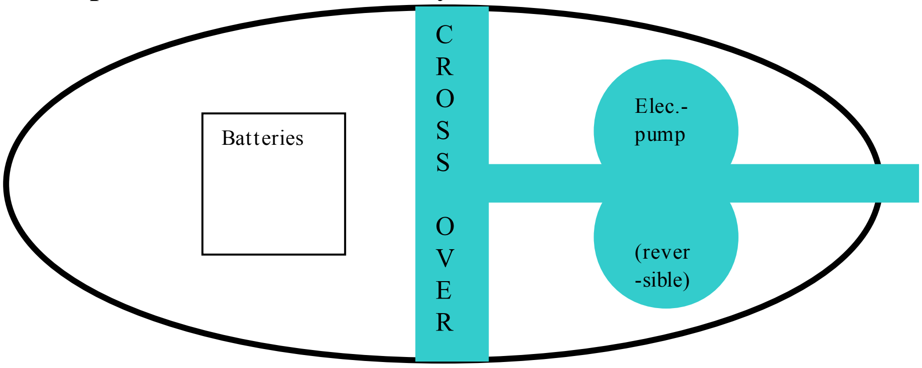
Dissymmetry of a propulsion by reciprocating waterjet

Experimental proof (one more!)

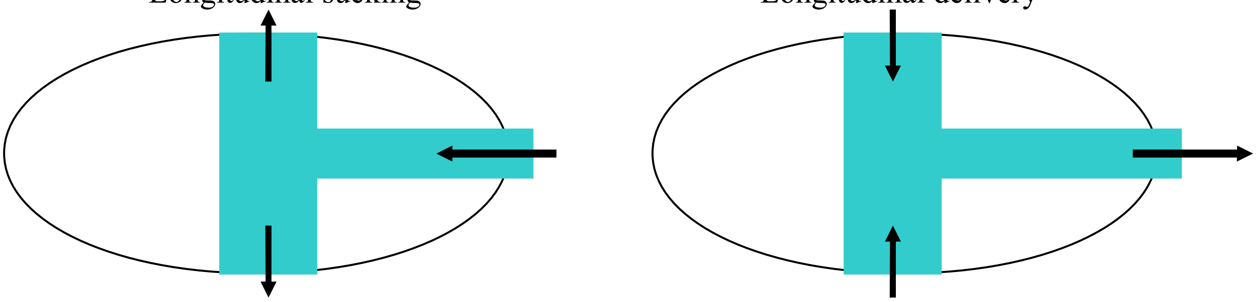
Purpose of the experiment: to show that sucking water on the bow of a ship has a negligible impact; though a jet backward propels enormously more.

Principle of the foresee assembly:



A symmetrical hull (according to transverse and longitudinal axis) to avoid endless discussions.
Electric pump located in the middle of a tube of internal diameter "d".
Internal diameter of the cross-over equal to more than twice the one of the tube.

Thus, on one hand the total pressure drop (upstream + downstream) will be nearly unchanged. And on the other hand, the speeds inside the cross-over will be very low and the resulting forces being opposed they will cancel each other.



Measurement of the boat velocity in both cases.

Practical results:

Test conditions are described in appendix.
Measurement of the boat velocity when propelled by jet. Result: 72mm/s.
Measurement of the boat velocity during sucking. Result not measurable. Velocity lower than 1mm/min.
Knowing that the thrust evolves as the square of the velocity, one can calculate the ratio between pushing and pulling forces. $\eta \le \left(\frac{1}{60x72}\right)^2 = \frac{1}{18662400}$; i.e. the pulling force (when sucking) is roughly 20 millions times weaker than the pushing one. Even though the reality could be slightly better (due to measuring uncertainties) the ratio is enormous. No doubt that the pushing force is much bigger than the sucking one.

Additional tests:

The here above mentioned tests were performed with an immobile boat, but what about a moving one? To know that we have modified the test rig by adding a pump (sucking on one end of the canal and delivering at the other end) in order to create a permanent flow. The boat was maintained in this flow by means of an elastic hauser, the length of which allowed to determine the towing force.

First the test were performed with the same boat as before.

1) Measurement of the rubber string length at rest.
2) Measurement of the rubber string length when taught by the stream acting on the boat, of which the pump is stopped.
3) Idem (2) but with engine sucking behind the boat.
4) Idem (2) but with engine sucking before the boat.

We got following results:
(2)-(1)-->57mN It is the hull resistance at a speed of approximately 45mm/s because the test canal is narrow and partly occupied by the hull. (The boat when free moves at 30.3mm/s).
(3)-(2)-->10.8mN Light lengthening of the rubber string.
(4)-(2)-->0mN Nothing could be seen.

These tests were realized as quick as possible, without raising questions. Results are given as is. Now, let's look at what we should have measured. At a 45mm/s velocity (relative velocity between boat and water) and with a flow of 1kg in 64 seconds for (3)-(2) we should have measured 0.045/64=0.7mN in one way and for (4)-(2) 0.7mN in the other way. For this latter, taking into account the measuring uncertainties, the "nothing could be seen" is normal. On the opposite, for (3)-(2) I guess I made a mistake when measuring the rubber string length.

The box shape and the wide main frame area of this boat could have hidden the sucking effect (area ratio approx 1/400), therefore another boat has been built. Smaller and more hydrodynamic, and with sucking nozzle not hidden. See appendix. With this new float, taking into account the measuring uncertainties, the sucking forces are very tiny compared the the pushing ones. The measurements confirmed the theory.

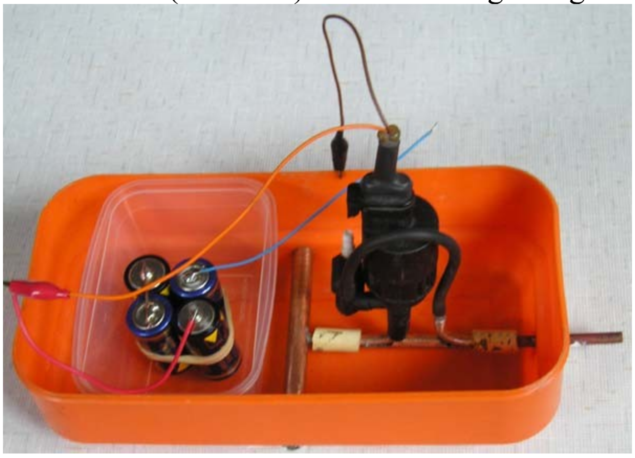
Conclusions :

- Sucking forward or backward of a boat has generally a negligible effect.
- The simplified assumptions (used in other documents) are justified.

PS: I made this above described experiments to convince (if it is possible) the skeptic guys. I knew for long from attending sea trials of a merchant ship that the sucking force is weak and generally negligible. It was on a sucking dredger approximately 100 meters long. Its dredging arm being disconnected, the approx 10000m^3/h pump has been running. It was sucking at the bow on port side and delivering in the dredging tank of the ship. Dredger stopped. No wind. After approx one hour the heading of the ship remained roughly unchanged. For the next test the pump delivered on the side. And there the ship turned as if powered by a transverse bow thruster.

Appendix

Photo of the (so-called) boat of the beginning.



One can see on the left the batteries compartment,
lower in the middle of the hull, the cross-over,
in black, the pump,
and on the right the tube used either to suck or to deliver.

The little piece of copper which connects the bends (for sucking and for delivery) is only a mechanical support.

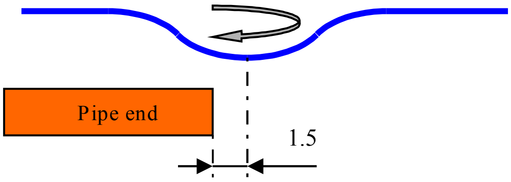
Measurement of the pump flow. Result: one little in 64 seconds.
Wetted surface of the hull: 591cm^2
Internal diameter of the tube: 4.4mm
Internal diameter of the cross-over: 10mm

The measurement of the propulsion velocity took place outside on a bench that is 4m long. The first meter was used for initial acceleration, and the last one for stopping. The real measurement was done on the central 2 meters. To eliminate some eventual wind influence, tests were run in both ways.

The first sucking measurement took place on the same bench. The velocity was seen low, but influenced by the wind. Sometimes the boat was going ahead or astern by some centimeters. New test were run indoor with a shorter and wider bench. Laterally the hull was kept at the center of the tank by means of two slides (with a play of some millimeters). When the pump was energized, the vibrations got rid of the light permanent friction forces.

Vortex at the suction side.

Test conditions and lighting allowed us to observe the water surface and the movement of some particles just above the suction side.



A small basin was created at the water free surface. Its centre was approximately 1.5mm ahead of the pipe. The water was rotating clockwise. (We are in the northern hemisphere).

Test rig with counter-stream.

The pump fitted below the water canal is a recovery from a washing machine. It sucks on the right by the biggest pipe and delivers on the left; thus creating a stream from the left to the right in the canal.

In a washing machine the delivery is at the top and the flow is little. Here, sucking and delivery being at the same level the flow is close to one cubic meter per hour.

Prototype number 2.

Sucking nozzle under the hull, cleared of the rest. Delivery above the water level (shared on both sides to avoid unwanted propulsive effects).

Note: In order to lighten as much as possible this float, the batteries were set outboard and connected to the boat by means of very soft electrical wires.