RADIO-ACOUSTIC RANGING ON THE SKERKI BANK

by

INGÉNIEUR HYDROGRAPHE PRINCIPAL A. BRUNEL.

(Extract from "Les Annales Hydrographiques" 1938).

In 1937, a French Hydrographic Expedition under the technical direction of Ingénieur Hydrographe Principal BRUNEL was entrusted with the surveying of the approach to the Skerki Bank. This bank, situated in the Mediterranean Sea, off the Bay of Tunis, about 45 miles to the North of Cape Bon includes two dangerous shoals: the Keith Reef awash and the Hecate Patch whose head is 7 meters under chart datum. Sounding positions were to be determined by radio acoustic ranging. The International Hydrographic Bureau has received Ingénieur Principal Brunel's report describing the survey operations. We reproduce hereafter the part which concerns radio-acoustic ranging.
(Translation from the French).

RADIO-ACOUSTIC RANGING INSTALLATION.

I. *General arrangements.* — The sounding Vessel "*Ypres*" provoked an explosion at the exact time of stations by throwing a primed detonating cartridge into the sea. The stationary Vessels "*Sentinelle*" and "*Estafette*" had been fitted with a retransmission gear including a microphone connected to a set for the Herzian retransmission of submarine noises, emitting on a wave length stabilised by a quartz (85 m. for the "*Sentinelle*", 75 m. for the "*Estafette*"). The microphone retransmitted the explosion noise immediately after it was received. These retransmissions were received on board the "*Ypres*" on two O. C. 13-120 short wave receivers tuned on 75 and 85 m. wave lengths. A special recorder registered by means of a peak on the record: 1° the explosion noise reaching the "*Ypres*" a short time after it was produced; 2° the herzian retransmission of sounds reaching the "*Sentinelle*" and the "*Estafette*". The distance between the "*Ypres*" and the two stationary Vessels were obtained, subject to a small correction, by multiplying the time interval between the two records by the velocity of sound.

II. INSTALLATION ON BOARD THE STATIONARY VESSELS.

A. *Microphones.* The microphones were "solid back" microphones. Most of the time they were immersed at a depth of about 10 meters under a cork buoy kept off the side of the vessel, a highly insulated cable about 100 meters long connected the microphone to the listening-in vessel. This device was intended to do away as much as possible with the disturbing noises coming from the stationary vessels.

In order to enable the listening-in vessel to locate the position of her microphone during night operations, it was found possible and without difficulty to place a lamp fed from the vessel electric main on the buoy.

B. *Sets for the herzian retransmission of submarine noises.* The retransmission sets constructed at the request of Ingénieur Hydrographe en Chef MARTI, by Monsieur GUERRIER Scientific Assistant at the Centre d'Etudes de la Marine at Toulon, included:

1° A pilot oscillator stabilised by a quartz on a single wave length (85 m. for the "*Sentinelle*" and 75 m. for the "*Estafette*";

2° A power amplifier energized by the above mentioned oscillator and supplying the aerial with oscillating power;

3° A modulator placed between the pilot and the amplifier, which brings on a mean voltage variation of the amplifying valve grids under the control of the microphone signals.

4° A low frequency amplifier to raise the microphone signal level so as to allow the application of an adequate voltage to the modulator.

The aerials consisted of a 400 millimeter prism made of four 19 m. long pieces of wire with a central down lead, 6 to 7 m. long.

The microphone amplifier fitted on the transmitters did not give satisfactory results; from a certain transmitting power, which is moreover very weak, the microphone amplifier seems to detect the high frequency emitted by the transmitting amplifier. Several attempts which were made to obviate these conditions: decrease of high voltage, separate feeding, shock self induction, proved ineffective. These amplifiers had to be replaced by M amplifiers placed at some distance from the transmitters and fed from separate batteries, the amplifier output being connected by a highly insulated cable to the primary of the entry transformer of the modulator. A variable resistance and a milliammeter were introduced in the microphonic circuit and an inverting system was installed to allow the replacement of the microphone by a Jacquet watch which switched off the current rhythmically. In these conditions each current interruption by the watch gave rise to a short and very characteristic signal, from which the general working of the set (with the exception of the microphones) could easily be checked from the cartridge throwing vessel, and allowed, if necessary, a new adjustment of the receivers. An other system which also proved effective on the "*Estafette*" was to start the C.E.T. sounder between stations, in which case the noise from the hammer was transmitted like that of cartridges.

The "*Estafette*" and "*Sentinelle*" operators could ascertain the quality of their emission by listening in on the vessel receiving set which although it was tuned out, perceived the transmission from the other sets on account of their nearness.

III. INSTALLATION ON BOARD THE SOUNDING VESSEL "*YPRES*".

The reception was effected by two shortwave O. C. 13-120 seriatim receivers connected to a small single wire aerial from 5 to 6 meters long.

These receivers were each equipped with a single valve amplifier connected to one of the oscillographs of the recorder.

The explosion record was made by means of an ordinary earphone, placed abaft on the hull and connected to an M amplifier.

The recorder used was a Boulitte Recorder with 3 Abraham oscillographs, one of which served for recording time by means of a contact chronometer beating half seconds.

A system of single control inverters made it possible to connect the parallel transmission oscillographs to the M. amplifier output for recording the starting peak and then to connect each one separately on to its one valve amplifier, for the purpose of recording retransmissions.

Computation of distances between the "Ypres" *and the stationary Vessels.* — The distance between two peaks a and b obtained on the record represented the time interval separating the reception on board the "*Ypres*": a, from the explosion taking place in the vicinity, b from the arrival which was retransmitted immediately, of the acoustic wave on board the stationary vessels. In calculating these distances, allowance should be made for the short time interval separating the time of the explosion from the time when the explosion was heard on board the "*Ypres*". This correction which depended on the speed of the sounding vessel and on the length of the detonator fuse remained practically constant and amounted to 0.04 sec.

The distances obtained after correction were those that separated the stationary vessels from the exact spot where the cartridge was immersed.

Hydrologic measuring operations. — An hydrologic survey of the Skerki-region by means of a Richard bottle and a reversing thermometer was undertaken with a view of determing the two elements: temperature and salinity, which permit the computation from the "Hydrographic Department Tables" of the velocity of sound which it is convenient to adopt for plotting sounding operations.

Twenty five stations distributed over the area to be sounded were effected. At each one the temperature and salinity were determined at various depths. In some stations, measurements were made at ten different depths (bottom, surface, etc.).

This survey gave the following results :

1°/ The density measured with an aerometer and reduced to its value at 0° C by means of Thoulet diagram is practically the same at whatever depth for the whole of the Skerki region. In view of the but slight influence of density on the velocity of sound, we assumed, for purposes of calculation, that density reduced to 0° C was uniformly 1.0305;

2°/ At various depths from 0 to 70 meters, the temperature varied rapidly, the variation reached as much as 10 to 12° C.

At 300 meters, its value is about 13°5 (beyond 70 meters, it varies very little: from 16 to 13°5). We had therefore the opportunity to check over the Skerki Bank the well known fact of the uniformity of the Mediterranean abyssal temperature which in 13° C, is also that of the Atlantic deep waters on the rise of the strait of Gibraltar.

On the surface, in the month of August, the temperature reaches 26° C., in June from 20° to 22° C. at a depth of 50 meters, the temperature may be 19° C. when that of the surface is 25° C.

We noted at various stations that a sudden discontinuity in the decrease of temperature as depth increased was likely to happen; on June 27th, near Buoy N° 1 (in the vicinity of the 36 m. Bank, in L = 37° 39' G = 10° 35', we obtained temperatures as follows :

48 meters	15°9'	
27 »	16°8'	
24 »	16°8'	
22 »	20°9'	
19 »	21°4'	increase of 4°,1 C. for every 2 meters decrease in depth.
13 »	21°9'	
6 »	22°2'	
surface	22°9'	

The outcome of these hydrologic measuring operations is that at least in its superficial layers (from about 0 to 70 meters) the Skerki sea, from the stand point of temperature distribution is an essentially heterogeneous medium in the summer.

What are the velocities of sound corresponding to these temperatures ?

At a temperature of 24° C. on the surface, the density being 1.0305, the Hydrographic Department Tables show that the velocity of sound in 1.531 m. 7.

At a temperature of 14° C (at a depth of some 300 m.) with a density of 1.0305, the velocity of sound is 1.508,5.

So that by adopting either one or the other of these velocities, a space of 10 seconds corresponds to a distance of either 15,317 or 15,085, which represents a difference of over 200 mètres.

Here arises a question which is preliminary to any radio-acoustic survey: does sound propagate on the surface or in depth ? It is a known fact that from an indirect measuring involving a determination of position by angle measurements and radio-acoustic ranging, American Hydrographers have inferred that everything goes on as if sound spread in deep layers.

It is of interest in connection with a Skerki survey where mixed position determinations have been effected, to ascertain whether the American Hydrographers's conclusions are substantiated or not.

If distances are calculated by taking the surface temperature, radio-acoustic distances are too long. In the area situated in the N.E. of the survey where depths are relatively great, a satisfactory concurrence is reached between the positions computed by angles and the distances to Buoy N° 3 calculated on the basis of a 1.508 m. 5 velocity corresponding to the temperature obtaining at a depth of 300 meters.

This concurrence seems to confirm the results arrived at by American Hydrographers. Nevertheless a velocity of 1.508 m. 5 gives decidedly too short distances when dealing with relatively shallow depths between the sounding and the stationary vessels. We noted this fact on the sounding profiles through the less than 100 meters depths which prolong the Hecate Patch South-Westwards.

We suggest the following explanation for this discrepancy: the propagation of sound always take place at the bottom, but in shallow depths, the temperature at the bottom is relatively high and may reach 18° C at a depth of 50 meters (1) to which corresponds a velocity of 1.517 meters.

The determination of the velocity of sound was made whenever we measured distances between two buoys by means of a taut wire gear. The stationary vessels were moored on to the departure and arrival buoys. Every five minutes a detonating cartridge was thrown out and the number of revolutions of the registering wheel was recorded at the same time. As the "*Ypres*" was almost constantly sailing over relatively shallow depths, when proceeding from buoy to buoy, a high velocity of sound had to be adopted in order to maintain agreement between the radio-acoustic distance and the wire measured distance.

A check of the positions obtained in radio-acoustic ranging by the angle methods leads us therefore to formulate the following conclusions :

In a region where the water temperature is not uniform, in connection with the plotting of acoustic soundings the velocity of sound seems to depend on the depths to be found between the sounding vessel and the listening-in station. This velocity may not be the same for the different listening-in stations and in these conditions the sea may act as an anisotropic medium.

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(1) In August at a depth of 5.500 meters in the 322° of Biddlecombe Patch.
Temperature at the bottom : at 310 meters 13°8
76 » 16°
57 » 20°
surface 26°

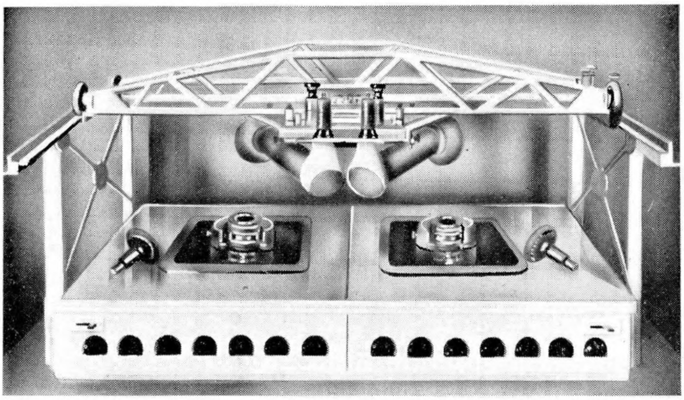

FIG. 1. — *Marking stereoscope with punching device.*

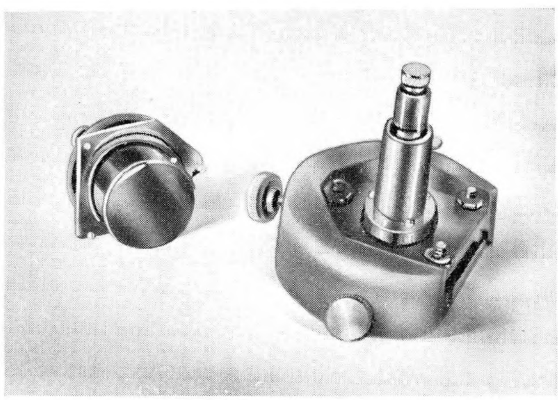

FIG. 2. — *Marking stereoscope punching device.*
Left, the marking plate which may be used alternatively instead of the punch.

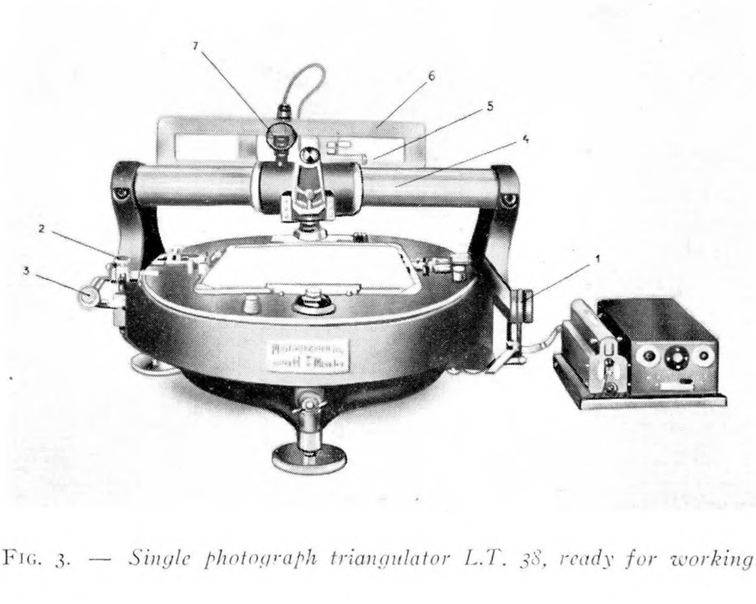

FIG. 3. — *Single photograph triangulator L.T. 38, ready for working.*