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THE NEW OCEANOGRAPHIC EQUIPMENT OF THE "D'ENTRECASTEAUX"

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Abstract

The D'ENTRECASTEAUX is SHOM's most important vessel. She began her active service 25 years ago, and her specific equipment has evolved in line with technological developments. In particular, in 1994, she was equipped with two systems enabling her to make oceanographic investigations while underway. These are an Acoustic Doppler hull-mounted Current Profiler (ADCP) by means of which current profiles over an 800-metre section can be obtained, and a towed vehicle (Sea Soar), able to oscillate between 0m and 400m depths, which can carry sensors such as a CTD probe or a fluorimeter.

This article evaluates the present surveying capacity of the D'ENTRECASTEAUX, with regard to hydrography, geophysics and oceanography and presents, in particular, her two new items of oceanographic equipment: the ADCP and the Sea Soar.

1. Introduction

The D'ENTRECASTEAUX is the principal vessel of the Hydrographic and Oceanographic Service of the Navy both as regards her characteristics (95m long, 2 440 t, able to carry 130 persons, autonomy of 60 days) and as regards her operational capabilities. She was designed from the start as a polyvalent vessel, able to carry out hydrographic work both offshore and along the coast, and to serve as a support for oceanographic cruises. For these purposes, she possesses good, permanently-installed equipment which allows a wide variety of work to be carried out both underway and on site, and she is able to receive supplementary equipment on a temporary basis to adapt her for the most varied tasks.

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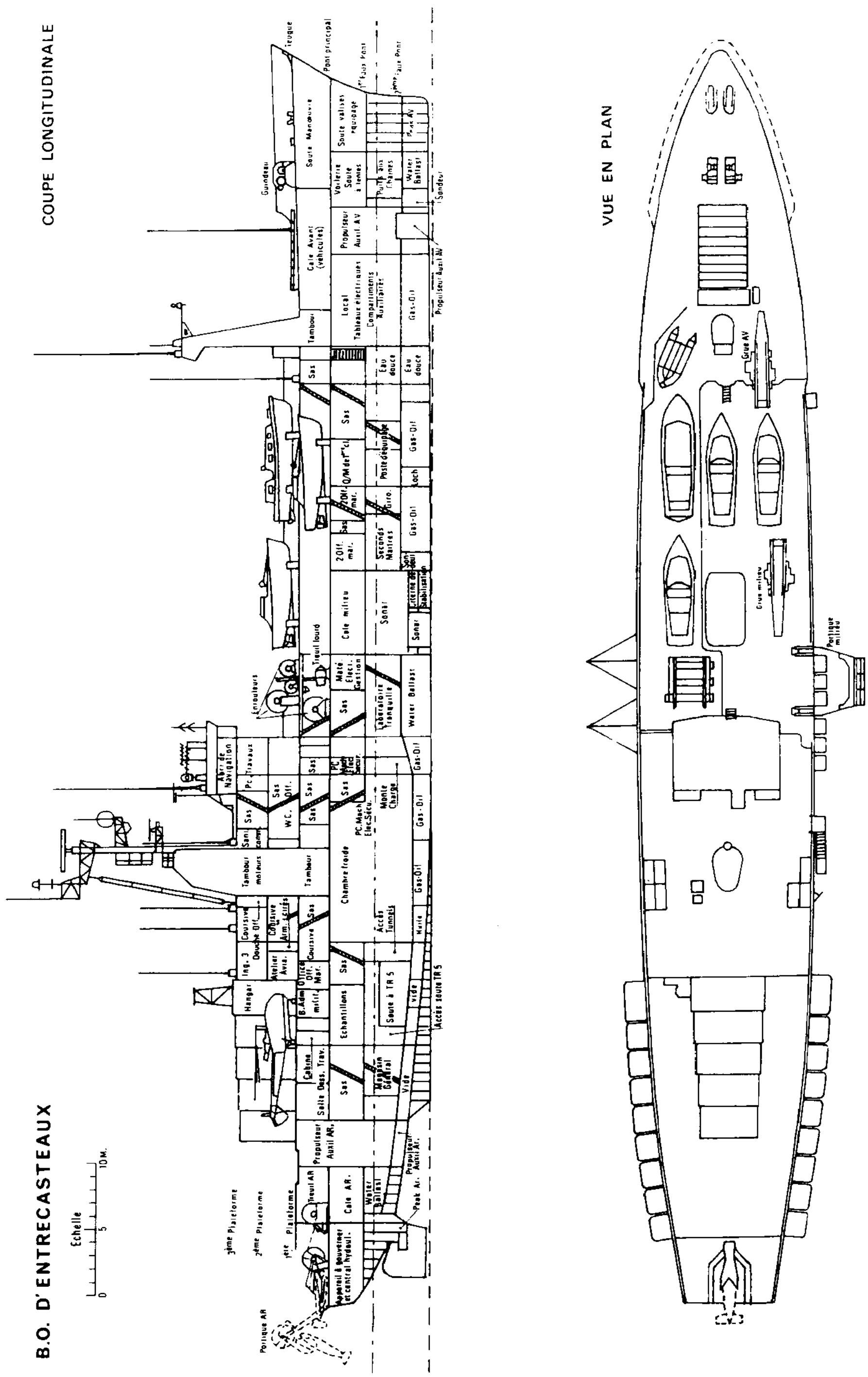

FIG. 1. Design of the D'ENTRECASTEAUX.

On 8 October 1996, she will celebrate a quarter of a century of service. In 1971, accurate position-fixing was an art, computers were in their infancy, and sensors were operated by components which were in no way microscopic. Has the D'ENTRECASTEAUX retained her initial capabilities, 25 years on, in 1996? This question is a particularly pertinent one today, when SHOM is preparing to renew its sea-going fleet.

2. ORIGINAL EQUIPMENT

The design of the D'ENTRECASTEAUX (Fig. 1) is articulated around a lateral working area which gives her a characteristic asymmetry. In this working area are found:

- two 15-ton hydraulic cranes for the manipulation of survey launches, cars and heavy material;
- a heavy hydraulic winch intended for operations of dredging, coring, trawling, mooring of autonomous lines and deep-water anchoring;
- an A-frame (winch support) capable of supporting a vertical strain of 3-tons, two metres over the side;
- a telescopic boom and three winches for hydrology.

Two survey launch cradles are fixed in this area. They are dismountable so as to be able to make room for additional laboratories installed in containers.

Aft of the vessel there is an area situated 2.5m above the waterline, mainly intended for putting towed equipment into use. It consists principally of an A-frame and a hydraulic winch. The narrowness of this area aft of the ship is due to the existence of a landing pad for an Alouette III helicopter. With her telescopic hangar and its refuelling capabilities, the D'ENTRECASTEAUX can thus carry and maintain a helicopter, which is particularly useful in hydrography.

The specific items of equipment installed at the outset were: Omega, Ragep, Decca, Toran or Loran C navigation receivers; sounders, including an Edo with narrow beam and stabilised base; Askania GSS2 gravimeters; the Richard bathythermograph or the Varian proton magnetometer. They have disappeared and been replaced by modern equivalents.

The only original capability which has disappeared is the possibility of anchoring in deep water. Conceived for acoustic measurements requiring a high degree of silence, it was abandoned in the late eighties, firstly because maintaining it was very costly, and secondly because the drifting vessel controlled by GPS offered performances in silence that were equally efficient as anchoring in deep water.

3. PRESENT CAPABILITIES IN HYDROGRAPHY

Regularly, the D'ENTRECASTEAUX carries out hydrographic survey work lasting several months in the French Overseas Departments. Since 1971 she has successfully carried out a dozen campaigns in the French West Indies, in Guyana and in the Indian Ocean. The latest took place in the Indian Ocean from 23 January to 30 June 1995.

The main aim of this 1995 campaign was to complete the re-charting of the approaches to La Réunion Island and the seeking of a channel in the coral lagoon of Mayotte, enabling deep-draught ships (up to 12m) to transit between the narrows of the eastern part of the island and the port of Longoni. In addition, advantage was taken of this campaign in the Indian Ocean to carry out preliminary work for the exploitation of SPOT satellite imagery in the Comores, at Mayotte and in the Glorieuses and Tromelin Islands, as well as port surveys in Madagascar and Djibouti.

The principal facilities put into use were the following:

- for position-fixing, the basic system is GPS, used in differential mode with portable stations transmitting corrections in HF (200km range) or UHF (up to 60km range). In areas with no permanent installations, these portable stations, put into place with the help of a helicopter, guarantee a positioning accuracy of 1-2m. without the necessity of heavy infrastructure.

  For work at scales greater than 1:1,000 (port surveys, for instance), a network of Sercel Axyle stations is used (accuracy of the order of 50cm, range 10km).

- bathymetric sounding was done either with the vertical echosounders of the D'ENTRECASTEAUX(two Raytheon deep-water sounders and two Atlas Deso 20 with heave compensor for deep water surveys, or with vertical Atlas Deso 20 and side-scan sonar Edgerton EGG 260 for surveys in shallow waters. The sea-bed investigations on hazards that are the most dangerous for navigation are carried out by divers.

- floating equipment used in shallow waters includes three 9-metre (8T) survey launches, three flat boats in aluminium for port work and three dinghies for the support of divers and for rotation of personnel.

- the tide and the currents were observed with the help of underwater digital equipment manufactured by MORS.

- the Alouette III helicopter which, in addition to its usual missions (transport of material and personnel to areas that are difficult of access), was used for more technical purposes such as taking vertical photographs to effect a photogrammetric cover of a limited area, the review of landmarks (oblique photos and positioning of landmarks) or the checking of photogrammetric restitution plotting sheets.

During such a campaign the D'ENTRECASTEAUX is a floating base for survey work out at sea carried out from the vessel itself and, above all, when anchored close to the areas to be surveyed, for work in shallow water. In the latter case, she plays many parts:

- as the point of departure and the rallying point for survey boats, the D'ENTRECASTEAUX ensures their refuelling and their maintenance.
- as a platform (landing pad) for utilisation and maintenance of the helicopter
- as a workshop for the preparation and repair of hydrographic equipment
- as a data processing centre
- as a living centre for the crews; about 130 persons are present on board.

It is true that neither the D'ENTRECASTEAUX nor the survey launches are equipped with multi-beam sounders. But for hydrographic surveys in shallow waters in the French Overseas Departments, which in most cases are of coral structure, such equipment would not be of great efficiency. Similarly, for hydrographic surveys off their coasts, the advantages of complete sounding cover to guarantee safety of navigation have not been proved, since, with the exception of Guyana, the shelf is of very limited extent.

The results obtained during the Indian Ocean cruise of the D'ENTRECASTEAUX in 1995 show that the vessel still has a remarkable potential for carrying out hydrographic surveys.

4. PRESENT CAPABILITIES IN GEOPHYSICS

In this field, the absence of a multi-beam sounder leads to the defining of cruises where non-systematic aspects will be stressed. In particular, the D'ENTRECASTEAUX:

- carries a Bodenseewerk KSS31 marine gravimeter. The size of the vessel allows it to sit well down in the water, which is an important factor in the quality of the measurements.
- is able to make deep cores (down to 10,000m) in sea state 5. The Kullenberg corer is generally rigged with a 10m tube with 1T weighting. It is used over the side from the A-frame on the midship deck.

The other equipment for geophysics consists of a Raytheon deep-water sounder, a set of Thomson SMMII magnetometers which give an accuracy of 2nT, and a Raytheon 3.5kHz sediment-sounder, the transducers of which are mounted as movable fish fixed under the hull and the exploitation system is the Delph II.

It is relevant to note here that the internal organization of SHOM forsees that work at sea should be carried out by units referred to as "Missions", composed of one or more vessels and a team of hydrographic surveyors required to embark aboard one or other of the Mission's vessels to carry out the technical work. The "Atlantic Oceanographic Mission", to which the D'ENTRECASTEAUX belongs, has also a second sea-going vessel, L'ESPERANCE, fitted with a SIMRAD EM12 Dual multi-beam sounder. The Mission's activity is therefore planned taking this sounder into account, which means that L'ESPERANCE essentially carries out the systematic geophysical surveying. This being so, the lack of such equipment aboard the D'ENTRECASTEAUX is compensated for by a specific definition of her geophysical work which takes into account that of L'ESPERANCE.

5. PRESENT CAPABILITIES IN OCEANOGRAPHY

The special feature of oceanographic cruises is the possibility of using a wide variety of sensors. Because of this, it is necessary to be flexible in arrangements, both in the working areas on deck and in the premises used for acquisition and processing of data.

Most of the equipment is embarked specifically for these cruises; it is then a matter of having available aboard ship vast rooms where PC calculators and work stations can be installed which today serve as interface for initialization, acquisition and checking of observations. Equipment that must be moored is prepared in a laboratory communicating directly with the midships deck and usually put into operation using the winches and A-frames found on this deck. Generally, such equipment consists of:

- Guildline- or Seabird-type CTD probe submerged on an multicore tow cable in a cage equipped either with a rosette or with a Doppler-effect RDI-type current profiler.
- drifting swallow floats (Rafos) or drogues with Argos positioning;
- various lines of instruments: thermitance lines, tomographic transmitters, etc.;
- towed acoustic hydrophones;
- expandable XCTD, XBT or XCD probes.

The D'ENTRECASTEAUX is required to remain on site for several hours so as to deploy the equipment described above. To hold her on site she has two 360° directional propellers which enable her to remain at a fixed position in relation to the sea or the seabed in sea state 5 or even 6. The dissymmetry of the hull gives the teams working on the midship deck efficient protection against swell and wind coming from the port side.

When the space available aboard the D'ENTRECASTEAUX is not specifically adapted for certain measuring operations, or when the relevant instrumentation is too bulky to be installed for a particular cruise, one or more containers are carried aboard.

Finally, it is relevant to focuse on two permanent items of oceanographic equipment installed in 1994 on the D'ENTRECASTEAUX,intended for the continuous acquisition of data while underway. These are described in the following paragraphs.

6. ACOUSTIC DOPPLER HULL-MOUNTED CURRENT PROFILERS

6.1 Equipment installed aboard the D'ENTRECASTEAUX

The physical part of an ADCP (Acoustic Doppler Current Profiler) consists of three main elements: the receiver-transmitter base, the console which carries out the first calculations, and the PC with software to pilot the acquisition of data and enable them to be stored.

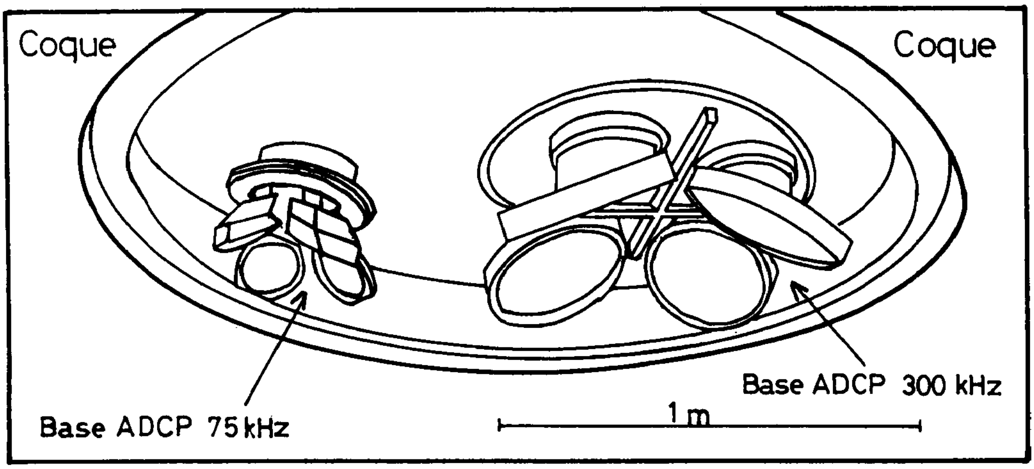

FIG. 2.- Plan of the implantation of the ADCP profiler bases fitted to the hull of the D'ENTRECASTEAUX.

The hull of the D'ENTRECASTEAUX is equipped with two bases transmitting on frequencies of 300kHz and 75kHz. These bases are each composed of four transducers arranged at an angle of 90° on the horizontal plane and offset by 30° compared with the vertical. The horizontal dimension of the bases is 85cm for the 300kHz and 40cm for the 75kHz profilers (Fig. 2).

To protect the ceramic of the transducer, the latter is covered with a layer of urethane which also guarantees that the ADCP is waterproof. In addition, an acoustic window insulates the transducers from the sea water. This window is separated from the base by fresh water.

The control consoles of the two ADCPs are installed in the gravimeter room of the D'ENTRECASTEAUX,a place which is well ventilated and cooled. They contain the electronic components required for transmission, reception and processing of the signal. The internal micro-processor controlling the ADCP's functioning pilots the acquisition sequence, which involves the following operations:

- initialization of the internal functions,
- transmission of an acoustic wave via the four transducers and the power regulator,
- reception of the reverberated echo, which is amplified and translated into a basic frequency band centred around zero; thus one obtains directly the Doppler frequency shift,
- transformation of the four echoes in a cartesian reference by using the ship's gyrocompass data and, where necessary, the attitude parameters,
- taking into account of the temperature measured on the transducer. Since the Doppler effect depends only on the sound velocity at the level of the bases, this simple measure is sufficient for calculating the velocity of currents.

The micro-processor repeats these operations up to a number P of pulses which define a set. At the end of this set, the data are transferred by GPIB liaison onto a PC-compatible computer.

Two PCs (one per frequency) constitute the third main element of the system installed aboard the D'ENTRECASTEAUX. They are linked to the electronics and to the ADCP micro-processor, on the one hand, and to a positioning system (generally GPS) on the other.

They make it possible, thanks to the TRANSECT software of RDI, to pilot the ADCP by means of controls contained in the configuration file, and to record the current-meter data issued by internal calculations. Current measurements may be displayed using several types of representation (vertical or horizontal profile, spatio-temporal section, ...).

The TRANSECT software includes five menus, permitting:

- acquisition, recording and display of the data on screen,
- definition of liaison parameters with the ADCP and the navigation system,
- taking into account of the bias and corrections used in the calculations: depth and direction of the bases, bias when rolling, pitching and on course, salinity of the water in which the bases are submerged, type of calculation of velocity, coefficient for absorption of sound in sea water...
- determination of parameters of the current profile (size and number of cells, spatio-temporal means....) as well as of the type of data recorded (e.g. raw or averaged data),
- post-processing of raw data according to parameters other than those of real-time acquisition.

6.2 Measuring

The difference between the reception frequency and the transmission frequency is proportional to the speed of perpendicular movement in the propagation of sound (Doppler effect). The sound wave transmitted by the ADCP is reverberated from the micro-particles in suspension in sea water. On the frequencies used by the ADCP of the D'ENTRECASTEAUX,it is essentially zoo plankton which reverberates the sound wave. This reverberation is in direct correlation with sea currents, since such micro-particles follow the movements of the water layers.

The Doppler effect is due only to the radial speeds between the transmitter and the receiver. In order to measure the three components of the current, it is necessary to have at least three acoustic beams. With the four acoustic beams of the D'ENTRECASTEAUX's ADCPs it is possible to calculate two horizontal components (speed following the axis East-West and North-South after moving from the coordinator system linked to the ship to a geographical coordinator system), and two vertical components; the difference between the latter two components provides an estimation of the current measurement error which is representative of the quality of the data and/or of the homogeneity of the horizontal current.

The most important characteristic of the ADCP is its capacity for measuring current profiles. The profile is decomposed into layers of equal vertical dimension, called *cells*. An average current per cell is measured and it is possible to programme up to 128 cells per current profiler (in practice, about 50 cells are generally used, of 4m for the 300kHz and of 16m for the 75kHz). The cells are produced by signal processing technics. Transmission is a pulse of a certain length which can be modified but which is generally chosen to be equal to the size of a cell. The return signal is split up by moving a temporal listening window which corresponds to a cell (see Figure 3 which shows that the resulting current is a measurement weighted both in time and in space).

Finally, to obtain the absolute current components, in addition to the geometric processing already referred to for reduction of measurements to a reference datum on land, the ship's speed must be taken into account. This may be determined in several ways : a navigation system such as the GPS, Bottom-tracking by the ADCP (determination of speed by Doppler measurement on the seabed when it is within range of the base), or based on a reference layer (layer of no speed or known speed). The GPS speed gives fairly good results, according to the strength of the current to be measured. The Bottom-Track speed gives coherence between the acoustic current measurement and the measurement of the vessel's speed which is also acoustic.

6.3 Performances

The different frequencies enable different ranges and resolutions to be obtained; nominally, the 300kHz should carry to a range of 200m with a resolution of 4m and the 75kHz to 800m with a resolution of 16m. In practice, the range of the 300kHz is typically of 170m, whatever the speed, and that of the 75kHz is reduced in inverse proportion to the speed from 700m at 8 knots to 200m at 14 knots. Soiling on the windows of the bases leads to a reduction in range, essentially

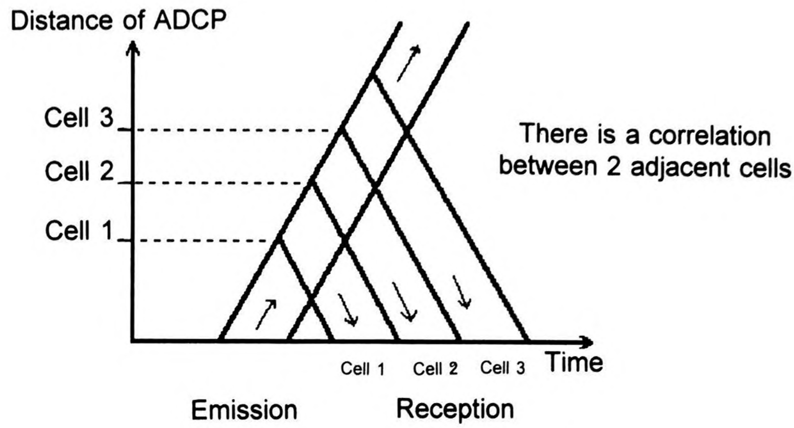

FIG. 3.- Insonification by ADCP.

noticeable on the current meter using 75kHz frequency. For each frequency there exists a blind zone in which, due to the intensity of the reverberated echoes, no measurement is possible: these are the first 10 metres for the 300kHz profiler and the first 100 metres for the 75kHz profiler. Thus the two systems mounted on the D'ENTRECASTEAUX are complementary for obtaining a continuous profile of measurements in the 10 - 800m section.

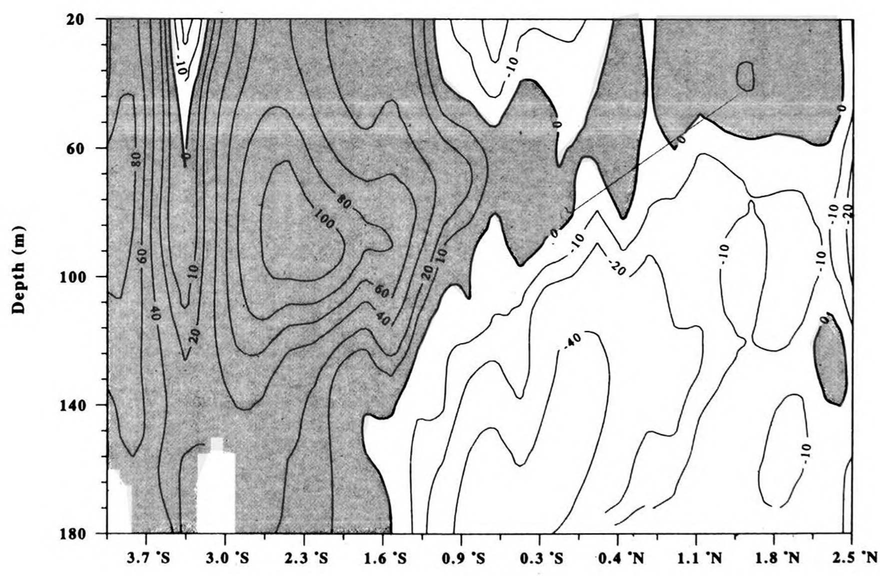

FIG. 4.- North-South component of the current observed in February 1995 on crossing the Equator in the Indian Ocean (spatial processing by CODAS software); speeds are in cm/s.

The quality of position-fixing of the carrier is obviously essential in summing up the measurement error. If only GPS in natural mode is available, the noise (1σ) on the estimated speed of the ship is from 15 to 30cm/s and one can merely envisage the detection of large currents such as permanent currents or those associated with fronts. With higher positioning accuracy, the noise on the ship's speed diminishes (1 to 5cm/s with Differential GPS) and one has access to finer structures such as shearing currents. Nevertheless, it is always possible to process the data acquired with a non-optimal positioning system by analysing the sets of observations with hypotheses of spatial and temporal continuity; Figure 4 is the result, after temporal pre-processing (Kalman filter) of an analysis in spatial correlation (Codas software).

The noise of acoustic measurement is theoretically as follows:

$$\sigma\ (cm/s) = \frac{1.6 \times 10^7}{F \times l \times B \times \sqrt{P}}$$

where F : ADCP frequency in Hz
l : length of the pulse transmitted in m (generally equal to cell size)
B : coefficient, function of angle of beams (1 for an angle of 30°)
P : number of pulses transmitted to calculate an instantaneous current measurement

Comparison of the measurements obtained by the two current meters enables one to verify that this formula provides a good estimation of the noise of acoustic measurement for the parameters determined aboard the D'ENTRECASTEAUX (P=4, l = 4 for 300kHz ADCP, l = 16 for 75kHz ADCP); it is optimistic if the size of the cells is reduced. Nevertheless, in order to obtain this result it is necessary to take into account two calibration coefficients: the scale factor and the misalignment angle.

These coefficients, which depend on the environment, must be determined regularly during a measuring exercise (e.g. analysis over intersecting routes).

7. THE "SEA SOAR" TOWED SYSTEM

7.1 Presentation

The Sea Soar, manufactured by the British firm Chelsea, is a towed vehicle designed for the transport of measuring instruments at varying depths in a controlled manner. Its functioning principle is ingenious. When towed, its propeller is driven by the effect of the ship's wake and it thereby supplies energy to a pump which generates hydraulic pressure. The pressure is injected to a valve controlled by a signal from the control console. This valve spreads the pressure via a fluid towards a piston, the longitudinal movement of which modifies the incline of the vehicles wings so that the vehicle dives or soars (Fig. 5).

The vehicle is towed by a multicore tow cable which carries, apart from the power for the internal pressure sensor, in one direction, the signals from the sensors to an acquisition workstation (Terminal X) and, in the other direction, the orders controlling the valve previously referred to.

This control console has several displays which indicate the elements necessary for driving the Sea Soar:

- depth of the vehicle measured by pressure sensor linked to the vehicle;
- tension of the cable, measured by a strain sensor (between 100 and 1200kg);
- indicator of inclination of the vehicle wings;
- verniers to control the soaring or diving speeds, the maximum depth desired, the response time of the controls, the horizontal position of the wings, which varies according to the loads carried.

7.2 Modes of functioning:

Four modes of functioning are possible:

- natural (undulating) mode: the ideal path of the vehicle would be a regular saw-toothed diving and soaring with depths varying from 0 to 500m and vertical rising and falling speeds of 1.5m/s. In the case of the D'ENTRECASTEAUX, the length of the cable is 600m, 440m of which is faired; for a towing speed of 7.5 knots the vehicle oscillates between 10m and 380m, with speeds of 1.8m/s.
- control mode enables the operator to control directly the soaring or the diving of the vehicle using one of the verniers described above. The operator has two galvonometer-type indicators to show whether the vehicle is diving or soaring and the position of the vehicle wings.
- manual/undulation mode where the fish oscillates around a given vehicle depth.
- external mode (not accessible as configured aboard the D'ENTRECASTEAUX) which allows for pilotage of the vehicle by a dedicated calculator.

7.3 Sensors

The Sea Soar vehicle is a receptacle able to carry different types of sensors. The vehicle is 1.9m long, with a span of 1.35m and 45cm high; in air, it weighs 150kg.

The value of the system lies in the fact that it enables horizontal sections to be made, giving a non-dynamic description (as the fish is moving) of the section of water. On the D'ENTRECASTEAUX, the equipment carried is generally as follows:

- a Seabird CTD probe which measures the temperature and the conductivity of the sea water,

- a fluorimeter, the ultra-violet ray source of which stimulates certain substances, such as chlorophyll A, which then give off a luminous intensity. This luminous intensity, compared to the source transmission, gives a value commensurate with the density of the substance stimulated.

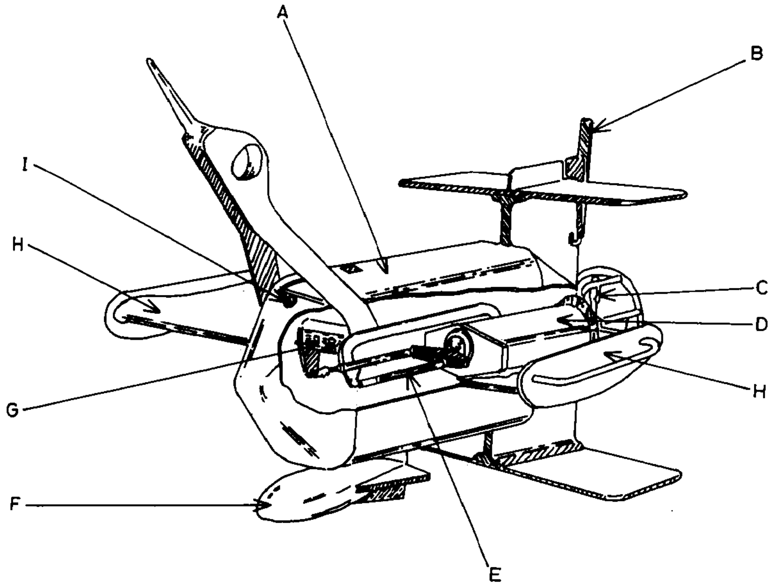

FIG. 5.- Plan of the towed vehicle of the Sea Soar system with the top cover (A), the rudder (B), the propeller (C), the hydraulic unit (D), the push rod (E), the streamline weight (F), the wing socket (G), the wings (H), and the entrance for the towing cable (I).

8. CONCLUSION

The hydro-oceanographic vessel D'ENTRECASTEAUX was designed twenty-five years ago, which is a respectable age for a ship required to deploy complex equipment and techniques. Its own capacity for manoeuvring, logistics and handling enable it to carry out present hydrographic and oceanographic missions efficiently.

Her original specific equipment has been replaced in order to keep pace with advances in technology. Most of her equipment, whether modular (computer equipment carried aboard, positioning receivers, ...) or permanent (sounders, current profilers,...) had not been heard of when the vessel was designed in the late sixties. When specifying the capabilities of the D'ENTRECASTEAUX, the flexibility of the space and working areas available was emphasized in order to obtain a good degree of adaptation for her missions and possibilities in the future. This flexibility remains a real aspect today and allows us to envisage with serenity her use by SHOM for some years to come.