INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

C.M. 1990/L:107
Biological Oceanography Committee

EFFICIENCY MEASUREMENTS OF GULF III AND HAI PLANKTON SAMPLERS IN A TOWING TANK

by

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1. INTRODUCTION.

Surveys of fish eggs and larvae have become an important tool in fish stock assessment. In the North Sea and waters west of the British Isles, stocks of herring, mackerel and horse mackerel are now monitored on a regular basis by means of egg and larvae surveys. In the North Sea, similar surveys have been started for plaice and cod.

Most of these surveys are joint programmes by several countries, and they are normally coordinated within the framework of ICES. As the results from different countries have to be combined into one estimate of total egg or larvae production, it is important that the sampling methods are standardised, and that all data are reported in the same units, e.g. numbers per square meter surface.

Despite attempts to standardise survey methods, the countries participating in the international surveys have so far been unable to agree on a standard plankton sampler. The technical development of the high speed samplers has proceeded along different lines in each of the countries, with the result that each country is using its own type of sampler. In this situation, it is very important to know precisely the efficiency factor of each sampler i.e. the ratio between the volume of water presented to the sampler, and the volume actually accepted.

Arnold and Harding (1971) were the first to describe a method for measuring the volume of water accepted by high speed samplers. They mounted the Lowestoft plankton sampler in a flume tank, and measured the flow through the mouth by moving a miniature flowmeter across the opening. In later years, English scientists investigated the differences between English and Dutch samplers in the same way, except for the fact that the sampler was towed at a controlled speed in a towing tank (Wood and Nichols, 1983). The results of these tests showed a sampler efficiency of 90% for the Dutch GULF III samplers, and 85% for the English 50 cm sampler.

As the English towing tank facility in Feltham was closed shortly after 1983, no further comparison of samplers used in different countries could be made in the UK. However, in view of the increasing practical importance of international plankton surveys, and the remaining uncertainty about the efficiency of the various samplers, Dutch scientists in 1990 started a new series of calibration experiments, in which the Dutch GULF III and the German HAI II sampler were calibrated in a towing tank facility in Wageningen, The Netherlands. The study was subcontracted to the MARIN institute that runs the towing tank.

This report summarises the main results of the tests in Wageningen. A detailed technical report is available on request from the author.

2. MATERIAL AND METHODS.

Specifications of the GULF III and HAI II samplers are given in figures 1 and 2. The GULF III is an encased sampler, whereas the HAI is unencased. Another difference between both samplers is the angle of the nose cone; the GULF has a rather blunt angle of 52 degrees, whereas the HAI has a sharper angle of 30 degrees.

The towing tank at MARIN is 100 meter long, 6 meter wide, and 4 meter deep (figure 3). The samplers were attached to a carriage that could tow them at a controlled speed through the water.

The volume of water passing through the sampler was measured by a series of 9 Prandtl tubed that were fitted on a vertical support across the mouth of the sampler (figure 4). The measurements of each tube (or pair of tubes) were taken to be representative of the flow through the corresponding annulus of the mouth opening, and the total flow was calculated by integrating the data for the various annuli.

The tests were repeated with the mechanical flowmeters that are normally used in conjunction with these samplers. These flowmeters were watched by underwater video cameras, that were mounted on the nose cone of the sampler.

Test were performed at speeds of 2.0, 2.5, and 3.0 m/s, and at drift angles of 0 and 10 degrees. Tests runs were also made with the target speed being reached starting from a lower level or from a higher level, in order to investigate possible hysteresis effects on the flow through the sampler.

3. RESULTS.

3.1. Flow pattern across mouth opening (without net)

The pattern of the flow in the mouth opening of the sampler, as measured by the Prandtl tubes, is shown in figure 5. The measurements are given for a sampler speed of 2.5 m/s which corresponds to the normal operating speed of 5 knots for the samplers. The measurements were made without net inside the sampler. In both the GULF and HAI sampler, relatively high entry velocities occur at the edge of the mouth, whereas the flow is reduced towards the centre of the mouth opening.

The velocities are higher in the HAI than in the GULF sampler. In the HAI, the velocity at the edge of the mouth opening is 20% higher than the sampler speed, and in the centre 10-15% above sampler speed. In the GULF, the entry velocity at the edge is 10% above sampler speed, and in the centre slightly below sampler speed.

The effective entry velocity across the mouth opening is calculated by multiplying the measurements by each (pair of) Prandtl tubes with the surface of the corresponding annulus of the mouth opening, and then summing the values for all annuli.
The effective entry velocities for both samplers at a towing speed of 2.5 m/s are given below. The ratio between effective entry velocity and sampler speed is called sampler efficiency.

effective entry velocity (m/s) at a sampler speed of 2.5 m/s (no net)		
sampler	GULF	HAI
effective entry velocity	2.639	3.251
sampler efficiency	106 %	130 %

3.2. Relationship between effective entry velocity and sampler speed.

The effective entry velocities of the two samplers at different speeds are shown in figure 6. For the GULF sampler, the effective entry velocity is more or less proportional to the forward speed of the sampler. This is not the case for the HAI sampler. At speeds over 2.5 m/s the effective entry velocity tends to drop suddenly, apparently as a result of the flow becoming irregular (turbulence at the edge of the mouth opening).

3.3. Relationship between flowmeter readings and volume accepted.

Both samplers are equiped with mechanical flowmeters during normal operation. These flowmeters are calibrated against speed in free flow conditions. It is interesting to compare the readings of the flowmeters in the mouth of the sampler with the effective entry velocity as measured by the Prandtl tubes. Measurements are presented here for the standard sampler speed of 2.5 m/s.

Sampler	GULF	HAI
flowmeter revs at 2.5 m/s free flow	1.57	3.60
flowmeter revs in sampler at 2.5 m/s	1.80	4.45
estimated sampler efficiency from flowmeter	115 %	124 %
actual sampler efficiency (Prandtl tubes)	106 %	130 %
error from flowmeter measurement	9 %	- 6 %

In both cases, the flowmeters in the mouth opening of the sampler do not give an accurate indication of the effective entry velocity. In the GULF sampler, the effective entry velocity is overestimated, whereas in the HAI sampler, the effective entry velocity is slightly underestimated.

3.4. Effects of the presence of the net.

The above experiments were all conducted with an "empty" sampler, that is a sampler without net. The effect of the net was tested in a series of test runs, in which the sampler (equiped with Prandtl tubes) was towed first without net, then with a normal net inside (unclogged), and finally with a net that was tied together somewhere halfway down the end, in order to simulate the effect of clogging. All test runs were made at a sampler speed of 2.5 m/s. The results are given below.

effective entry velocity at sampler speed of 2.5 m/s		
sampler	GULF	HAI
no net inside	2.639	3.251
normal net	2.521	3.251
clogged net	2.522	3.262

The presence of a net has little effect on the volume accepted by the sampler. An unclogged net reduces the volume accepted by 4% in the GULF, and it has no effect at all on the volume accepted by the HAI. A moderate amount of clogging (such as simulated by the net tied together) has no further effect on the volume accepted.

3.5. Effect of drift angles.

Towing the sampler at a certain angle in relation to the forward speed may affect both the volume accepted by the sampler, and the registration of the accepted volume by the flowmeter in the mouth of the sampler. Both effects were investigated in a series of test runs.

The pattern of the flow across the mouth, as measured by the Prandtl tubes, changes as the sampler is towed at a certain drift angle (figure 7). In the GULF sampler the pattern of flow becomes asymmetrical, but the total volume accepted by the sampler is not very much affected (text table below). In the HAI sampler, however, the volume accepted drops when the sampler is towed at a drift angle of 10 degrees or more, apparently as the result of increased turbulence.

effect of drift angle on effective entry velocity (m/s) at a towing speed of 2.5 m/s		
sampler	drift angle	effective entry velocity
HAI	0 degrees	3.251
	5	3.160
	10	2.949
	15	2.579
GULF	0	2.639
	10	2.593

The mechanical flowmeter in the GULF appears to be very sensitive to drift angles. If the sampler is towed at an angle of 10 degrees, the flowmeter readings are reduced by 23% as compared to a tow at zero trim. From the results of the Prandtl tube measurements, it is known that the actual volume accepted remains more or less constant. The flowmeter, therefore, appears to be very sensitive to an asymmetric flow pattern in the mouth of the sampler.

No measurements we made of the effect of drift angles on the mechanical flowmeter in the HAI sampler.

3.6. Tests for hysteresis.

Both the GULF and the HAI showed no signs of hysteresis.That means, the flow through the net at a given sampler speed did not depend on the way in which the target speed was reached (starting from a lower or a higher speed).

4. DISCUSSION.

The results of the tests show a considerable difference in performance between GULF and HAI sampler. The HAI has a higher efficiency (130%) probably due to its sharper nose cone. It is also more sensitive to changes in speed and drift angle. At speeds slightly above the recommended towing speed in routine surveys (2.5 m/s) the flow through the nose cone becomes irregular and the effective entry velocity drops. The same happens if the sampler is towed at a drift angle of 10 degrees or more.

The GULF has a lower efficiency (due to its blunt nose cone), but its performance is more robust. The effective entry velocity increases proportionally with speed, and it is not affected by small drift angles of the sampler. The only problem with drift angles is that the flowmeter performance is strongly affected.

The test results for the GULF are rather different from the ones reported by Wood and Nichols (1983). They report a flow profile across the mouth with the highest velocity in the centre and the lowest at the edges; precisely the opposite of the results presented here. The efficiency of the GULF was estimated by Wood and Nichols at 90%, whereas we now find 106%. Possibly the position of the (mini) flowmeter in the tests of Wood and Nichols was not ideal; they mounted the flowmeter 1.7 cm in front of the mouth opening. When in later experiments (Milligan 1990) the flowmeter was brought level with the edge of the mouth, a higher efficiency was measured.

Our findings about the effect of a net inside the sampler agree with those of Wood and Nichols. The presence of a net, even partly clogged, has hardly an effect on the volume accepted. Sometimes, there is even an increase in volume accepted, probably as a result of more regular pressure gradients and less turbulence in the front part of the sampler.

It is also clear that readings of a flowmeter in the mouth of the sampler cannot be taken as direct measurents of the flow through the sampler. Because of the irregular flow pattern in the mouth of the sampler, and the fact that a simple impeller doesnot integrate flow over the entire mouth, the actual average speed across the mouth is normally different from what the flowmeter indicates. This is an observation also made earlier by Wood and Nichols.

The results of our tests show that intercalibration tests of plankton samplers are badly needed if results from different countries are to be combined. It is therefore proposed that all samplers used in international surveys are calibrated under standard conditions.

5. REFERENCES.

Harding, D. and G.P. Arnold, 1971. Flume experiments on the hydrodynamics of the Lowestoft high-speed plankton samplers : 1. J.Cons. int. Explor. Mer 34 (1): 24-36.

Milligan, S., 1990. Flume experiments and calibration of Lowestoft high-speed plankton samplers 1971 - 1986. In prep.

Wood, R.J. and J.H. Nichols, 1983. Further comparative data on herring larvae caught by English and Dutch high-speed plankton samplers, together with the results of a flume calibration of the Dutch sampler.
ICES C.M. 1983/H:9, 10 pp.

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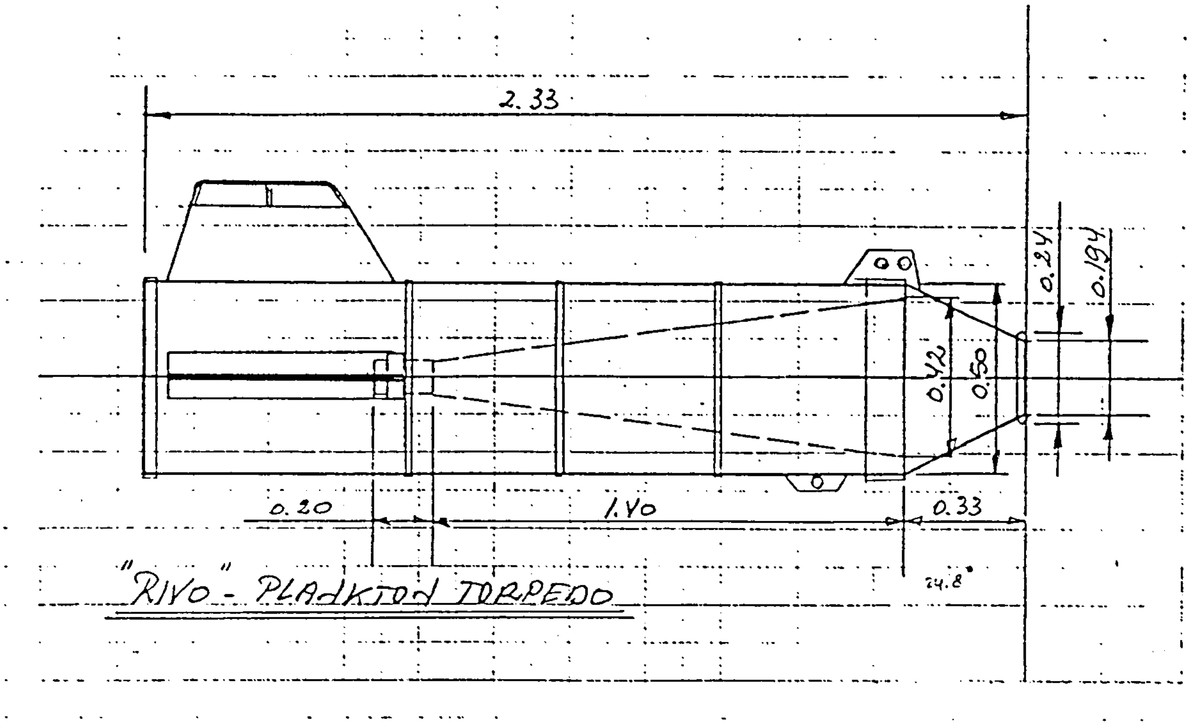


Figure 1. General arrangement GULF III plankton sampler
dimensions in m)

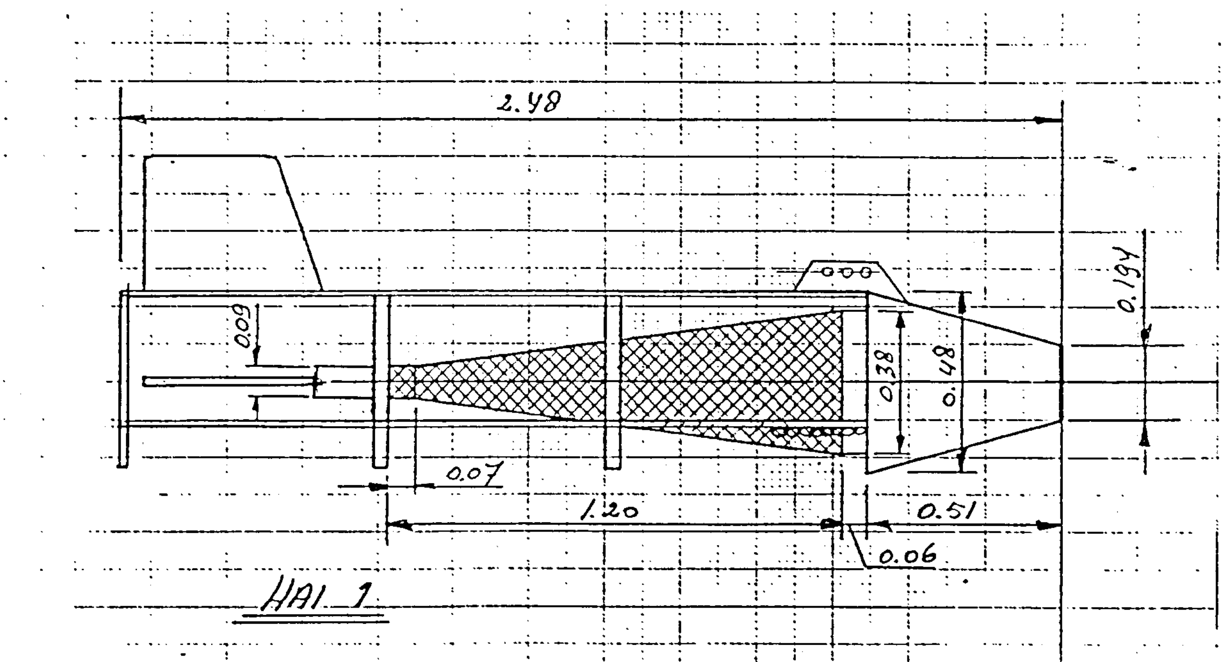


Figure 2. General arrangement HAI-2 plankton sampler
(dimensions in m)

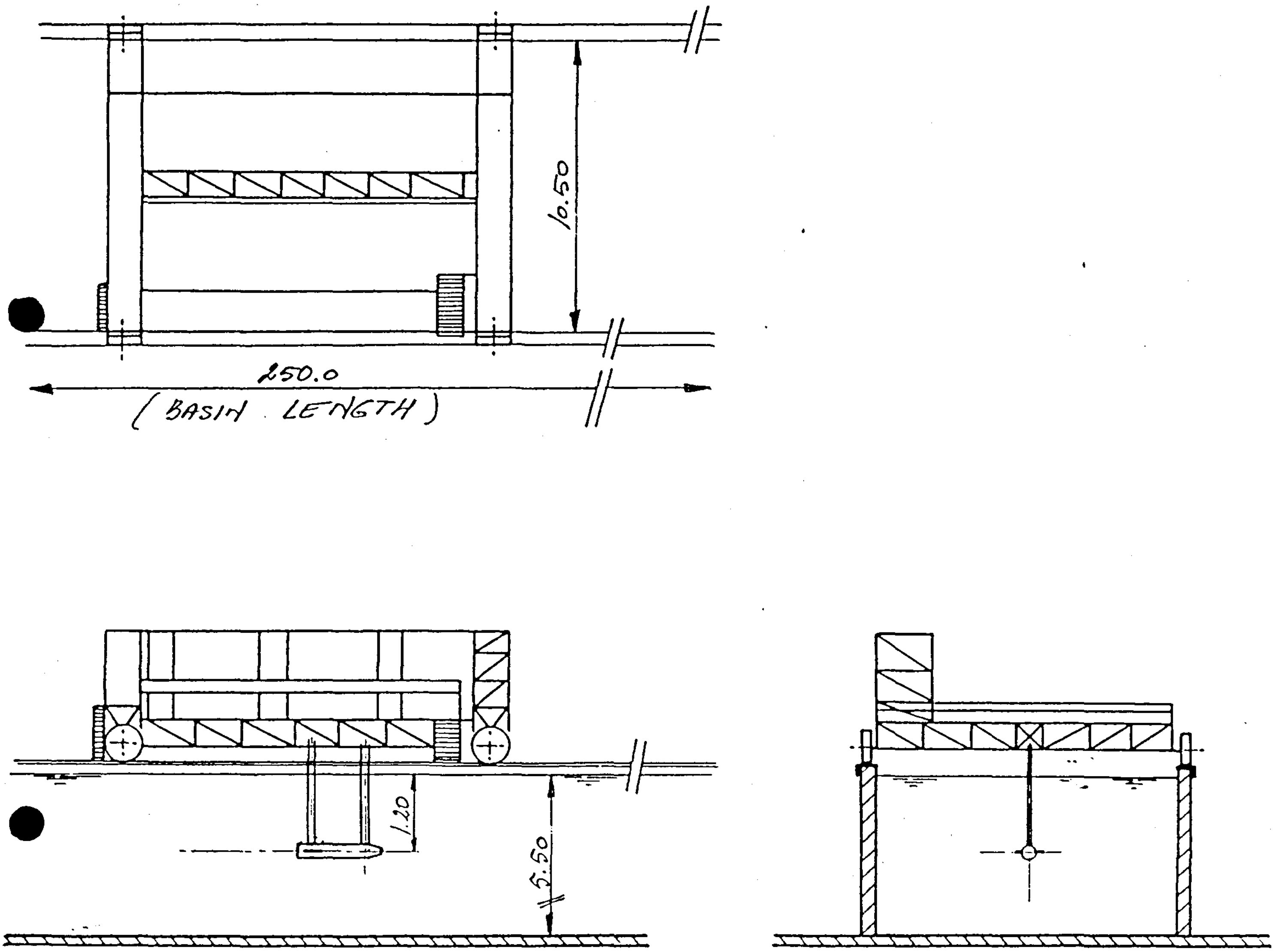


Figure 3. Set up test tank (dimensions in m)

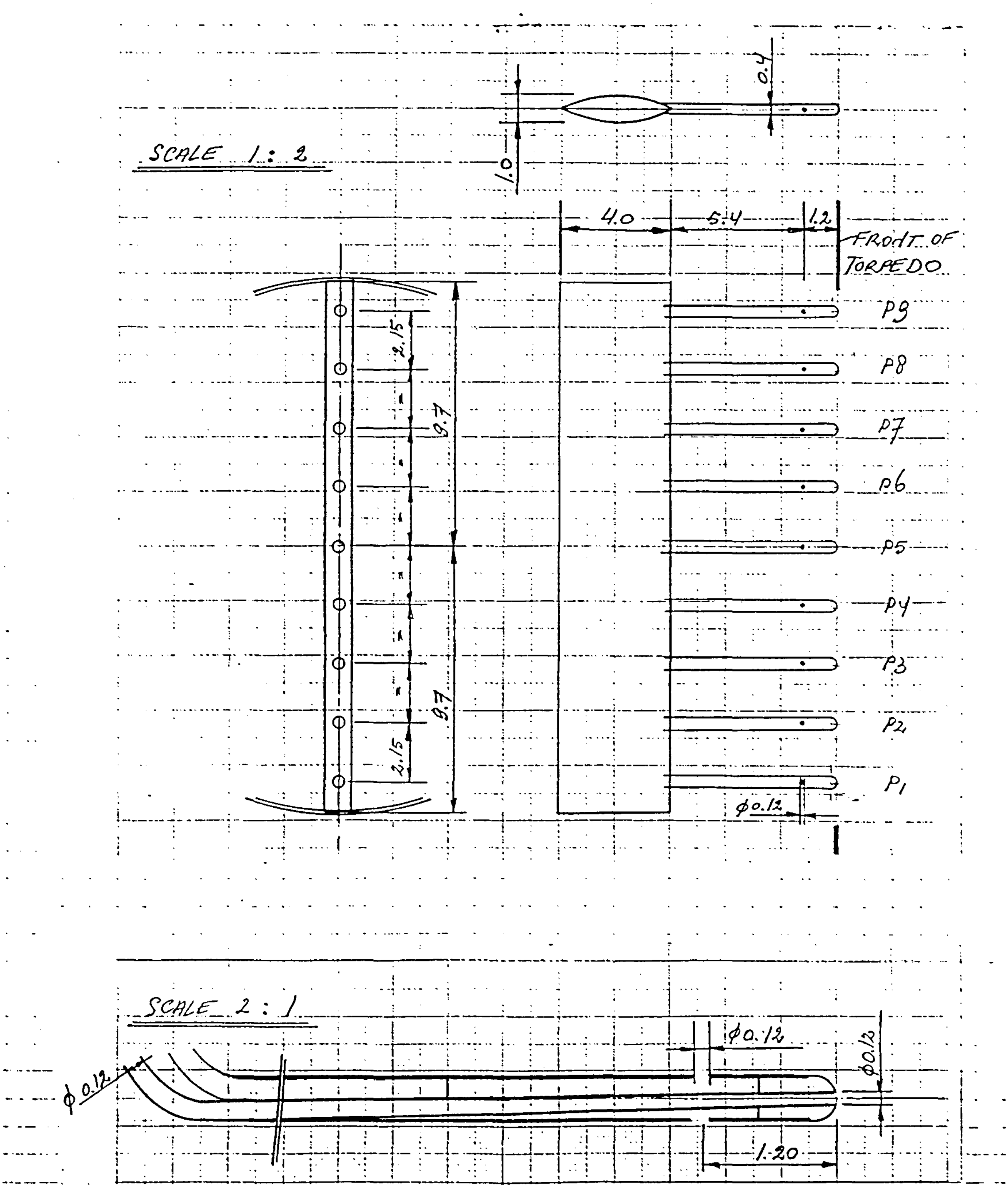
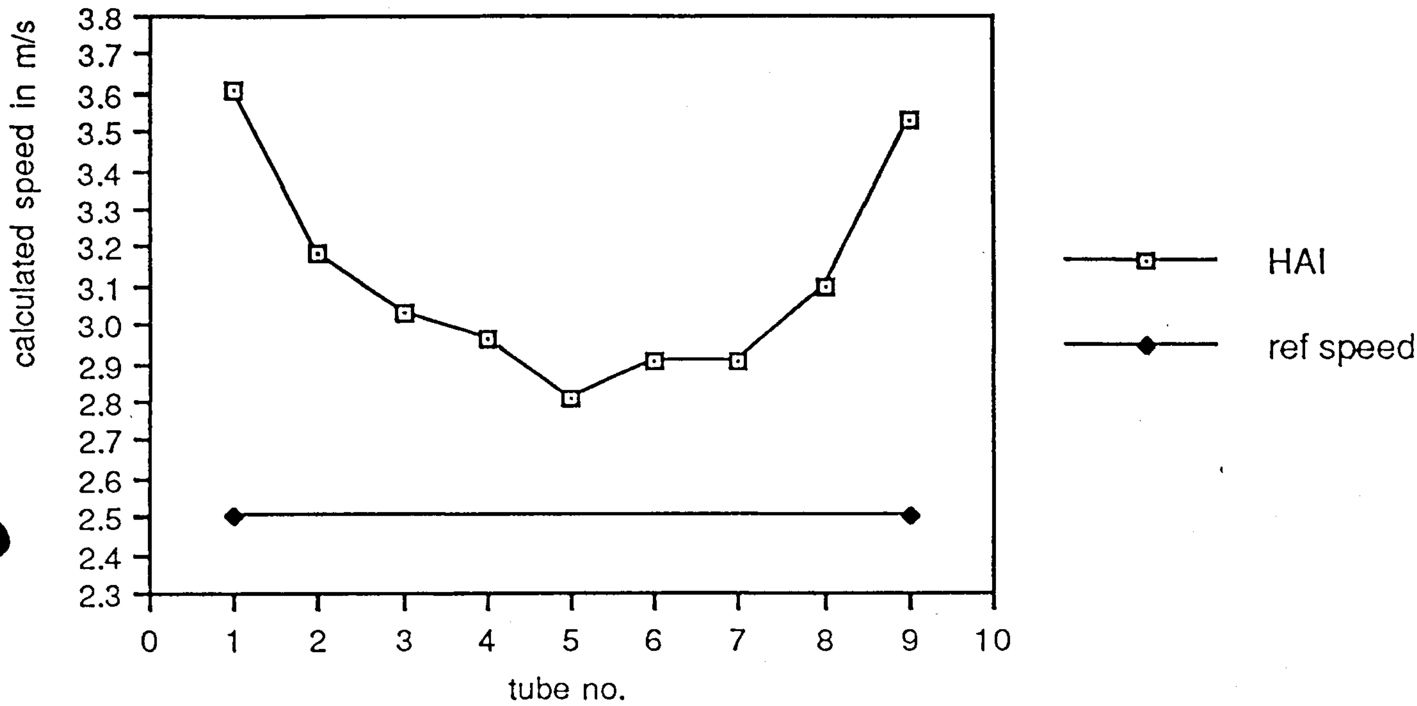


Figure 4. Set up of Prandtl tubes (dimensions in cm)



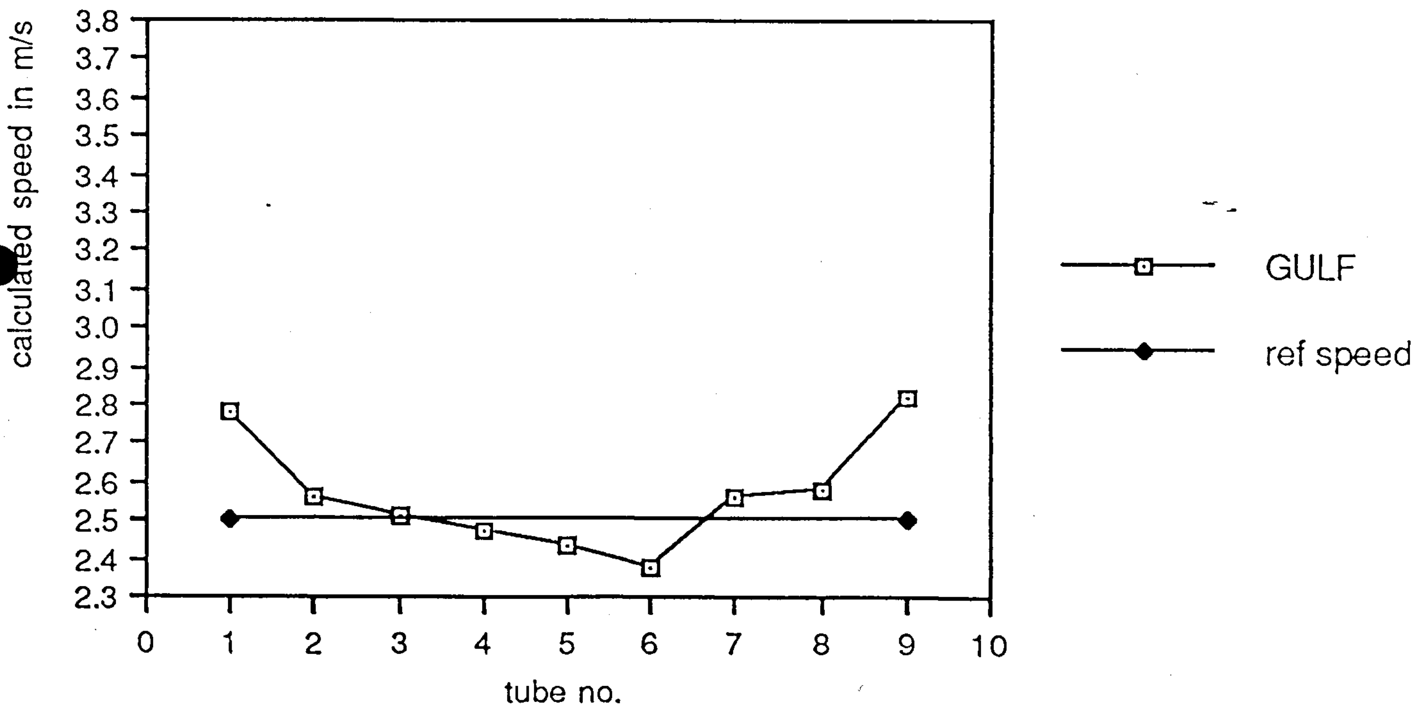


Figure 5. Flow pattern across mouth opening of sampler at 2.5 m/s towing speed

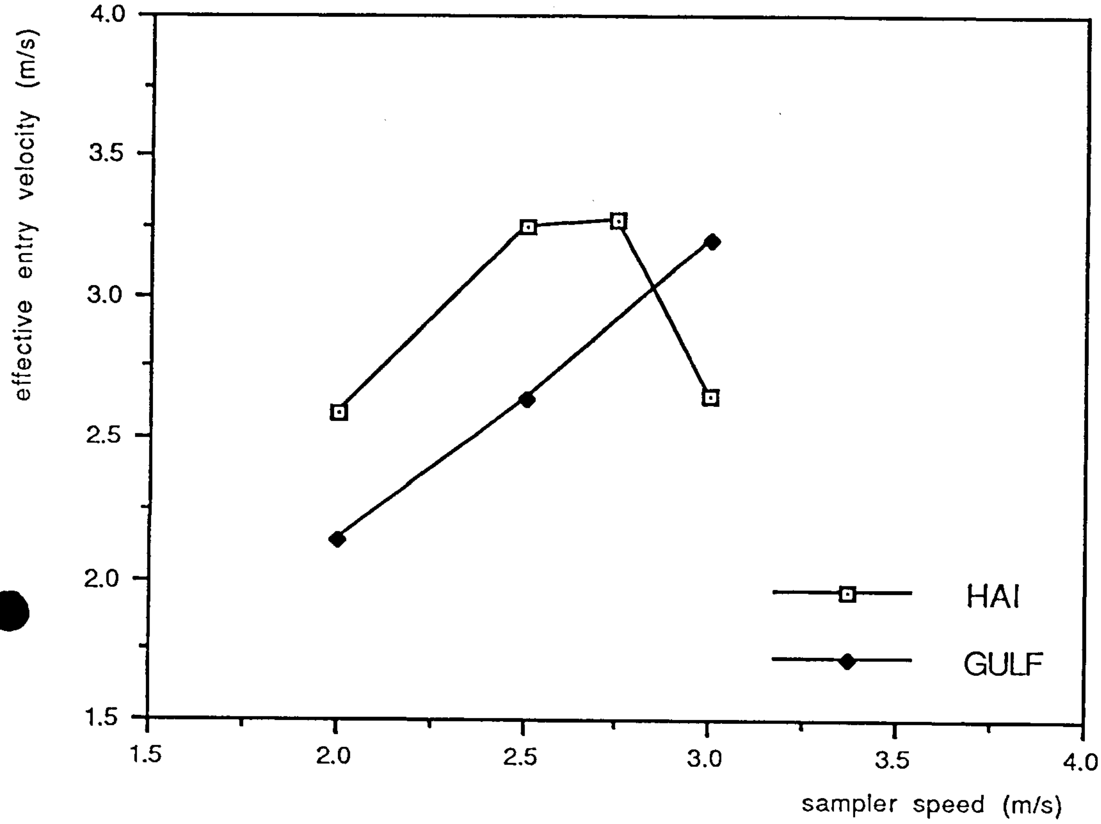


Figure 6. Effective entry velocity of water through mouth opening at different towing speeds

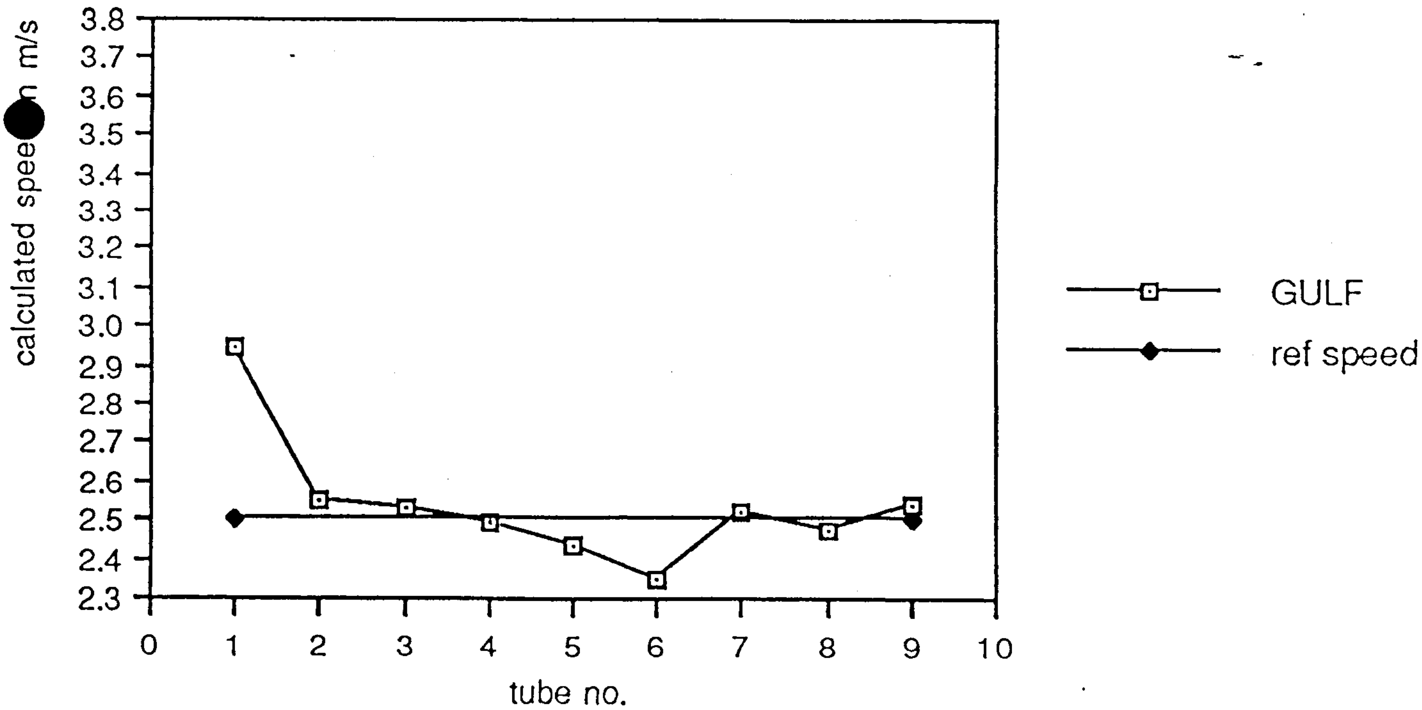


Figure 7. Flow pattern across mouth opening at 10 degrees drift angle. Towing speed 2.5 m/s.