Work Instruction for Propeller Polishing with SubBlue Robot

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Introduction

Work instruction, reason and purpose

This is a work instruction pertaining to SubBlue Robotics propeller polishing operations with the SubBlue robot.

The purpose is to inform the user of all necessary procedural and safety precautions.

It also describes the principle responsibilities of parties involved in the operation.

This work instruction was worked out by SubBlue Robotics for operating in Rotterdam, and is submitted to Rijkswaterstaat in the Netherlands.

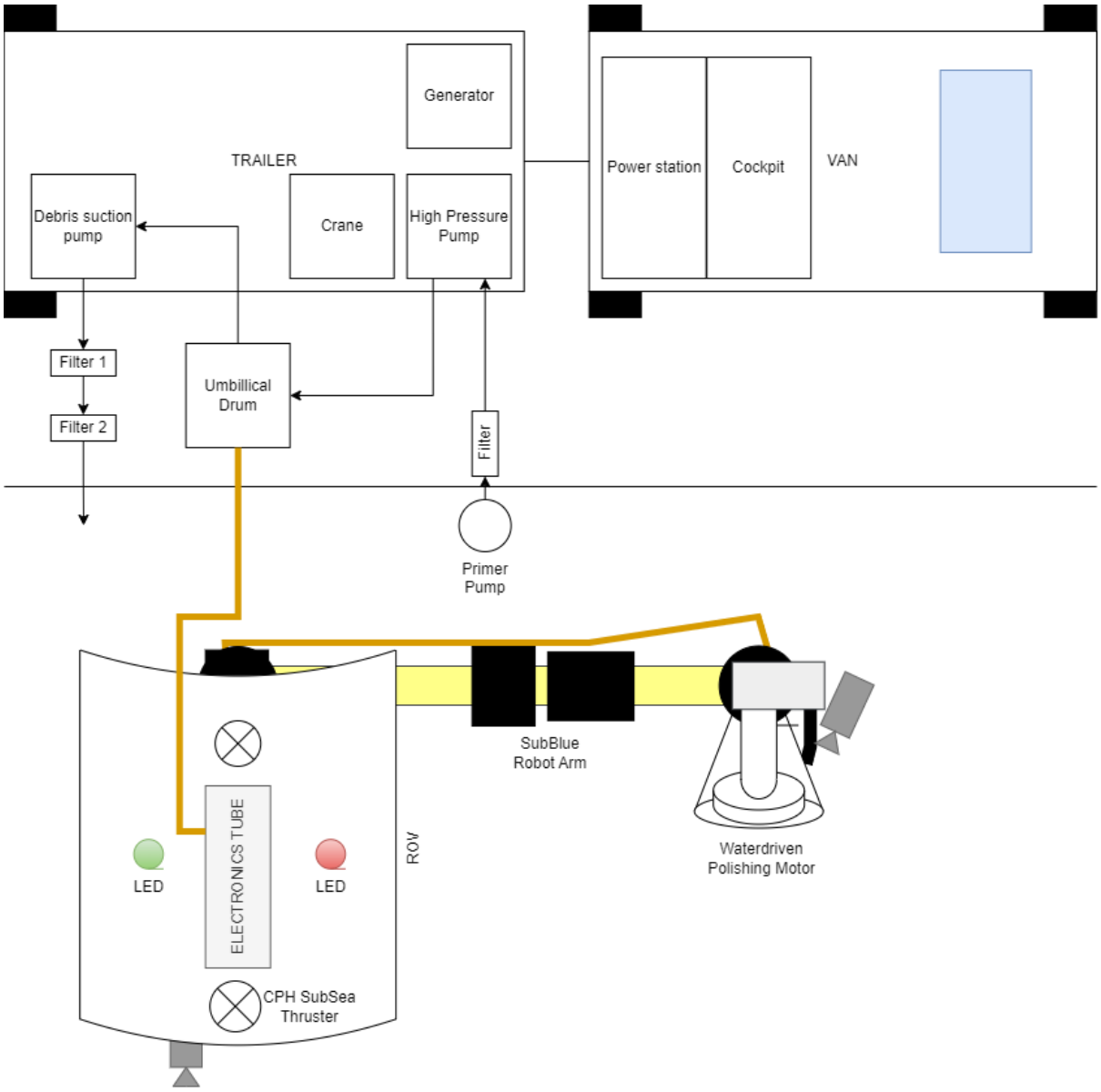
Duties and responsibilities

Person	**Duties and responsibilities**
Project Manager (manager)	Responsible for getting relevant information from the customer – technical drawings of the propeller, addresses, relevant phone numbers, maps of the site of operation, requirements by customers of e.g. inspection. Does not have to be on-site, but is available on call. Is available for contact in case of safety breaches. Orders relevant repairmen, authorities or lifesaving personnel if necessary.
Safety and Equipment Officer (equipment officer)	Responsible for packing equipment, including safety equipment for the operation. Assists the robots operator with his awareness of what is going on at the harbour. Manages the robots umbilical during operation (making sure it is not too tight or too loose or make loops or gets entangled). Is always on comms through headphones with the operator. Manages contact with visitors if necessary. Operates the crane to lift the robot into and out of the water.

	Helps setting up equipment before and after generator is active. Changes filters when agreed to by the operator. Must inform project leader of safety breaches.
Robot operator (operator)	Overall responsible for the propeller polishing operation at site. Operates the robot. Has technical knowledge about all components of the system and overview over how to diagnose errors. Takes pictures of the propeller before and after operation, using the robot system. Polishes the propeller using the robot system. Turns on generator when safe. Informs project leader of safety breaches if the Safety and Equipment Officer is unable.

Plan of action

Diagram



Work preparation checklist

The safety and equipment officer is responsible for approving the checklists before the equipment is moved to the site (for the categories marked “before operation”. This is done before each operation.

Required materials before operation	**Check**
2x Filters 0,35 micron	
2x Filters 5 micron	
10 liter freshwater for cleaning in a hand operated pump	
1 liter antifreeze liquid for protecting thrusters from frost (if risk of frost)	
Extra gallons of diesel for the generator and pick-up train crane	
Food and water for personnel	
Headphone battery sets, fully charged	
Security checklist before operation	**Check**
1x Electrical safety glove set (LAUS)	
2x Safety life vests	
2x Yellow or orange visibility vests	
2x Yellow or orange hardcap helms	
2x Headphones	
2 pairs of gloves	
2x Yellow or orange visibility rain-vests and rain-pants	
2x Yellow or orange visibility kettle suits	
2x Yellow or orange visibility jackets and pants	
Phones	
On-site preparation checklist	**Check**
Check if ship is located where promished	
Check if there is space for the equipment at the appropriate place behind the ship	
Check if the crane can have its support-legs planted at an appropriate lifting location	
Check if there is space for rolling out the umbillical	

The robot operator is responsible for checking the items on the robot start-up checklist, prior to starting the generator that powers the robot. Prior to starting up the generator that powers the robot, check the following items:

Robot pre-start up checklist	Check
1. Ground-wire from generator is connected to the sea or to a spear hammered into the ground	
2. High pressure pump has its power connected to the SubBlue powerstation	
3. High pressure pump has its signal lines (also connected to an output solenoid controlled by CAN) to the SubBlue cockpit	
4. The primer pump has its power connected to the SubBlue powerstation	
5. The debris suction pump has its power connected to the SubBlue powerstation	
6. The robot umbilical power is connected to the SubBlue powerstation	
7. The robot umbilical water supply hose is connected to the high pressure pump outlet	
8. The primer pump outlet is connected through a filter to the inlet of the high pressure pump	
9. The primer pump is fully submersed in the supply water source (watertank or in the harbour), and its mounting rope is securely fastened, so the primer pump doesn't sink or float or applying tension to its electrical cable or outlet hose	
10. The robot umbilical signal and camera cables are connected to the SubBlue cockpit.	
11. The cockpit PC is active and connected to the robot signal lines	
12. The robot power, high pressure power, primer pump and debris suction pump power all have their circuit breakers activated, as to not power during turn-on of generator	
13. The robot has been connected to its umbilical cable: a. Electrical power b. Electrical signals c. Camera signals d. High pressure hose outlet e. Debris return hose inlet f. Umbilical cable has been robustly tethered to the robot in a way to relief stress on connectors	a b c d e f
14. The robot is submersed in the seawater, but is still connected to the hook on the crane. It can be lifted into the water by crane.	
15. The debris return hose of the umbilical has its outlet connected to the inlet of the debris suction pump	
16. The output hose of the debris return pump is connected to the SubBlue filter system	
17. The high pressure pump prefilter and the debris return hose filters are not clogged.	
18. Generator has its powercable connected to the SubBlue powerstation	
19. The generators circuit breakers are active, meaning the generator will not output power when turned on	

20. The generator is filled with at least 20 L of diesel	

The generator can now be turned on. Its electronic display can now be checked for how much diesel is loaded in the generator. The generators circuit breaker can now be deactivated. The operator can now enter the cockpit and turn off the circuit breaker for the robot power. Using the PC program of SubBlue Robotics, the operator can now ping the robot electronics system through the Controller Area Network through the umbilical cable. Once a connection is established, the operator can check the robots systems:

Robot post-start up checklist	**Check**
1. Check the all cameras feeds are working by observing the monitors next to the PC	
2. Turn on LEDs and observe if robot lights up.	
3. Turn on thrusters Safe Torque Off system, and check if the CAN message receiver receives errors.	
4. Test each thruster (left, right, bottom, front, back) by turning them off and observing the movement of the robot, and check if the CAN message receiver receives errors.	
5. Turn on each robot arm joint and move each joint a degree back and front, and check if the CAN message receiver receives errors.	
6. Check for CAN message errors coming from the barometer, inclination sensor and joystick.	

If there have been no CAN errors on the error display, the operation can proceed.

Procedure

The robot can now be steered remotely by the operator out of the crane hook and to the propeller to be polished. Once the robot arm is unfolded and in position to polish, the waterdriven polishing motor can be activated for the first time, by following the procedure:

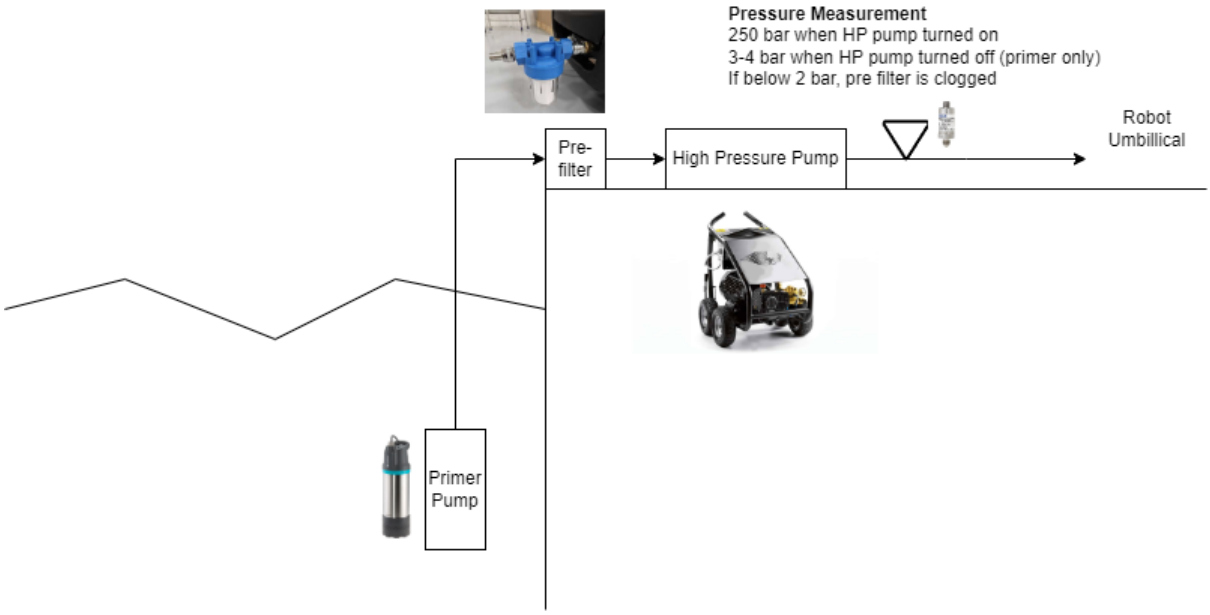
1. The primer pump digital switch is turned on using the PC program
2. The primer pump circuit breaker is turned off manually
3. The operator or the equipment officer present listens if the primer pump turns on and observes if water is flowing through the primer pump hose to the high pressure pump through the pre-pump filter. If the hose is transparent, you can see the water flow, otherwise the waterflow can be felt by holding the hose in your hand for a few seconds
4. The operator turns on the solenoid, that is mounted on the output of the pump systems, through a digital switch. The solenoid is turned on through a digital switch using the PC program.
5. Now the operator is waiting until the primer pump has filled up the high pressure pump and umbilical hose with water. This can take a few minutes. Once the water reaches the polishing motor, it will start rotating at a slow pace. This can

be observed from a camera by the operator. Once the motor starts rotating, this is an indication that the pumps and hoses are now sufficiently filled with water.

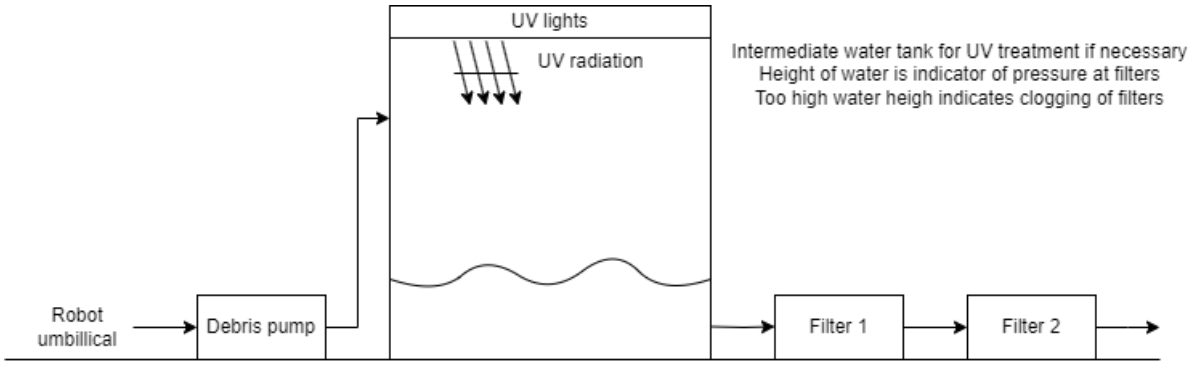
6. The high pressure pump can now have its built in circuit breaker turned off
7. The high pressure pump digital switch is turned on using the PC program
8. The high pressure pump circuit breaker (in the SubBlue cockpit) is turned off manually
9. The polishing motor is observed by operator through camera, it should spin up to a high speed and start sucking water up into the debris hose. At this stage, the umbilical hose is being emptied from air bubbles. The operator and the equipment officer is also listening to the high pressure pump, it will also be emptying itself from bubbles for a minute.
10. Once the debris hose is outputting water through the filter system, and the pump system seems to be working, the operator can turn off the circuitbreaker for the debris suction pump to test it. There should be a confirmation that it turns by listening to it, and observing the return hose – more water should come through and out into the filter system
11. Now, the solenoid can be closed (through CAN on the PC) to block the pump system. The polishing motor should now slowly decelerate its spinning on the camera monitor. The software has a built in system that turns off the debris suction pump when the solenoid is closed.

Now that all systems have been tested, the propeller polishing can commence. The robot software has built in systems for turning off and on pump power to prevent overheating. The pump get turned off after a few minutes of idle time (while the solenoid is closed). Every time the operator leaves the cockpit, he/she must activate the manual pump circuit breakers in the cockpit.

During the polishing operation, the equipment officer periodically checks the condition of the filters and how much water is coming out of the filter system. If it looks clogged and the outputted water is clearly reduced, the filter must be changed for a fresh one, while the solenoid is closed. The pressure at the output of the high pressure pump is monitored, which is downstream of the pre-filter. In between polishing sessions (max 2 hour), the high pressure pump is deactivated, and the monitored pressure now reflects the pressure of the primer pump minus the pressure loss of the pre-filter. Normally this pressure is around 3-4 bar, but if it is reduced significantly, say to 2 bar, this is an indication of a clogged filter.



For the other filters than the pre-filter: the debris pump is pushing water from the polisher into a “buffer”-tank, whereafter the filters are fed water from the buffertank. As the the filters get clogged, the buffer tank fills more rapidly, until it water reaches a valve on the top of the tank (the height of this valve is an indirect measurement for the pressure upstream of Filter 1 and 2). This height is checked in between polishing sessions (max 2 hours).



When the operation is done, the robot arm is steered by the operator away from the propeller and the polishing motor is turned on again, sucking up water into the filter system. The purpose here is to empty the debris hose of debris. Once the suction system has been on for a minute, the debris return hose is folded by the equipment officer to block water passage. The operator can now turn off the polishing motor, and the operator removes the debris hose from the filter system while keeping the debris hose blocked. This is done to keep the debris from flowing back from the filter into the debris hose. Now the debris hose can be mounted on the filter system again, filled with air. The polishing motor will not be run again.

The robot arm is folded by the operator into its transport position and the robot is steered back to the crane. Once the robot is lifted into the crane, and the arm is visibly

mounted in its safe transport position, the crane is used to lift the robot up slightly. The entire system can now be turned off in the following order:

1. Circuit breakers of pumps are turned on manually
2. The built in circuit breaker of the high pressure pump is turned on manually
3. Using the PC program, the Controller Area Network is closed. The PC program is closed
4. The robot circuit breaker is turned on
5. The generator circuit breaker is turned on
6. The generator is turned off
7. The power cable between the generator and the SubBlue power station is disconnected

The robot can now be lifted up to the surface again by crane. The primer pump and ground wire in the sea can be lifted up by hand to the shore. There should now be no more equipment in the water. The Robot should now be cleaned by fresh water brought by the team (or if the robot can be transported inside within 24 hours, it can be cleaned at the workshop.) The thrusters are flushed through a flushing system on the robot, while the equipment officer rotates the thruster propellers by hand. If there is any risk of frost, the thrusters are flushed again with an appropriate anti-freeze blend.

Water sample

Some time during the polishing, there should be sampled water from the effluent flow out of the filters. There is a stainless steel ladle mounted next to the filters, which will be used. To take a water sample, follow the steps:

Water sampling	**Check**
Use brought freshwater to clean stainless steel ladle	
Place stainless steel ladle at the output of the effluent flow (after filter 2)	
Pour the contents of the stainless steel lade into a stainless steel water test tube	
Close test tube and note the date and time on the test tube	

Duty of care

The robot operator is responsible for all parts of the operation, including which steps should be taken when, and what should be done if there is an issue during the start-up procedures. The equipment officer is there to assist the operator and be his eyes on conditions outside of the cockpit, especially in the harbour (e.g. incoming ships, entangling umbilical).

The waterline is dimensioned to be waterproof, but the operator should keep an eye out for water spillage out of the hoses. After each side of a propeller blade is polished, there

should be an inspection of the water tank to check if its overflowing, but it is fitted with a bilge pump that would empty the water tank through filters, which is activated automatically. If spillage of debris-filled water cannot be prevented, the operation must be cancelled.

The operator must be authorized by SubBlue Robotics.

Acceptance criteria prior to acceptance of contract

SubBlue Robotics has received information about the ships propellers and the location where the ship will be located. The project manager must check if there is enough space on the location for the SubBlue set up. The project manager must check if there are obstacles on the ship near the propeller. If there are obstacles near the propellers, the operation may get cancelled. Typically the ship owners does not know the condition of his propeller before hand, it is possible that the propeller is in such good a condition it does not make sense to polish the propeller with any disc SubBlue Robotics is allowed to use. However, typically propellers degrade enough in just a few months (depending on temperature of waters and standing-still time) that a polish with a silicron carbide scrubber disc is warranted. The silicon carbide scrubber is the disc SubBlue Robotics used for the water collection tests that form the background of this application. If the ship owner already knows that his propeller is too heavily fouled with barnacles and the like for a silicon carbide scrubber not to be enough, requiring a diamond disc, the job will be cancelled by SubBlue Robotics.

The project manager and operator together decide if the job should proceed.

Once SubBlue Robotics has access to video footage of the customers propeller, its condition should be inspected. Based on the type of fouling on the propeller, advise the below table on how to proceed:

Acceptance criteria	**Accept?**
Only visible damage is calcium layer and roughness	Yes
Primary fouling (slime, algae etc. < 1 µm thickness)	Yes
Secondary fouling (small barnacles, “worms” etc. < 1 mm thickness)	Yes
Tertiary fouling (macro fouling, big barnacles, clams, > 1mm)	*Advise below

*In case of tertiary fouling, estimate the height of the macro-fouling, and use the following formula:

$$T = \frac{2htR^2\pi}{V_b}$$

Here,

$h = Height\ of\ macrofouling\ [mm]$

$t = 5\ minutes\ (time\ to\ empty\ debris\ suction\ pump\ basket\ of\ macro.fouling)$

$R = Radius\ of\ propeller\ [m]$

$V_b = 20\ l, volume\ of\ debris\ pump\ basket$

$T = Added\ time\ to\ deal\ with\ macro\ fouling\ [minutes]$

The result of using the formula is an estimate of how much added time it will take to deal with the macro fouling. If the time is manageable according to the schedule of the ship, the job can proceed (to be decided between the robot operator and project manager), with the following added job:

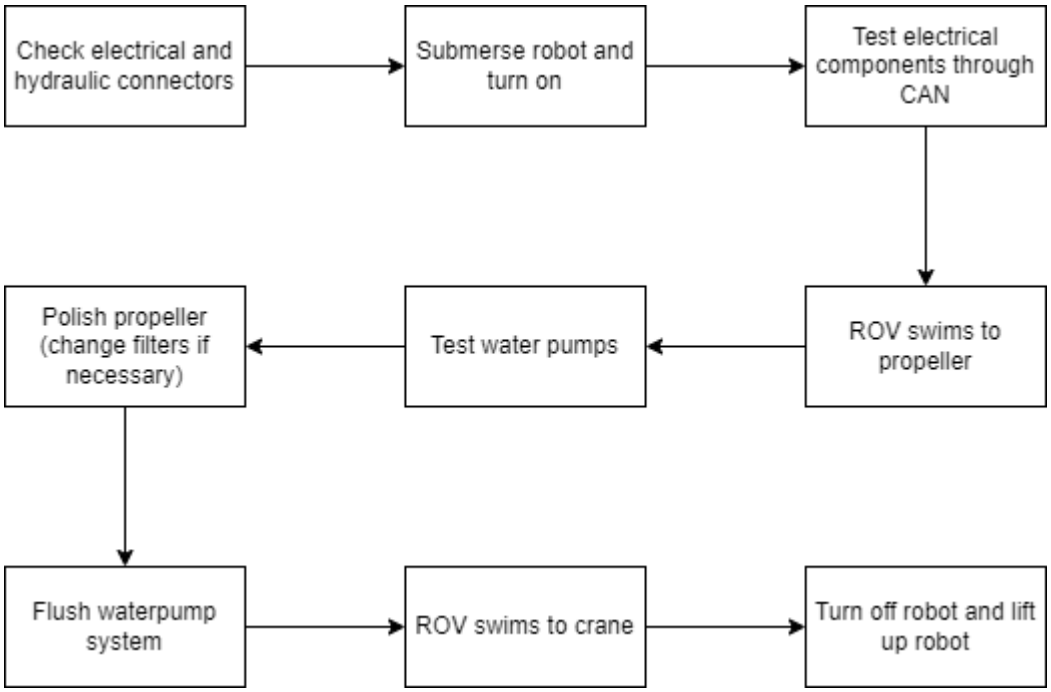
1. The debris suction pump is near-constantly inspected by the safety and equipment officer
2. Once the debris suction pump is near full of macro-fouling, the safety and equipment officer signals the robot operator to stop polishing
3. The robot operator pauses polishing and closes all pumps.
4. The safety and equipment officer waits thirty seconds, and then opens the lid of the debris suction pump
5. Inside the debris suction pump is a debris-basket of around 20 liters containing said macro-fouling, which should be emptied into a container, or the trunk of the vehicle, to be dealt with later off-site
6. The safety and equipment officer puts the debris-basket back into the debris suction pump and carefully closes the lid.
7. The robot operator primes the water hydraulics system by running the polishing motor until water comes through the debris suction pump, while the polishing tool is in no contact with the propeller
8. The polishing operation can now proceed
9. Repeat 1-9 until operation is finished

If for any reasons, it is impossible to go through these steps, or if the calculated time T added to deal with macro fouling is too high, the operation must be cancelled. A typical value could be with a propeller of radius 3,5 meters and 10 cm barnacles, which gives an added time of

$T = \frac{2 * 10mm * 5\ \mathrm{min} * (3{,}5m)^2 \pi}{20\ l} \approx 192\ minutes,$

Which is about 3 hours. So if it is possible to add 3 hours of operation time for the crew and for the ship owner, the polishing operation can proceed. If not, the operation should be cancelled.

Roadmap of the procedure



Precautions

Contingency plan in case of oilspill/pollution

The polishing system is waterdriven and the product uses no hydraulics, so there is no risk of oilspill. The high pressure pump, primer pump and debris pump are electric and does not run on diesel.Description of crucial steps to ensure safety and correct procedure

Only authorised personnel from SubBlue Robotics should operate the robot. The the equipment officer must be approved by SubBlue Robotics. The criteria for the authorisation and approval of personnel consists among others of

- Robot operator
    - Deep knowledge of the robot system
    - Basic understanding of each component – how they are powered and commanded
    - Basic understanding of electronics and ground safety-issues
    - Trained in operating the robot, and has overview over the functionality of the Graphic User Interface and Controller Area Network
- Safety and equipment officer
    - Appropriate behaviour at harbour – respect for safety rules, use of life vests, hardcap helms
    - Appropriate respect for power components – electronics, pumps, cables

- Pays attention to the harbour movements
- Can operate a crane

Telephone numbers of authorities who should be consulted

SubBlue Robotics CEO, +45 [redacted]

General information

Wastewater treatment plant

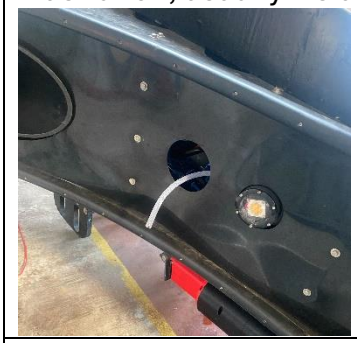
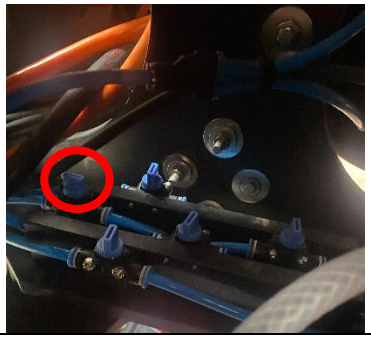
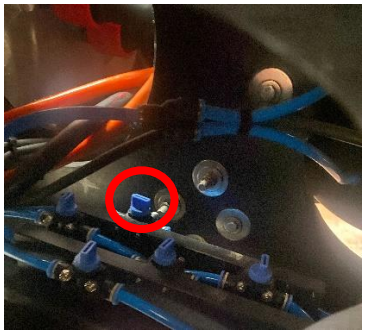
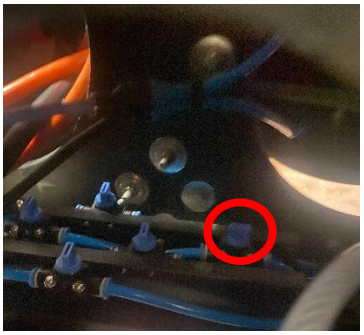
The treatment plant consists of two subsequent filters at 0,35 micron and 5 micron, for which the debris return hose outputs water through and into a watertank filled with filtering sand or coal. The watertank is enclosed by a protective plexiglass plate, and inside there are mounted UV lights. The UV lights can be turned on if the relevant harbour requires killing lifeforms in the filtrated water. The plexiglass plate protects people from the UV light.

Water samples can be taken during operation by collecting them in a container, preferably plastic or stainless steel on the effluent flow of filter 2. This can be done anytime during the polishing operation. It can also be done before and/or after the operation by running the polishing motor in some distance from the propeller, so all water collected is just the background harbour water.

Each filter can be changed by screwing off their lids, removing the old filter, inserting a new fresh filter and screwing the lid back on.

Maintenance procedure of polishing system and water treatment system

Maintenance procedure of polishing system and water treatment system	**Check**
The whole robot is flushed with freshwater that has been brought along along with a hand operated pump	
Insert flushing hose into the robots built-in thruster flushing system	
Open left thruster valve, close all others. Flush while rotating left thruster	
Open front thruster valve, close all others. Flush while rotating front thruster	
Open right thruster valve, close all others. Flush while rotating right thruster	
Open back thruster valve, close all others. Flush while rotating back thruster	
Open bottom thruster valve, close all others. Flush while rotating back thruster	
UV light tank is cleaned of debris into a container	
UV light tank is flushed with fresh water	

Thruster flushing system on left side of ROV		
Flushing hose shown for illustration, usually inside 	Left thruster opened, others closed 	Front thruster opened, others closed 
Right thruster opened, others closed 	Back thruster opened, others closed 	Bottom thruster opened, others closed