Result: The gas generated is pure hydrogen

Fig 11: Tip equipped with a spacer device

Fig 12: Gas recovery device

Fig 13: Gas recovery

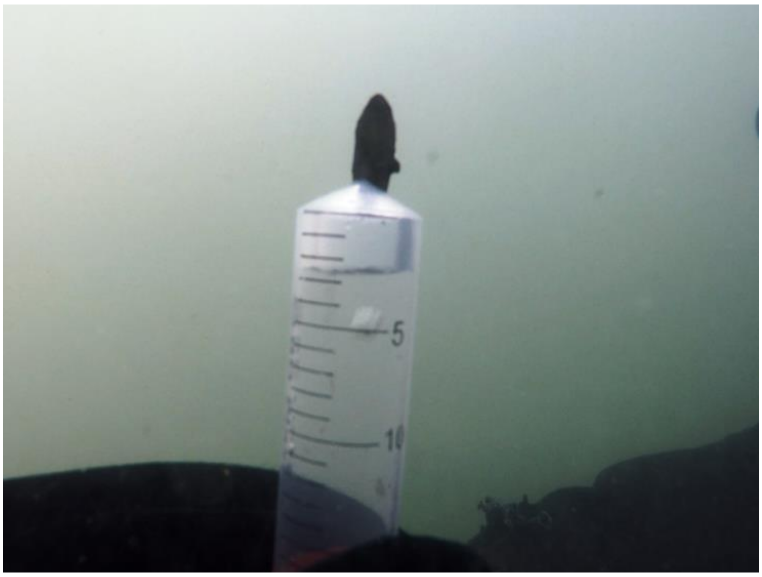
What is the rate at which hydrogen is formed?

Test n° 5

- Equip an electrode tip with a spacer device to prevent the formation of an electric arc
- Connect the earth clamp to the positive pole
- Set the current at 150 Amperes
- Approach the electrode tip to the metal piece
- Recover 3 ml of gas in the test tube and note the filling time

Result: The requested level is reached in 25 seconds, either 0.12 ml / sec or 7.2 ml / minute (the back flow has not been calculated).

Fig n° 14: Hydrogen flow measurement



Does the inflammation of pure hydrogen have an explosive effect?

Test n° 6

- Remove the spacer devise
- Connect the earth clamp to the positive pole
- Set the current at 150 Amperes
- Approach the electrode tip to the metal piece
- Recover about 1 ml of gas
- Create an electric arc without oxygen supply

Result: The gas ignites spontaneously by generating a whitish flash accompanied by a very weak "pop" sound.

Fig 15: Pure hydrogen exploding test

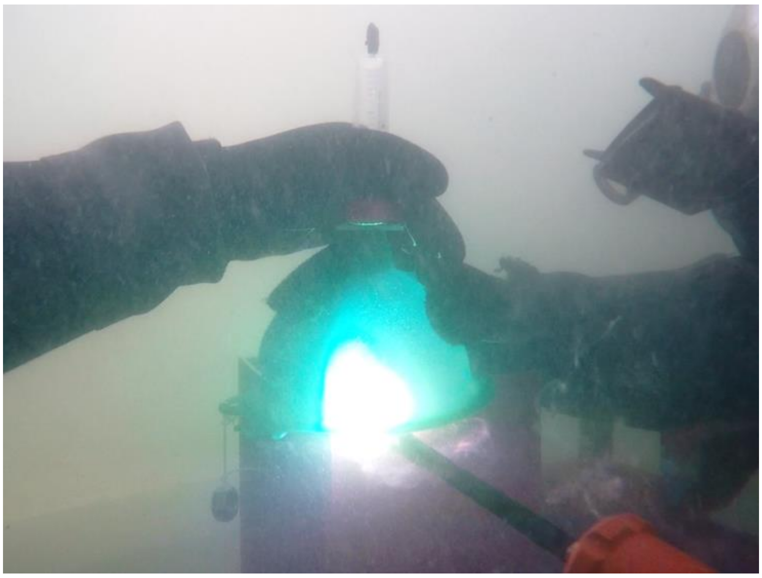
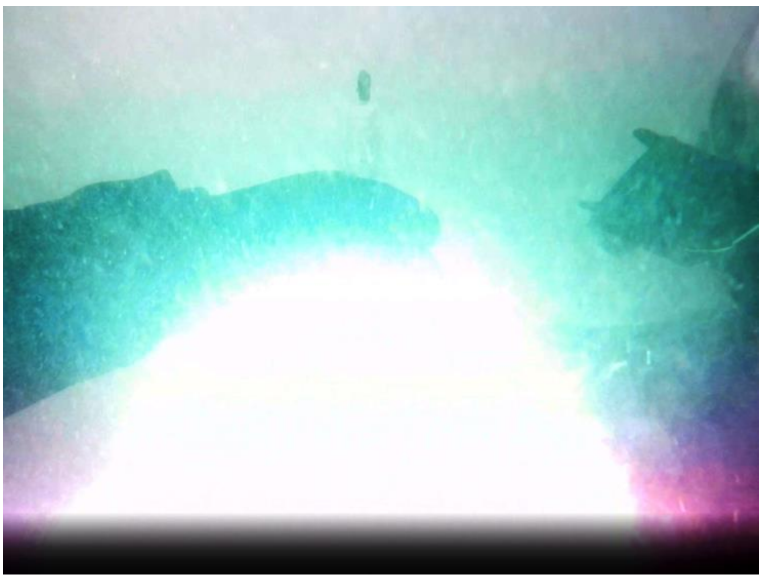


Fig 16: Pure hydrogen exploding test.



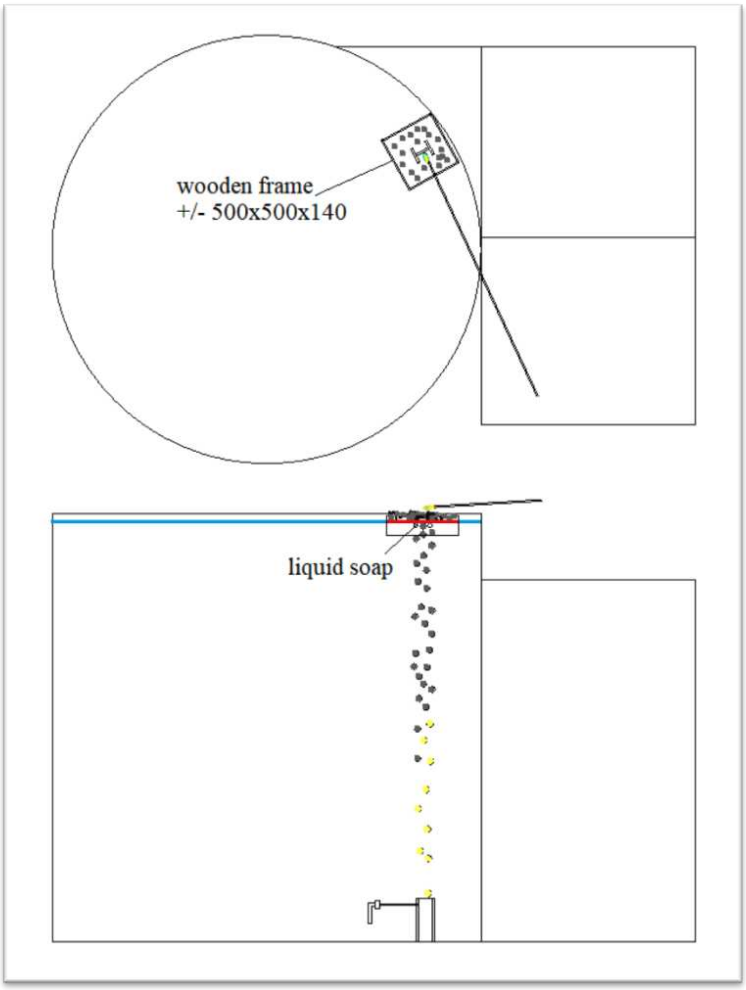
Are the residual gases generated by “hot” cutting flammable?

Test n° 7

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install the piece to cut on the bottom of the tank
- Send an oxygen jet against the piece to be cut
- Place the recovery wood frame over the bubbles
- Put the liquid soap inside the frame
- Cut out an entire electrode and simultaneously test the flammability of the bubbles that form in the frame

Result: Bubbles (1/2 spheres) with a diameter between 1 and 3 cm are formed into the soap and some burst by making small "pops" which shows the presence of pure hydrogen.

Fig 17: flammability test



Are the residual gases generated by "hot" cutting flammable?

Test n° 8

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install the gas recovery tube
- Install the metal piece in the recovery tube
- Cut out an entire electrode and simultaneously test the flammability of the gases flowing back into the tube

Result: The gases ignite very slightly in a discontinuous manner which demonstrates the presence of a small percentage of pure hydrogen in the residual gasses.

Fig 18: Installation of the gas recovery tube

Fig 19: Installation of the metal piece into the gas recovery tube

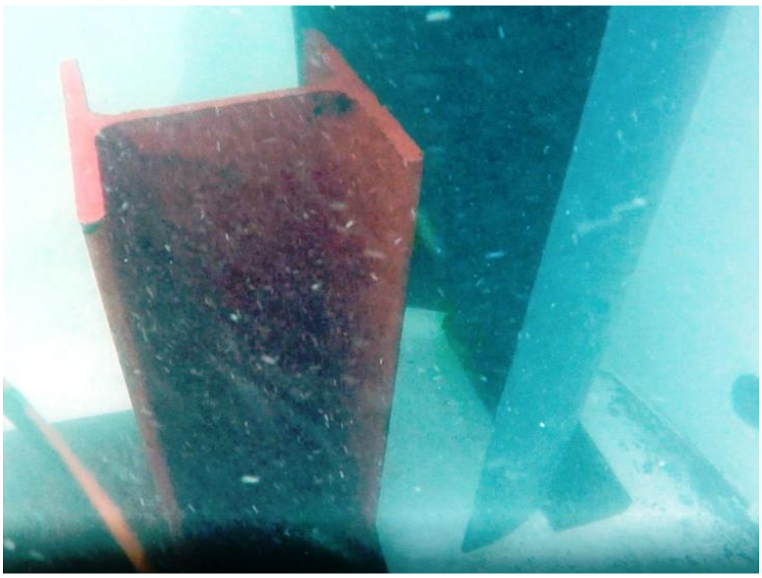
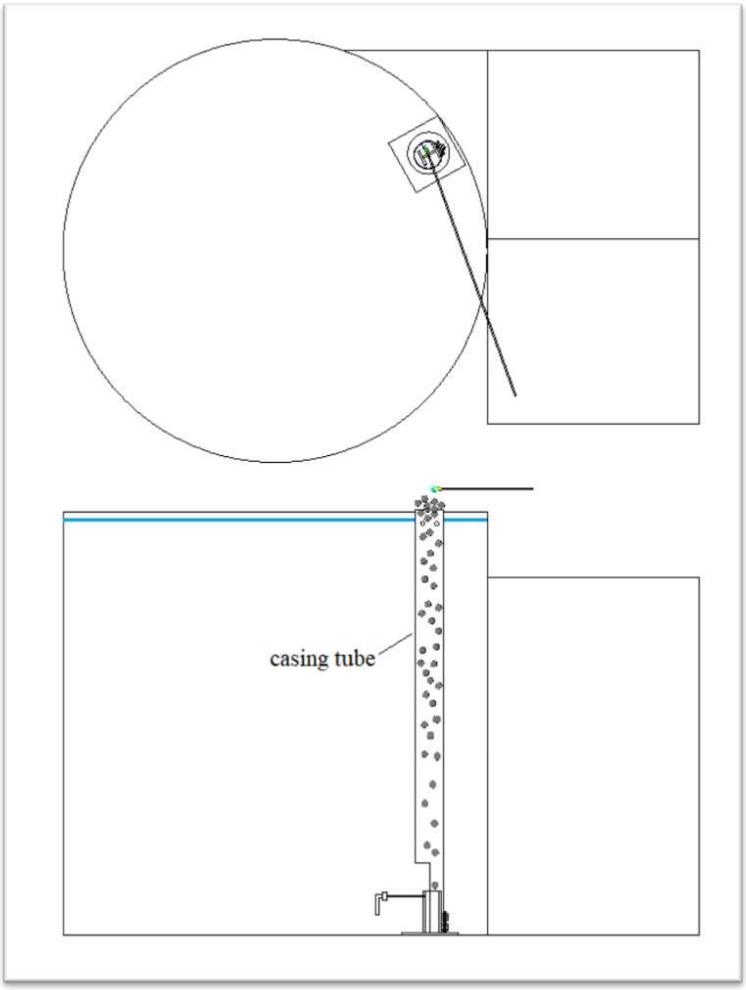


Fig 20: Flammability test



Are the residual gases generated by "hot" cutting in straight polarity explosive?

Test n° 9

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install a recovery bag (30 l) on the recovery tube
- Cut out an electrode during 5 seconds
- Measure the cutting length
- Set on fire
- Measure the sound level

Result: No audible explosion / Bag burns violently but without flash.

Does the $H_{2\,\%}$ increase with the cutting time?

Test n° 10 (A) (B) (C)

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install a recovery bag (30 l) on the recovery tube
- Cut out an electrode during 10/20/45 seconds
- Measure the cutting length
- Set on fire
- Measure the sound level

Result: No audible explosion / Bags burn violently but without flash.

Are the residual gases generated by "hot" cutting in straight polarity at 200 Amps explosive?

Test n° 11

- Set the intensity to 200 amperes
- Set the O_2 pressure to 7 bar
- Install a recovery bag (30 l) on the recovery tube
- Cut out an electrode during 45 seconds
- Measure the cutting length
- Set on fire
- Measure the sound level

Result: No audible explosion / Bag burns violently but without flash.

Are the residual gases generated by "hot" cutting in reverse polarity explosive?

Test n° 12

- Reverse the polarity
- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install a recovery bag (30 l) on the recovery tube
- Cut out an electrode during 45 seconds

- Measure the cutting length
- Set on fire
- Measure the sound level

Result: No audible explosion / Bag burns violently but without flash.

Are the residual gases generated by “cold” cutting explosive?

Test n° 13

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install a recovery bag (30 l) on the recovery tube
- Make it “cold” after starting
- Cut out an electrode during 45 seconds
- Measure the cutting length
- Set on fire
- Measure the sound level

Result: No audible explosion / Bag burns violently but without flash.

Are residual gases generated by cutting in a concrete block explosive?

Test n° 14

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install a recovery bag (30 l) on the recovery tube
- Install the concrete block inside the recovery tube
- Cut out an electrode during 45 seconds
- Set on fire
- Measure the sound level

Result: Two little pops inside the concrete during burning / No audible explosion / Bag burns violently but without flash.

Fig 21: explosiveness test for the cutting operations

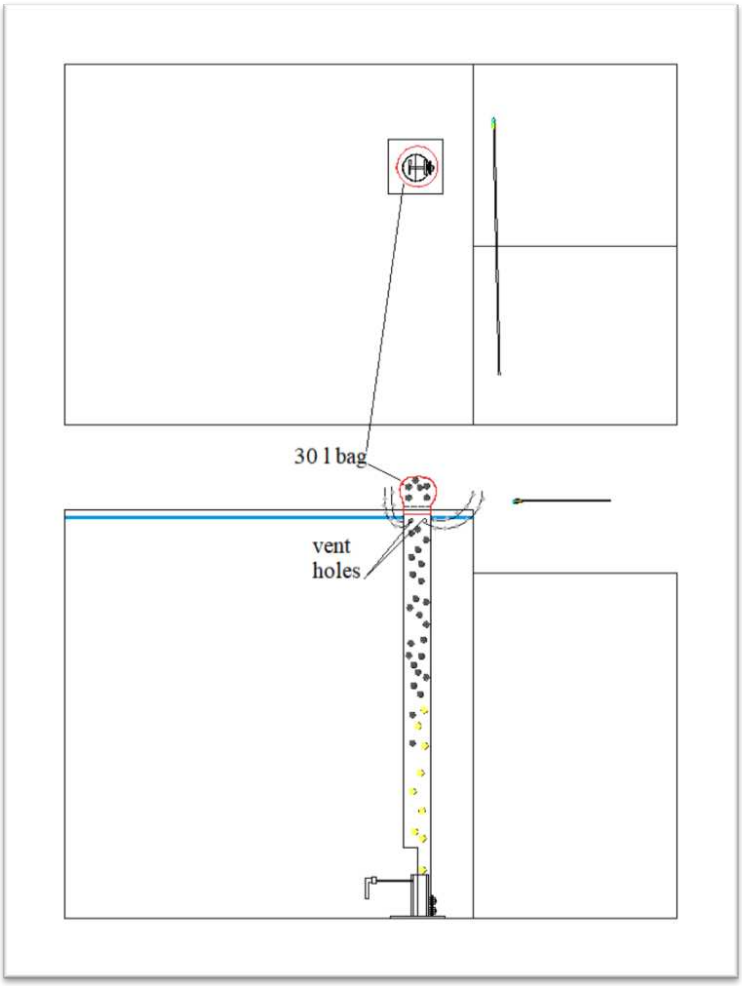


Fig 22: flammability / explosiveness results for all cutting tests

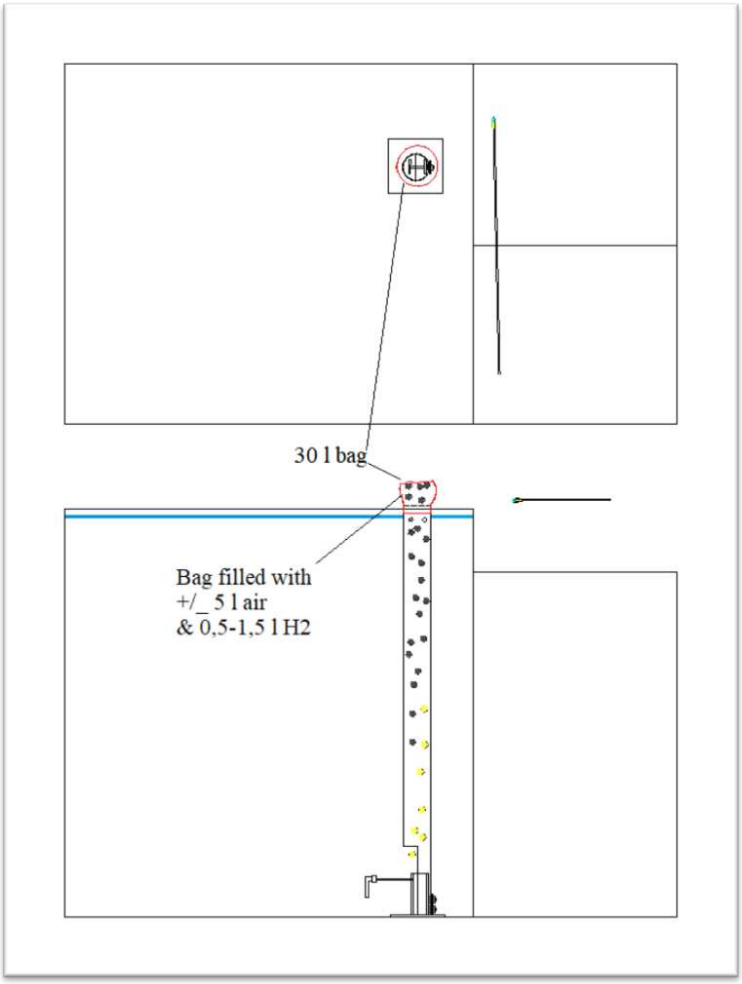
Are the residual gases generated by welding in straight polarity flammable / explosive?

Test n° 15

- Set the intensity to 150 amperes
- Install a recovery bag (30 l) on the recovery tube
- Weld two complete rods
- Set on fire
- Measure the sound level

Result: Loud explosion (99 dB) stronger than the used reference fire cracker (88 dB)

Fig 23: explosiveness test for the welding operation



What is the residual percentage of oxygen after “hot” cutting?

Test n° 16 (A) (B)

- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Install the metal piece
- Install the recovery can (60 l)
- Send a flow of O_2 to check the bubbles axis
- Purge the can
- Cut out an electrode during 45 seconds
- Let the gas settle for 2 minutes
- Analyse the residual O_2 percentage

Result: 97% & 98%

What is the residual percentage of oxygen after “cold” cutting?

Test n° 17 (A) (B)

- Purge the can
- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Cut out “cold” an electrode during 45 seconds
- Let the gas settle for 2 minutes
- Analyse the residual O_2 percentage

Result: 98% & 98%

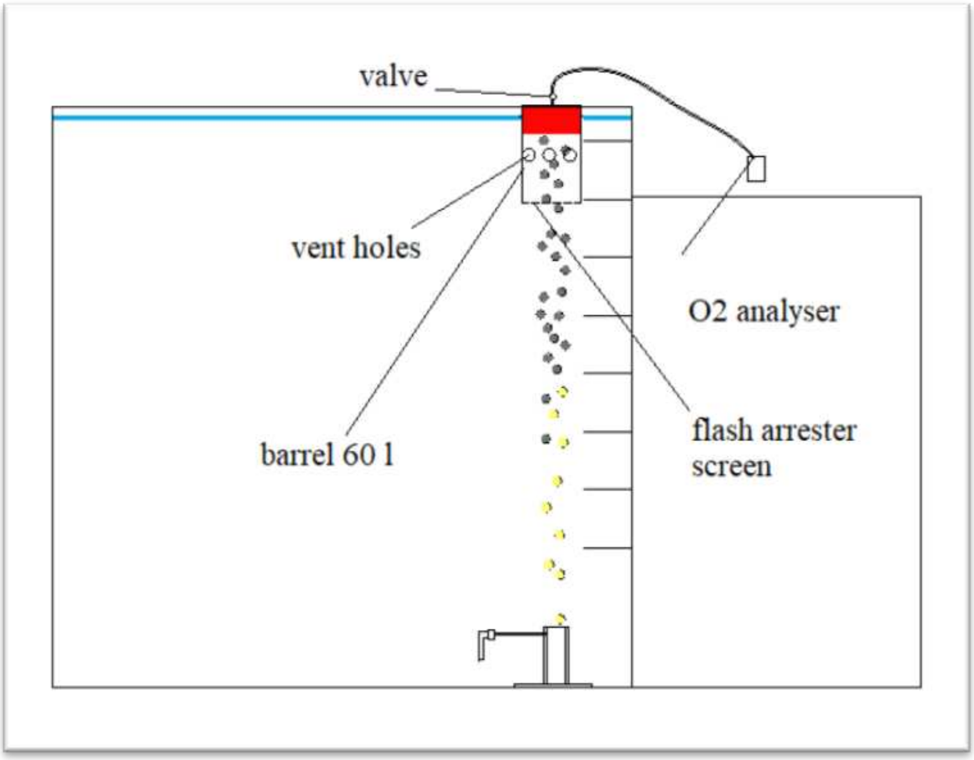
What is the residual percentage of oxygen after cutting in a concrete block?

Test n° 18 (A) (B)

- Purge the can
- Install the concrete block
- Set the intensity to 150 amperes
- Set the O_2 pressure to 7 bar
- Send a flow of O_2 to check the bubbles axis
- Purge the can
- Cut out “cold” an electrode during 45 seconds
- Let the gas settle for 2 minutes
- Analyse the residual O_2 percentage

Result: 92% & 98%

Fig 24: Gas recovery system



Do the gases generated by the vaporisation of water in contact with hot steel contain hydrogen?

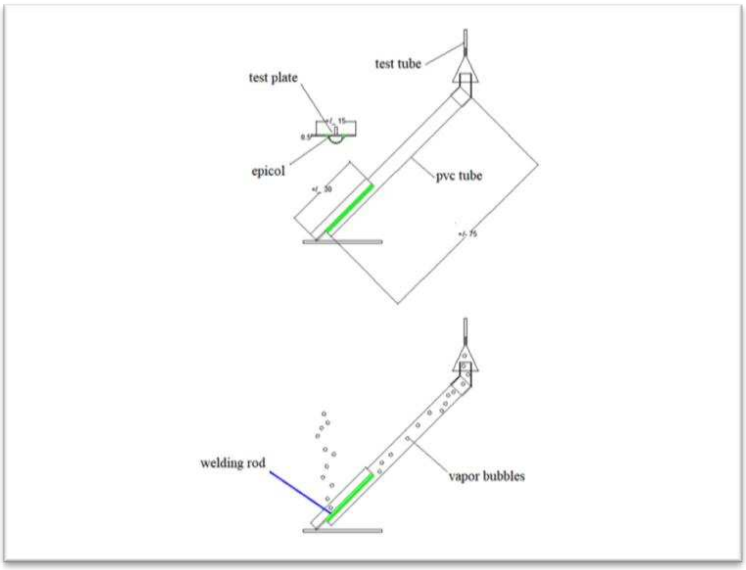
Test n° 19

- Set the intensity to 140 amperes
- Install the 7 mm test plate in the vice
- Weld to complete rods
- Recover the test tube
- Make a flammability test on the surface

Result: welding produced 7 ml of gas at the test depth / little “pop” revealing the presence of H_2

Fig 25: Vapour bubbles flammability test[9]

Fig 26: Vapour bubbles testing set



Do the gases generated by the slag contain hydrogen?

Test n° 20

No tests were performed to recover and analyse the gas generated around the slag, but after having consulted several documents online and after viewing a large number of cutting video where we can see the presence of a halo of a whitish colour whenever bubbles of gas rising from the bottom come into contact with the cutting flame, it is safe to say that its bubbles contain pure hydrogen.

Fig 27: Rising H_2 ready to enter into contact with the flame

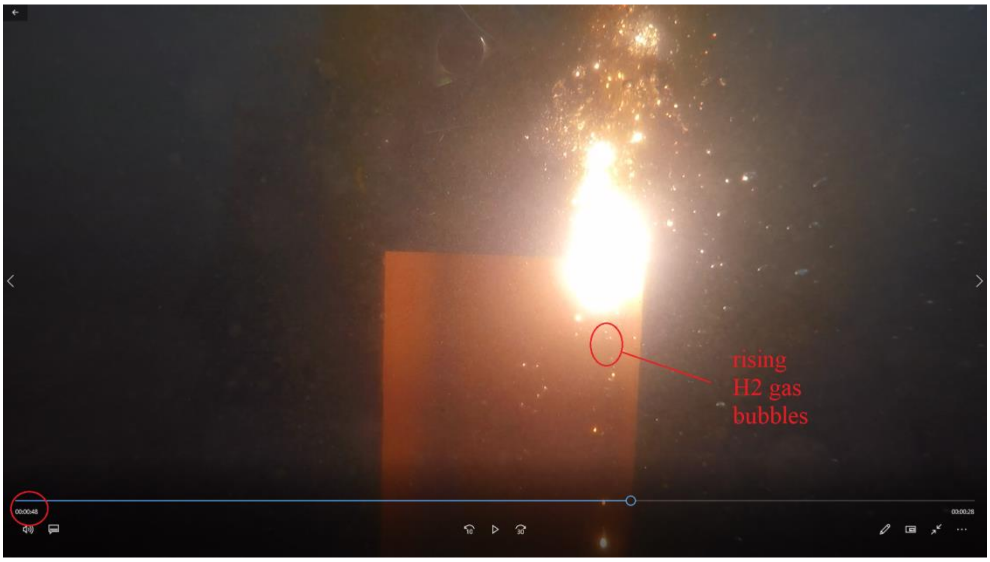
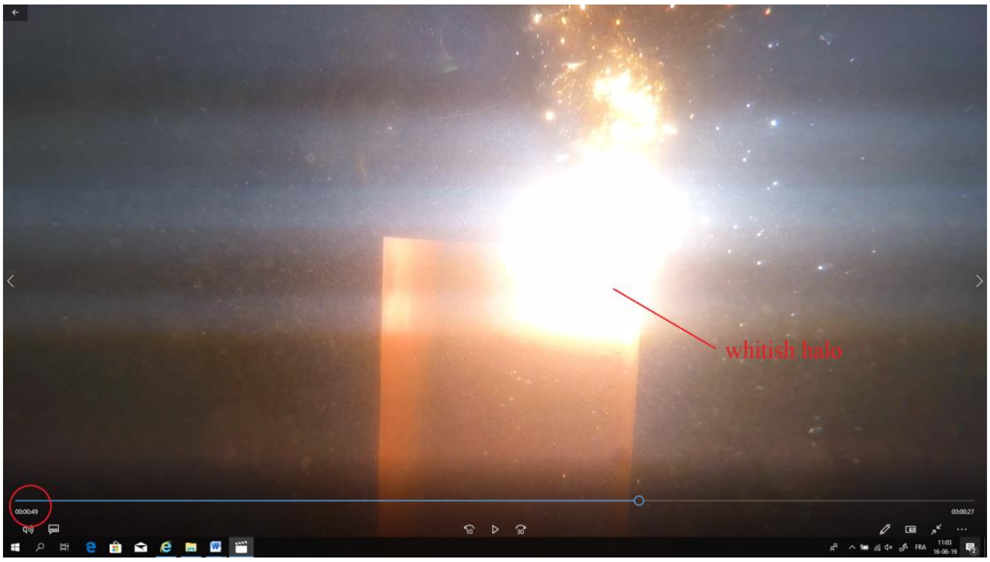


Fig 28: H_2 entering into contact with the flame



What is the flow of hydrogen generated by the slag droplets?

Test n° 21:

No tests were carried out to record the number of bubbles as well as the average volume of gas generated by a cut, but after viewing a large number of cutting video and in view of the slag recovered, it can be estimate that the cut of one cubic centimetre of steel generates about fifteen (15) incandescent slag droplets having a volume of between 65 and 15 mm³ (66.6 mm³ average volume). From the moment it is created until its total cooling (+/- 8 sec) each slag droplet will generate about 40 bubbles containing H_2, that's to say a total volume of gas per cm³ of cut of about:

$$15 \times 40 \times 66{,}6 = 39960 \text{ mm}^3 \text{ or } 39{,}96 \text{ cm}^3 \rightarrow 40 \text{ cm}^3$$

Fig 29: Slag droplets

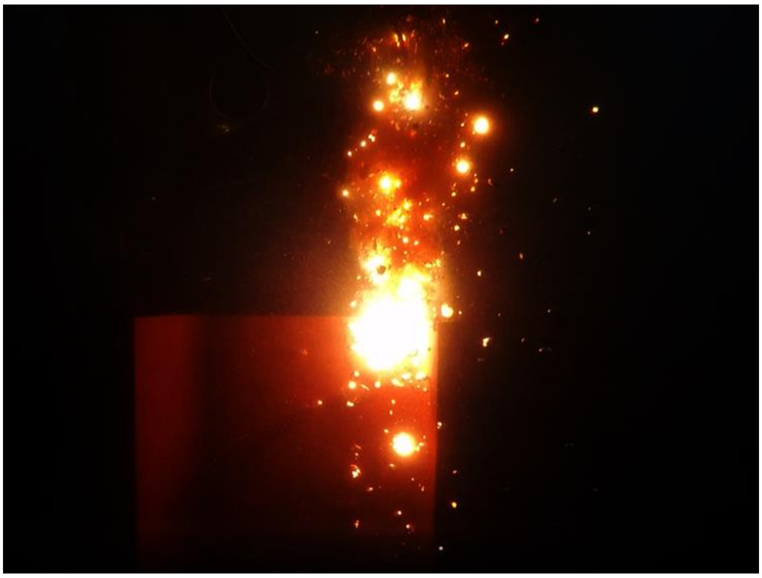


Fig 30: Residual slag droplets

Table 1: Summary results

Test n°	AMPS	Cutting time (s)	Cutting length (cm)	Cut volume (cm³)	O_2 consumption (l)[1]	Burned O_2 (l)[2]	Residual O_2 (l)	H_2 by electrolysis (cm³)[3]	H_2 by vaporization (cm³)[4]	H_2 total (cm³)	Theoretical H_2 %[5]	Residual O_2 %	Sound wave (dB)
9	150	5	3	3	32,5	16,2	16,2	0,6	120	120,6	0,74		/
10A	150	10	7	7	65	32,5	32,5	1,2	280	281,2	0,86		/
10B	150	20	14	14	130	65	65	2,4	560	562,4	0,86		/
10C	150	45	25	25	292	146	146	5,4	1000	1005,4	0,69		/
11	200	45	27	27	292	146	146	5,4	1080	1085,4	0,74		/
12	150+Ve	45	25	25	292	146	146	/	1000	1000	0,68		/
13	cold	45	24	24	292	146	146	/	960	960	0,5		/
15	150	110								0,5 l to 1,5 l	10 to 30		99
16A	150	45			292							97	
16B	150	45			292							98	
17A	cold	45			292							98	
17B	cold	45			292							98	
18A	cold	45			292							92	
18B	cold	45			292							98	

Explanation:

1) O_2 mean consumption / sec = 6,5 l
2) 50% O_2 used to burn steel
3) H_2 produced electrolysis / sec = 0,12 cm³
4) H_2 produced vaporization / cm³ of cut = 40 cm³
5) (H_2 total : residual O_2) x 100 / 1000

Results analysis

Tests 1 – 5

Contrary to what is sometimes thought, we find that in fresh water the phenomenon of electrolysis is present and generates hydrogen.
If we compare the production rates (see Fig 31 & 32), we notice however that it is much less important than that produced in seawater.

Fig 31: Difference in hydrogen production flow (fresh water)

Fig 32: Difference in hydrogen production flow (sea water)[8]

Test 2

In this test it can be seen that no oxygen bubbles are created at the earth clamp side.
It would appear that this is due to the fact that the "anode" in this case the work, is made of steel and therefore rather than creating bubbles, the oxygen oxidizes the metal and dissolves it.

Test 6

This test confirms that pure hydrogen or close to the upper limit of explosiveness (95,8 %) doesn't explode anymore and hence no shock wave is felt by the diver.

Tests 7-8

Discontinuous combustion of surface gases shows that hydrogen bubbles are generated irregularly during cutting.

Tests 9-10

Since we had no indication of the type of decomposition regime (combustion or deflagration) that the gas contained in the bag would take, we opted to check this in a progressive way by choosing 3 rather short cut sequences (5/10/20 seconds). The ignition of the first three bags showed that the decomposition regime was carried out within two seconds in the form of a vigorous combustion demonstrating the presence of a high percentage of oxygen.
After these first three tests, it was logical to think that since hydrogen has a lighter molecular weight than oxygen, part of it could remain confined to the top of the bag during longer cutting sequences and thus increase the proportion of hydrogen. This is apparently not the case since for all the other tests the gases contained in the bags burned in the same way.
It would therefore seem that, whatever the volume of the entrapment, the percentage of the various residual gases remains virtually identical regardless of the number of electrodes used.

Tests 9-14

It can be seen that regardless of the type of configuration, none of the tests generated enough hydrogen in the residual gases to cause the bags to explode.

Why?

The answer is simple,

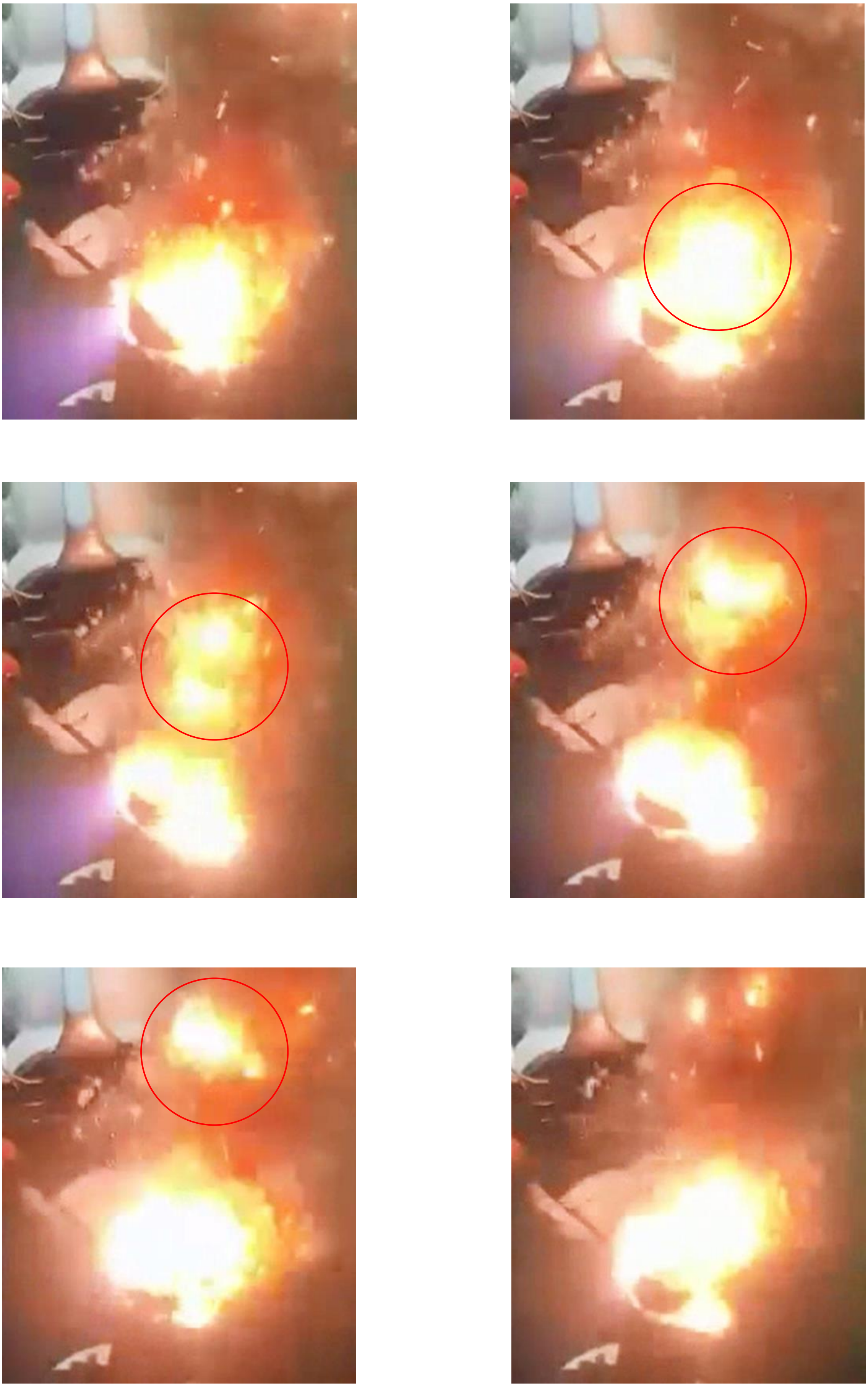
1° even if in the case of fresh water, the production of H_2 by electrolysis is not important, it is interrupted as soon as the electric arc is created. During this period only a few molecules of hydrogen are then produced by the leakage currents.

2 ° a certain part of the hydrogen bubbles produced by the leakage current or by the vaporization burn during the ascent when they come into contact with the incandescent slag (see fig 33).

3° if we look at the table 1; we see that the volume of H_2 produced by electrolysis or by evaporation is far too low compared to the amount of O_2 used during cutting. As a result, the proportion of the H_2 / O_2 mixture remains well below the lower explosive limit (3.9%) of this mixture.

This low percentage of hydrogen is confirmed by the 16 - 18 tests results.
For these analysis tests, it was not possible to use a hydrogen analyser because this type of device was not available for rent and as the purchase of this device was too expensive to a single job, we have therefore decided to analyse only the percentage of the residual oxygen rising to the surface. The maximum percentage of hydrogen in the residual gases could then be estimated by simple subtraction.
Thus, if we go back to the results table we see that the maximum percentage of H_2 analysed in the gases could turn around 3%, but in reality it must be taken into account that other gases (CO, CO_2, N_2)[3,4,5] are also created during cutting and at the same time, it should be noted that a large part of the combustible gases generated by the cutting are burnt before they begin their ascent.
One must therefore expect that in the tests we have carried out, the final percentage of hydrogen is less than 3%.

Fig 33: Residual gas burning sequences [10]



Test 14 & 18
With this test we have simulated the cutting of a pile filled with concrete.
During one of the cuttings a small « pop » occurred while that at the same time a piece of concrete flew away.
The analysis of the first test shows that 92% of oxygen was measured in the residual gas but as concrete is made of organic products, it is probable that in these concrete tests most of the remaining gas was CO instead of hydrogen.

Test 15
Why was there an explosion?
As already specified, for a gaseous mixture to be explosive it must contain a certain proportion of combustible gas as well as oxygen or air.
So questions:
1 ° does residual welding gas contains oxygen?
If we refer to the analysis[11] carried out on a well-known type of electrode, we see that the percentage is extremely low (0.65%).
2 ° does the residual welding gas contain one or more combustible gases?
Here also, if we refer to the same analysis, we note that they contain various combustible gases, mainly hydrogen.
As the production of hydrogen by electrolysis ceases as soon as the arc is initiated, it is likely that in addition to the vaporization of water a portion of the hydrogen as well as the other combustible gases is produced by the decomposition of the flux coating.
3 ° how was there an explosion despite the absence of oxygen?
In this case, the gases were recovered in a bag that already contained about 5 litres of air. According to the intensity of the explosion, it has been estimated that the percentage of hydrogen before firing was probably between 10% and 30% (30% being the optimum mixture for an H_2 / Air mixture), that is to say that the combustion of the two welding electrodes has generated between 0.5 l and 1.5 l of hydrogen.
What this test demonstrates is that although residual gases from underwater welding do not constitute an explosive mixture while coming up in the water, it can, however quickly become so if it is mixed in a containment zone with gas exhaled by the diver.

Test 19
When cutting underwater it is possible in case of visibility to see that during cooling, the kerf edges generate some small bubbles of steam. Since the process of producing these bubbles is different from the one made around the slag droplets, I wanted to know if they also contained hydrogen. The test therefore consisted to weld two electrodes to a plate sufficiently thin to make the back face blush and thus create steam which was then returned to the test tube.
During this test, 7 ml of gas containing hydrogen was actually recovered.
Unfortunately during welding, the intensity of the arc punctured the plate and it is therefore not ruled out that a few hydrogen bubbles passed into the recovery tube.
Therefore, the results of this test cannot be taken into account.

In view of the results obtained during these different tests, it seems that, with regard to freshwater cutting, the risks of explosion by hydrogen formation are limited and usually only concerns the nasty and painful small explosions that occur mostly during the cutting of sheet pile slots.

If one refers to what is written in some of the documents mentioned in the bibliography these blowbacks can be the result of a steam explosion.

These little explosions might take place when a molten droplet contacts the water due to the collapse of the vapor film that surrounds it. The molten droplet can then undergo fine fragmentation (nucleation) that will lead to shock waves.

However, as these small explosions occur mainly in alkali metals and more rarely in steel I personally have another theory.

When a diver is cutting into a sheet pile slot, he usually tends to insist in it with the electrode to be sure that the slot is completely cut.

One can therefore imagine that at the end of the combustion of his electrode a small pocket of oxygen remains confined in the upper part of the recess. It is then sufficient that at the same time one or two incandescent slags droplets are also present in this small cavity to generate enough hydrogen by evaporation and thus create a mixture that will explode when a new rod is made hot.

Fig 34: Formation of an explosive gas mixture into a sheet pile slot (initial state)

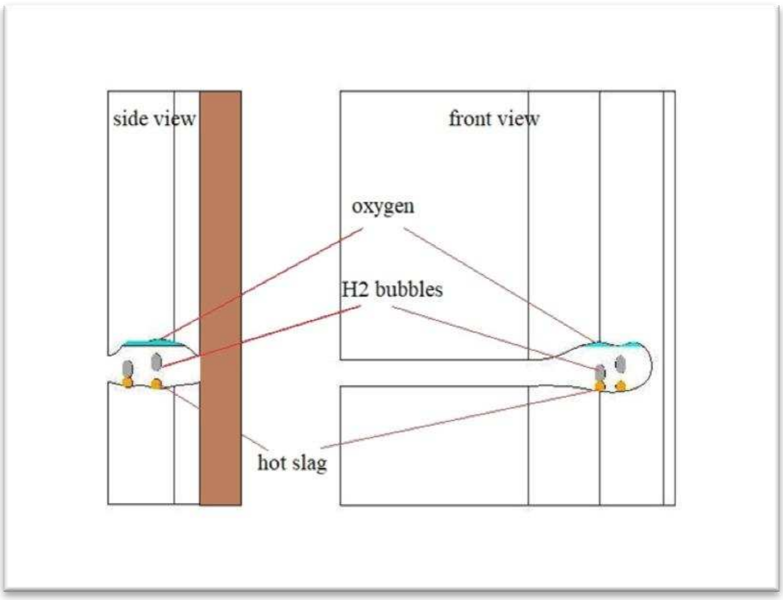
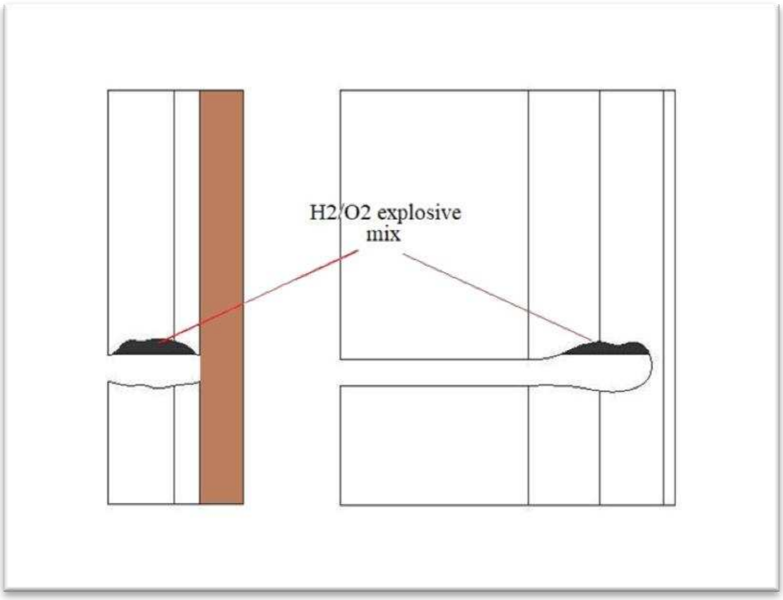


Fig 35: formation of an explosive gas mixture into a sheet pile slot (final state)



Apart from an accumulation of hydrogen in an entrapment, other sources generating fuels may be encountered:

- Seabed methane
- Paints and bituminous coatings
- Metallic alloys and exotic mixes
- Hydrocarbons
- Others

But if we look at the Longstreath incidents list, it seems that accidents related to the cutting in fresh water are rather rare.

Conclusions

Based on the results obtained after our series of tests, it appears that the residual gases generated during a fresh water exothermic cutting contain a lower percentage of hydrogen than is generally predicted. Does this mean that commercial divers are therefore exposed to fewer risks?

CERTAINLY NOT
FUELS MAY COME FROM OTHER SOURCES
SO PLEASE
VENT! VENT! VENT!

Note: As the water characteristics between salt water and fresh water is quite different, the results mentioned in this document are only valid for cutting operation in fresh water.
These same tests as well as a series of others will soon be redone in salt water with this time the technical assistance of the Mr Bart DEHING and his company DB Diving.

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