Electro-Clean Process for 15-L Batch production

August 21, 2020

Production of Dilute HOCl (for surface disinfection) using 15 L Batch-process (for Community-Scale Use)

Safety Hazards:

In this procedure, ordinary salt (NaCl), preferably **non-iodized** table salt, dissolved in ordinary drinking water, is treated with low-voltage (5 volts DC) electricity. DC voltage is considered safe for direct accidental contact with "live" energized components up to 50 volts (3). However, please understand that this 50-volt standard is applicable only for contact with intact skin. If electrical contact occurs to broken skin, harm can be caused at a much lower voltage than 50 volts.

During the chemical reaction process, chlorine gas is produced. US government OSHA allows time-weighted average (TWA) exposure at a workplace of 0.5 ppm, and Short Term (ST) exposure to chlorine at 1 ppm (1, 2). Short-term exposure to chlorine gas at concentrations above these levels (but less than 5 ppm), can cause excessive flow of tears (lacrimation), nose and throat irritation, runny mucus discharge from the nose, excess salivation. Higher-level exposures have more severe health effects. Extremely high levels are fatal. Persons may have different sensitivity to exposure to chlorine gas. **If even low-level exposure symptoms appear, STOP!!**

1. To ensure your safety, **it is mandatory to perform this procedure in an open, well-ventilated space** such as a balcony, covered deck or covered roof-top, open shed, etc. You can also perform it near an open window, if you have a table fan blowing air at it, so all chlorine gas gets blown outdoors through the window.
2. Additionally, **do not connect the switched mode power supply (SMPS) to the external grid-power source until you make sure the reactor is set up correctly.**
3. **To make any changes or adjustments to the reactor circuit, first switch off the power to the SMPS.**
4. **The SMPS itself is a sealed electrical device with high voltage components inside -- DO NOT OPEN the SMPS. If needed, you must take it for repairs to a qualified computer electrician.**
5. **The SMPS must be operated only INDOORS, and away from exposure to water or water spray.**

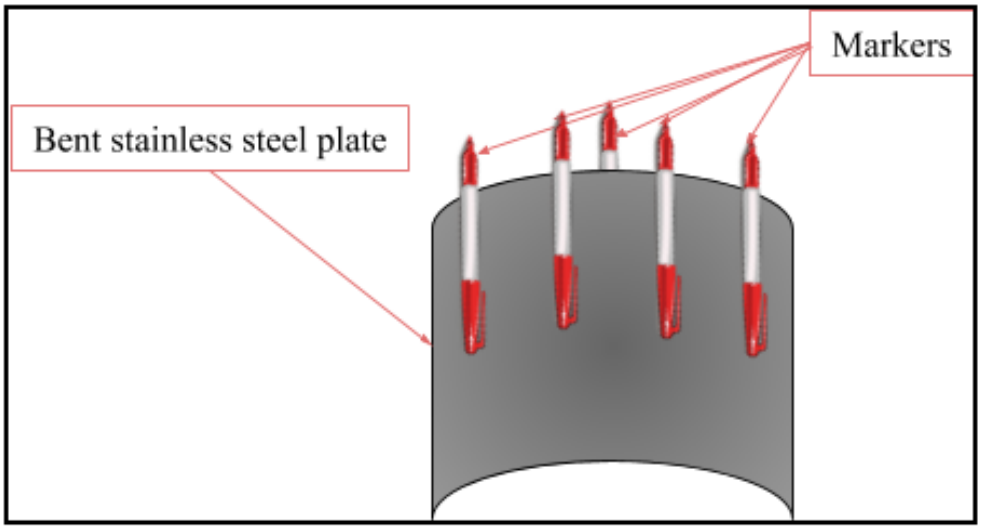
Materials:

1. 19 L to 20 L plastic bucket with its plastic lid (please obtain)
2. 450 grams per 15L batch of table salt, non-iodized (please obtain)
3. White vinegar (or filtered lemon juice), 150 mL (please obtain)
4. 4 uncoated carbon welding rods - or copper-coated if uncoated is unavailable (try to obtain)
5. 35 cm x 35 cm stainless steel plate
6. 5 V, 40 A switched mode power supply (SMPS)
7. 5 nickel-plated alligator clips
8. 5 speaker wires, each 12 gauge, 0.5 meters long, with a banana plug attached to one end (please obtain)
9. 60 cm of 12 gauge wire
10. Plastic pipette (3 or 5mL)
11. Kitchen weighing scale (electronic-scale sold for kitchen use, 1 gram sensitivity)
12. Hach 1454200 Free Chlorine Kit
13. pH paper strips
14. Digital DC voltmeter ammeter, equivalent of that shown on link below (try to obtain) (https://www.amazon.com/DROK-4-5-100V-Voltmeter-Multimeter-Automotive/dp/B07QVXXGVR/)
15. Ruler
16. Protective plastic mesh (please obtain)
17. A piece of conducting metal to act as **current distributor** (e.g. a 6-cm long piece of 1-mm thick bare copper wire, or a copper rod, or a 4-cm by 4-cm piece of 1-mm thick stainless steel plate).

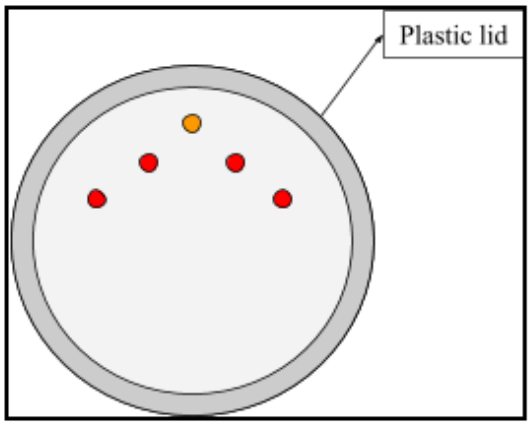
Procedure

Note: If the welding rods are copper coated, please go to **Appendix A** for instructions on how to remove to copper coating. If you are working with uncoated welding rods, directly go to step 1 below.

1) Bend the 35 cm x 35 cm stainless steel plate such that it fits inside the bucket along the sides. Take the stainless steel plate out of the bucket
2) Using the bent stainless steel plate, tape four ~1cm diameter markers on the stainless steel plate on the inside (concave) surface, and one ~1 cm diameter marker on the outside (convex) surface, as shown below. Make sure the markers are equally distanced and the coloring tip is pointing upwards. Paper tape, masking tape, office tape, or duct tape, will all work

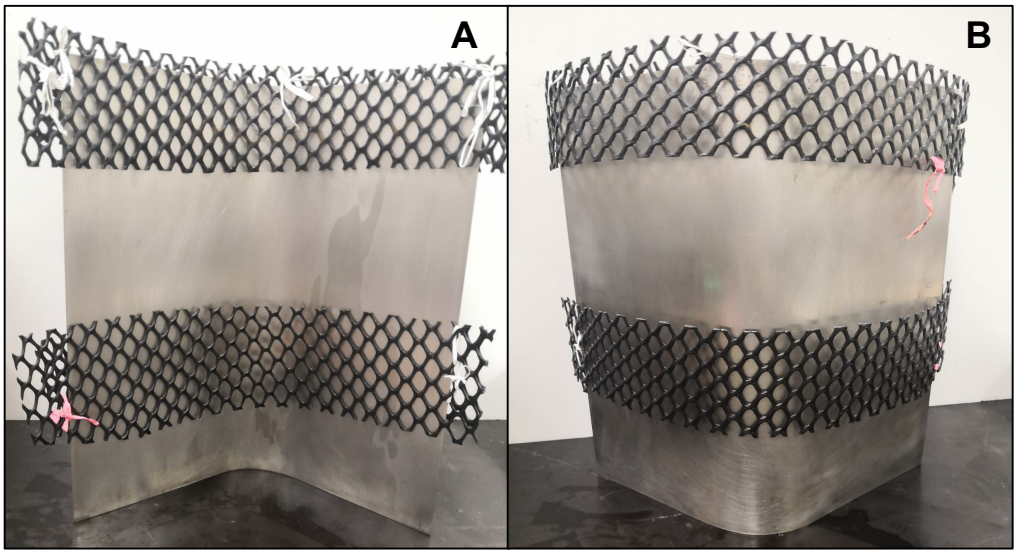


3) Place the stainless steel plate with the markers on it inside the bucket again
4) Mark the plastic lid by placing the lid on the bucket with the stainless steel plate with the markers in it. The marks on the plastic lid should roughly look like the image below:



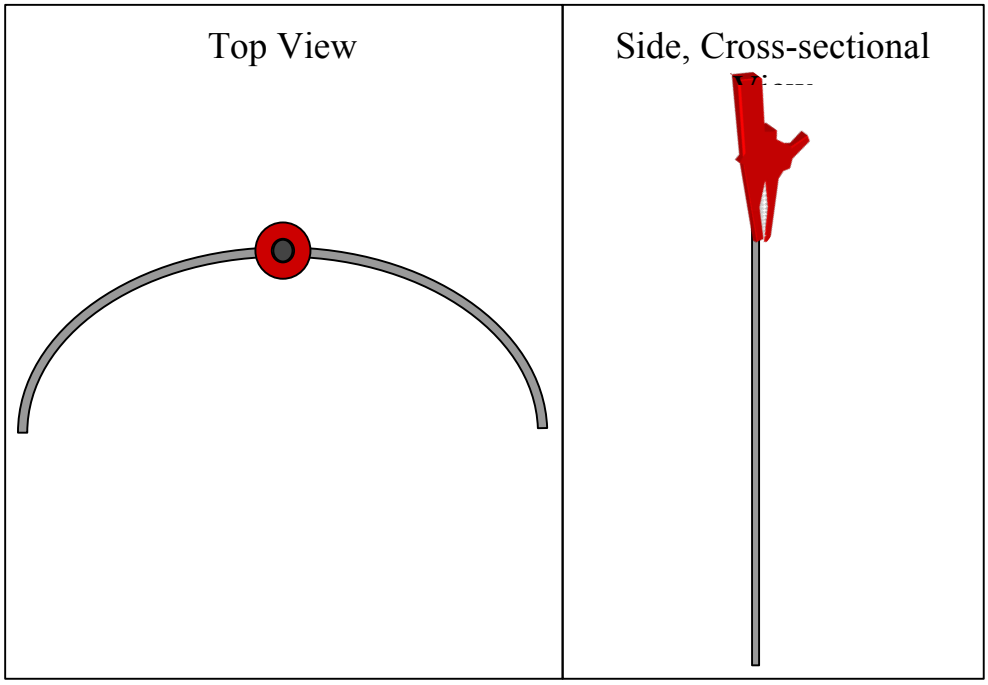
5) Take the stainless steel plate outside of the bucket
6) Remove the markers and wash the stainless steel plate with a brush, soap, and water
7) Rinse thoroughly. Then, dry with a paper towel
8) Using a power drill and a drill bit with a 1 cm diameter, drill holes on the plastic lid where the marks are. For the mark colored in orange in the illustration above, drill a 2 cm diameter hole. This hole will correspond to the alligator clip connecting to the cathode (stainless steel plate). Drill two additional holes anywhere else in the lid to prevent build-up of pressure from gases generated during the process
    a) Clean the plastic lid and remove any leftover plastic debris from the drilling

9) Remove any dust and/or debris from the bucket by washing it with soap and water, and rinsing it thoroughly with water.
10) Fill the bucket with 15 L of ordinary drinking water. In some countries, this will be municipal tap water, if not, then drinking water from any other source is Ok.
    a) You can measure 15 L by using a 1 L water bottle fifteen times.
11) Add 450 grams of non-iodized table salt to the filled bucket. Stir the solution (e.g., with the ruler or long spoon) until the salt dissolves completely.
12) Wash the 4 carbon welding rods using a soft brush (e.g., an old toothbrush will do) with soap and water. Rinse thoroughly. Then, dry with a paper or cloth towel.
13) Using a ruler and a marker, mark a 1 cm mark from the tip of each welding rod
14) Place the protective plastic mesh on the stainless steel plate as illustrated below:
    a) Note: the plastic mesh was tied up using Teflon (plumber's) tape on the sides. You could also use nylon or polyester strings from clothing, or plastic strings.

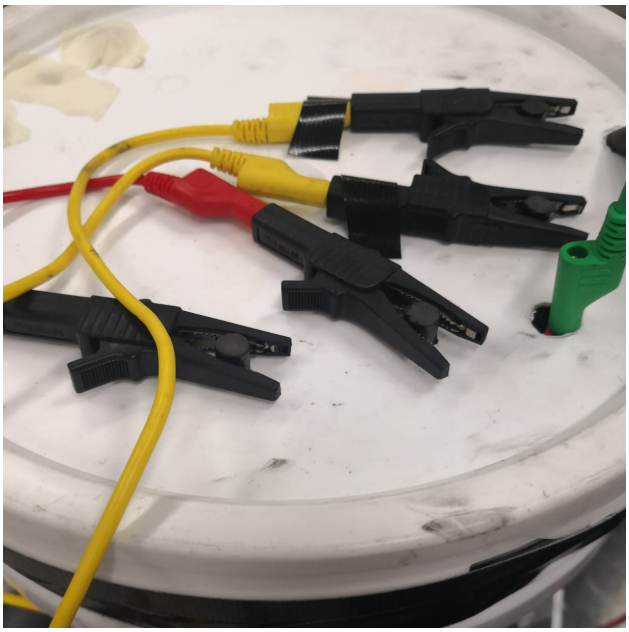


Stainless steel plate with protective plastic mesh front (A) and back (B)

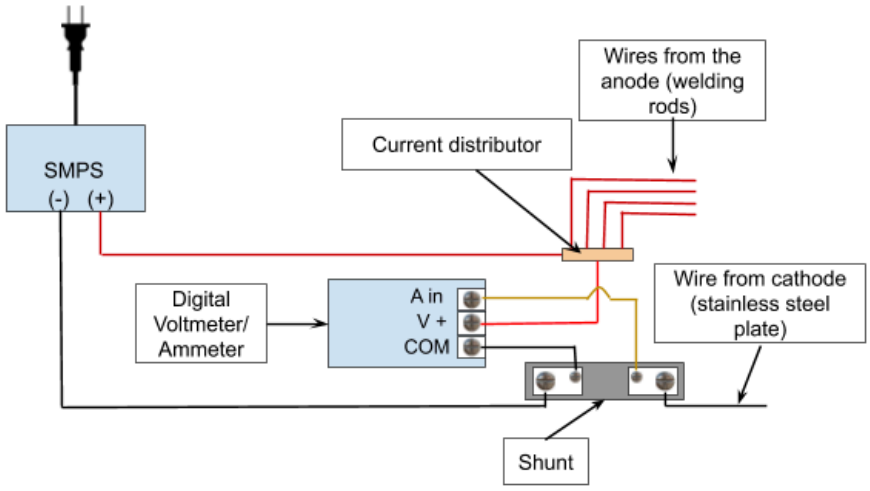
15) Place the stainless steel plate inside the bucket and connect the alligator clip tip in the middle of the plate as illustrated below:



16) Put the lid on the bucket, making sure that the alligator clip goes through its respective hole
17) For each welding rod, attach the alligator clip sideways to the 1 cm mark and put the rod in one of the remaining holes
18) Connect the speaker wires with banana connectors to the alligator clips. In the end, it should look like the image below:



19) Connect the other end of the wires connected to the rods to the current distributor. See Item 16 in Materials list.
20) Connect the wire coming from the positive terminal of the SMPS to the current distributor
21) Cut ~15 cm of the 12 gauge wire (Item 9 from Materials list) and connect one end of this wire to the "V +" input in the digital DC voltmeter-ammeter, and the other end to the current distributor
22) Connect a speaker wire with the banana connector to the cathode alligator clip (this alligator clip is inside the 2 cm hole). This wire will be referred to as the cathode wire.
23) Connect the cathode wire to the big bolt on the right side of the shunt (See figure below)
24) Cut ~15 cm of the 12 gauge wire (Item 9 from Materials list) and connect one end of this wire to the "A in" input in the digital DC voltmeter-ammeter, and the other end to the small bolt on the right side of the shunt (See figure below)
25) Cut ~15 cm of the 12 gauge wire (Item 9 from Materials list) and connect one end of this wire to the COM terminal of the digital DC voltmeter-ammeter and the other end of the wire to the small bolt on the left side of the shunt (See figure below)
26) Connect the wire negative terminal of the SMPS to the remaining big bolt on the left side of the shunt (See figure below)
27) In the end, the connections should look like the picture below:



Note: Not drawn to scale

28) When the connections are all set, plug in the SMPS to a power source
29) Check the current. It should be between 6 amps and 12 amps, depending on how far the rods are from the cathode and the depth of the rods inside the salt water. If the current is too high, and it starts smelling like burnt cable, unplug the SMPS immediately, and check your connections. **Make sure the rods are not touching the stainless steel plate.**
30) If the current is between the range (6-12 Amps), prepare for 3 hours of electrolysis.
31) Measure the current every half an hour.

32) After 3 hours, disconnect the SMPS from the wall plug
33) Remove the lid from the bucket, with the rods still connected to the alligator clips
34) Take the stainless steel plate out of the bucket and wash it with tap water
35) Let the solution stand while the carbon slurry, if any, settles to the bottom of the plastic bucket

Lowering pH with White Vinegar

Note: For a low-alkalinity (2 mM), high TDS (~500 mg/L) synthetic tap water with post-electrolysis pH of 9, approximately 110 mL of vinegar, per 15 L of solution, was needed to bring the pH down to ~6.4.

36) Take a 1 L solution out of the bucket
37) Using a pH strip, measure the pH of this solution
38) If the pH is ~9 or above, add 10 mL of vinegar. If it is below pH 9, add 5 mL and check its pH. Mix well with a long, clean spoon or ruler.
39) Start adding 1 mL of vinegar until the pH reaches between 6.5 and 6.0
    a) Mix well with a long, clean spoon or ruler everytime you add vinegar and before measuring pH
    b) Measure the pH every time after adding vinegar
40) After calculating how much vinegar is needed to lower the pH, add the same proportional amount (14x the amount) to the remaining 14 Liters in the bucket.
41) Return the 1 Liter experimental solution back to the bucket

Measuring Chlorine

Note: If you have access to DI water to perform dilution, please ignore the following step and proceed to Measuring Free Chlorine in Solution after Electrolysis

Measuring Free Chlorine in Tap Water:

42) Following the instructions provided in the Chlorine test Kit (in our case the Hach 1454200 Free Chlorine Kit), measure the Free Chlorine present in the tap water.
    a) Write this concentration down

Measuring Free Chlorine in Solution after Electrolysis:

Note: After three hours of electrolysis, the final free chlorine concentration was ~600 ppm Free Chlorine as Cl_2 when the current was ~8.5 Amps, in our laboratory. If using the Hach 1454200 Free Chlorine Kit, which can measure up to 3.4 ppm Cl_2, a 200 dilution factor will be necessary for Free Chlorine measurement.

43) Using the cooking weighing scale and a clean, empty cup, measure 250 grams (~250 mL) of tap water (or DI water)

44) Using the plastic pipette, take approximately 1.25 mL of the electrolyzed solution into the cup of tap water (or DI water). Mix diluted solution using a clean and dry spoon.
45) Use this diluted solution to measure free chlorine concentration.
46) Follow the instructions provided in the Chlorine kit. Do not forget to multiply the final reading by the dilution factor, which in this case was 200.
    a) If the concentration was below or above the range of the chlorine measuring kit, please change the dilution factor accordingly.
47) If you used tap water to dilute the solution, please subtract to the final Free Chlorine concentration, the Free Chlorine concentration measured in the tap water.

References

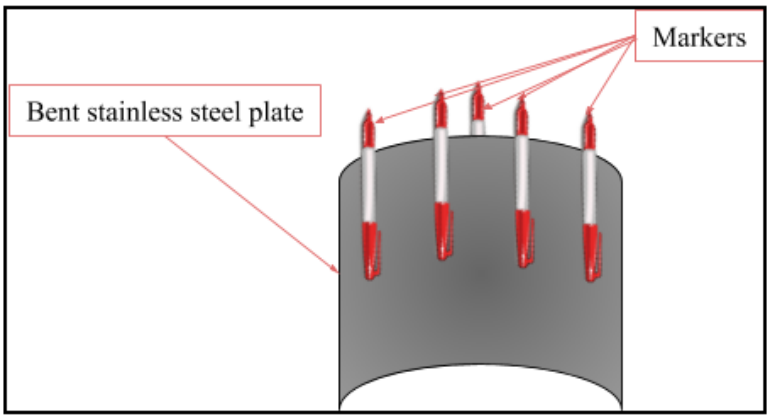
1. Air Contaminants Update Project. (2018, October 18). Retrieved August, 2020, from https://www.cdc.gov/niosh/npg/nengapdxg.html
2. CDC - NIOSH Pocket Guide to Chemical Hazards - Chlorine. (2019, October 30). Retrieved August, 2020, from https://www.cdc.gov/niosh/npg/npgd0115.html
3. Guarding requirements for 50 volts or more DC. (2015, September 4). Retrieved August, 2020, from https://www.osha.gov/laws-regs/standardinterpretations/2015-09-04

Appendix A

Removing copper coating from coated welding rods

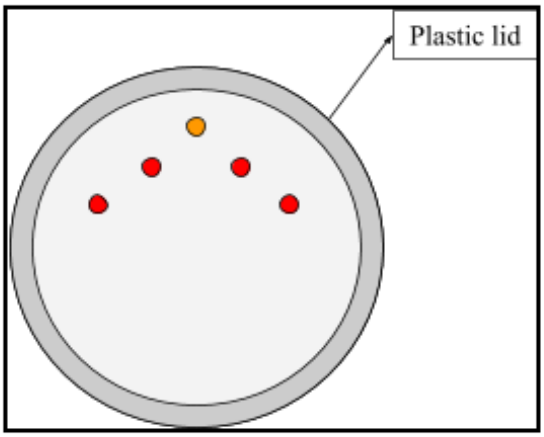
1.) Bend the 35 cm x 35 cm stainless steel plate such that it fits inside the bucket along the sides. Take the stainless steel plate out of the bucket.

2.) Using the bent stainless steel plate, tape four ~1cm diameter markers on the stainless steel plate on the inside (concave) surface, and one ~1 cm diameter marker on the outside (convex) surface, as shown below. Make sure the markers are equally distanced and the coloring tip is pointing upwards. Paper tape, masking tape, office tape, or duct tape, will all work.



3.) Place the stainless steel plate with the markers on it inside the bucket again.

4.) Mark the plastic lid by placing the lid on the bucket with the stainless steel plate with the markers in it. The marks on the plastic lid should roughly look like the image below:



5.) Take the stainless steel plate outside of the bucket.
6.) Remove the markers and wash the stainless steel plate with a brush, soap, and water. Rinse thoroughly. Then, dry with a paper towel.
7.) Using a power drill and a drill bit with a 1 cm diameter, drill holes on the plastic lid where the marks are. For the mark colored in orange in the illustration above, drill a 2 cm diameter hole. This hole will correspond to the alligator clip connecting to the cathode (stainless steel plate). Drill two additional holes anywhere else in the lid to prevent build-up of pressure from gases generated during the process.
    a.) Clean the plastic lid and remove any leftover plastic debris from the drilling
8.) Remove any dust and/or debris from the bucket by washing it with soap and water, and rinsing it thoroughly with water.
9.) Fill the bucket with 15 L of ordinary drinking water. In some countries, this will be municipal tap water, if not, then drinking water from any other source is Ok.
    a.) You can measure 15 L by using a 1 L water bottle fifteen times.
10.) Add 450 grams of non-iodized table salt to the filled bucket. Stir the solution (e.g., with the ruler or long spoon) until the salt dissolves completely.
11.) Wash the 4 carbon welding rods using a soft brush (e.g., an old toothbrush will do) with soap and water. Rinse thoroughly. Then, dry with a paper or cloth towel.
12.) Using a ruler and a marker, mark a 1 cm mark from the tip of each welding rod
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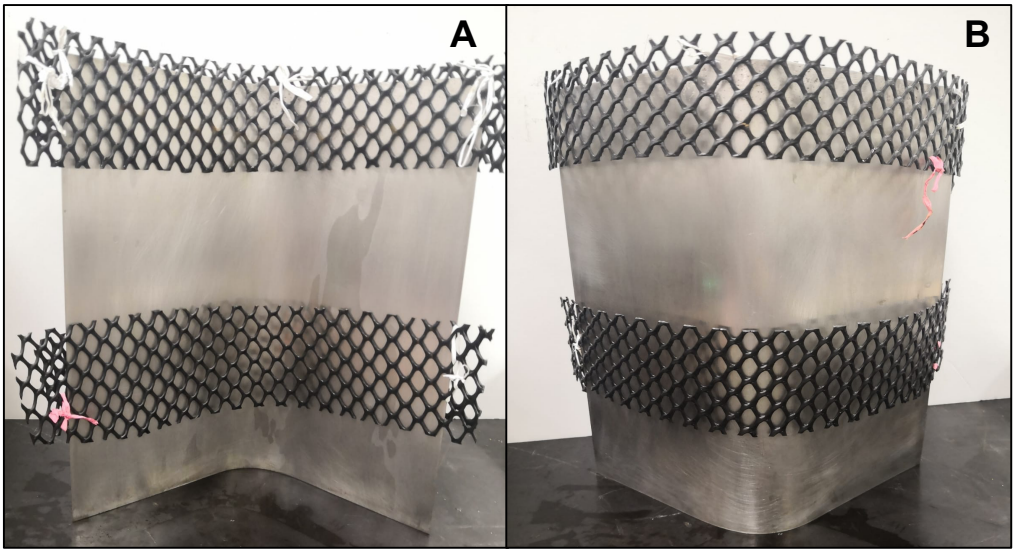
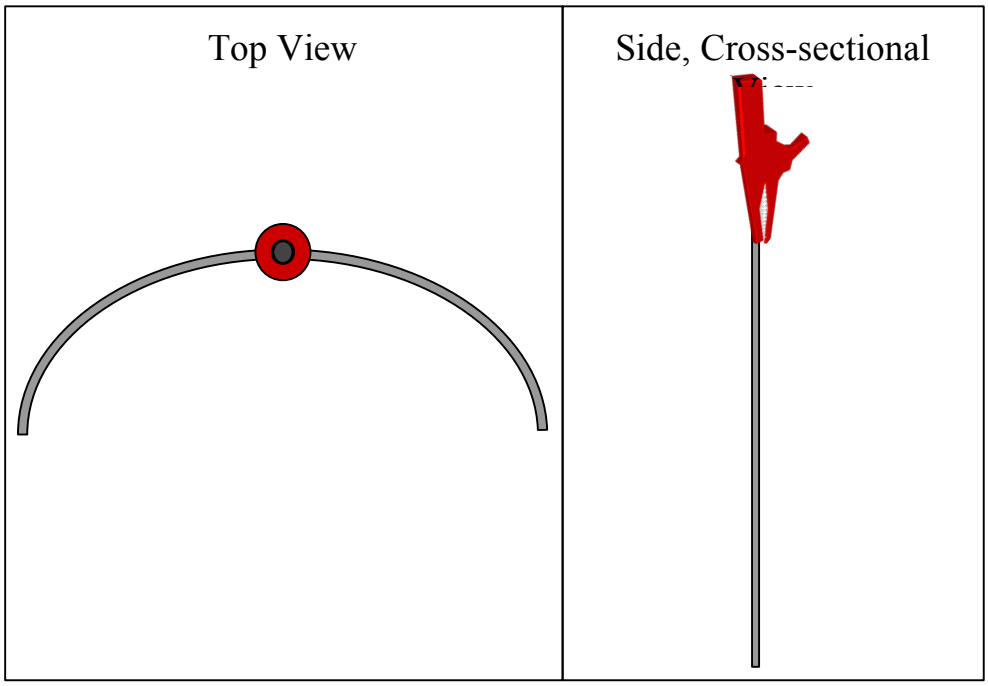


Stainless steel plate with protective plastic mesh front (A) and back (B)

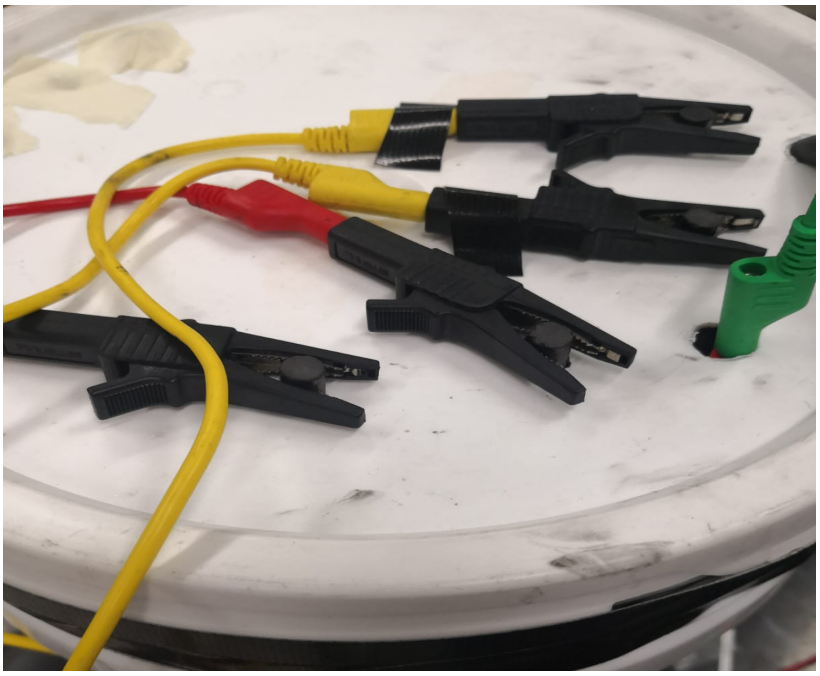
14.) Place the stainless steel plate inside the bucket and connect the alligator clip tip in the middle of the plate as illustrated below:



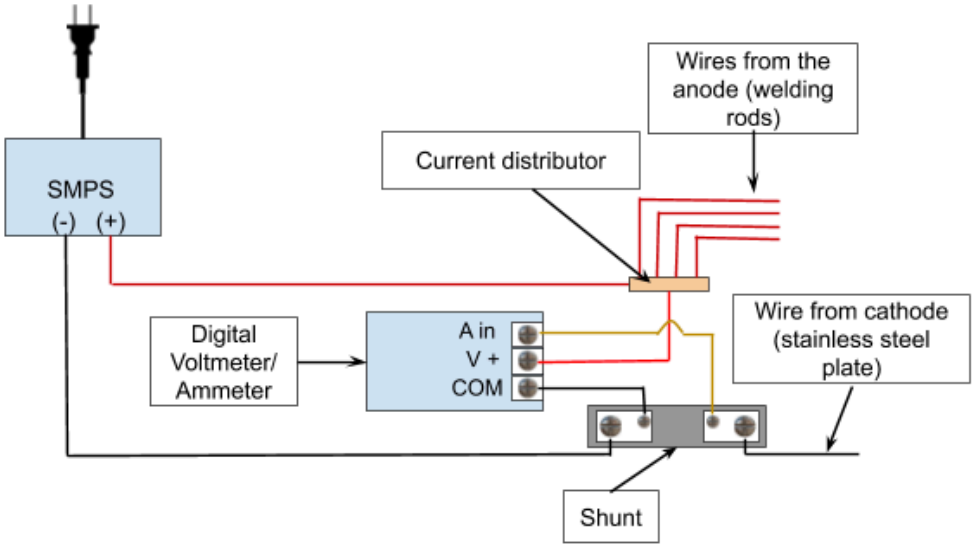
15.) Put the lid on the bucket, making sure that the alligator clip goes through its respective hole

16.) For each welding rod, attach the alligator clip sideways to the 1 cm mark and put the rod in one of the remaining holes

17.) Connect the wires with banana connectors to the alligator clips. In the end, it should look like the image below:



18.) Connect the other end of the wires connected to the rods to the current distributor. See Item 16 in Materials list.
19.) Connect the wire coming from the positive terminal of the SMPS to the current distributor
20.) Cut ~15 cm of the 12 gauge wire (Item 9 from Materials list) and connect one end of this wire to the "V +" input in the digital DC voltmeter-ammeter, and the other end to the current distributor
21.) Connect a speaker wire with the banana connector to the cathode alligator clip (this alligator clip is inside the 2 cm hole). This wire will be referred to as the cathode wire.
22.) Connect the cathode wire to the big bolt on the right side of the shunt (See figure below)
23.) Cut ~15 cm of the 12 gauge wire (Item 9 from Materials list) and connect one end of this wire to the "A in" input in the digital DC voltmeter-ammeter, and the other end to the small bolt on the right side of the shunt (See figure below)
24.) Cut ~15 cm of the 12 gauge wire (Item 9 from Materials list) and connect one end of this wire to the COM terminal of the digital DC voltmeter-ammeter and the other end of the wire to the small bolt on the left side of the shunt (See figure below)
25.) Connect the wire negative terminal of the SMPS to the remaining big bolt on the left side of the shunt (See figure below)
26.) In the end, the connections should look like the picture below:



Note: Not drawn to scale

27.) When the connections are all set, plug in the SMPS to a power source

28.) Check the current. It should be between 6 amps and 12 amps, depending on how far the rods are from the cathode and the depth of the rods inside the salt water. If the current is too high, and it starts smelling like burnt cable, unplug the SMPS immediately, and check your connections. **Make sure the rods are not touching the stainless steel plate.**

29.) If the current is between the range (6-12 Amps), prepare for 5 hours of electrolysis.

30.) Check the current every half an hour, making sure the system is working properly.

31.) After 5 hours, disconnect the SMPS from the wall plug

32.) Remove the lid from the bucket, with the rods still connected to the alligator clips

33.) Check if the coating has been removed from the welding rods. If not, put the lid back on the bucket, making sure the cathode and anode are not touching.

a.) Connect the SMPS back to the power source and continue the electrolysis. Disconnect the SMPS every half an hour to check if the coating has been removed. After the coating has been removed, take the lid off the bucket, with the rods still connected to the alligator clips and put it on the table.

34.) Take the stainless steel plate out of the bucket and wash it with a brush, soap, and tap water

35.) Disconnect the alligator clips from the rods

36.) Take the welding rods out of the lid and gently clean them using a brush, soap and water. Rinse thoroughly.

37.) In a sink, carefully dispense of the solution inside the bucket

38.) Clean the bucket thoroughly using a brush, soap, and water

39.) To generate Free Chlorine using the now uncoated welding rods, please go to **Procedure** and start from Step 10.