LAST COPY

w
JM

1

Technical Report No. 66

SACLANT ASW
RESEARCH CENTRE

OBSERVED SOUND VELOCITY AND TEMPERATURE PROFILES IN THE STRAIT OF GIBRALTAR DURING THE PASSAGE OF AN INTERNAL WAVE

by

T.D. ALLAN

15 OCTOBER 1966

NATO

VIALE SAN BARTOLOMEO, 92
LA SPEZIA, ITALY

This document is released to a NATO Government at the direction of the SACLANTCEN subject to the following conditions:

1. The recipient NATO Government agrees to use its best endeavours to ensure that the information herein disclosed, whether or not it bears a security classification, is not dealt with in any manner (a) contrary to the intent of the provisions of the Charter of the Centre, or (b) prejudicial to the rights of the owner thereof to obtain patent, copyright, or other like statutory protection therefor.

2. If the technical information was originally released to the Centre by a NATO Government subject to restrictions clearly marked on this document the recipient NATO Government agrees to use its best endeavours to abide by the terms of the restrictions so imposed by the releasing Government.

TECHNICAL REPORT NO. 66

SACLANT ASW RESEARCH CENTRE
Viale San Bartolomeo 92
La Spezia, Italy

OBSERVED SOUND VELOCITY AND TEMPERATURE PROFILES IN THE STRAIT OF GIBRALTAR DURING THE PASSAGE OF AN INTERNAL WAVE

By

T.D. Allan

15 October 1966

APPROVED FOR DISTRIBUTION

HENRIK NØDTVEDT
Director

Manuscript Completed:
21 June 1966

TABLE OF CONTENTS

Page

ABSTRACT 1

INTRODUCTION 2

1. INSTRUMENTATION 3

2. PROCEDURE 4

3. ERRORS 6
   3.1 Temperature 6
   3.2 Sound Velocity 6
   3.3 Depth 9

4. RESULTS 10
   4.1 Time Variation 10
   4.2 Space Variation 12

5. CALCULATION OF SALINITY 13

6. CALCULATIONS ON THE SOUND FIELD DURING THE PASSAGE OF THE INTERNAL WAVE 15

CONCLUSIONS 17

ACKNOWLEDGEMENTS 19

REFERENCES 20

FIGURES 21

OBSERVED SOUND VELOCITY AND TEMPERATURE PROFILES IN THE STRAIT OF GIBRALTAR DURING THE PASSAGE OF AN INTERNAL WAVE

By

T.D. Allan

ABSTRACT

Sound velocity and temperature measurements taken from the sea-surface to 350 m depth, close to one spot over a 24-hour period revealed the passage of an internal wave of approximately 60 m amplitude. The effect of this wave in breaking up a previously well-developed thermocline is demonstrated.

The results of computer calculations on the effect of such a wave on the ray paths from a hypothetical sound source are presented.

INTRODUCTION

The oceanographic conditions in the Gibraltar Strait generate rather striking internal waves, which propagate eastwards into the Alboran Sea. Neither the mechanism creating the waves nor their occurrence in relation to tidal or other cycles are as yet clarified. Moreover, the rate of decay of the waves as they move into the Alboran Sea is unknown. The fluctuations in oceanographic parameters during the passage of these waves causes corresponding variations in the acoustic propagation conditions. Consequently, apart from the general oceanographic interest of the phenomenon, it is also of interest in the field of acoustic detection.

In order to collect more data that may throw light on the problem, a cruise was undertaken in this area during the period 24 January to 6 February 1966. The measurements included a time-variation study at a point almost equidistant between Europa Point and Ceuta, and a series of stations spaced one mile apart along various courses in the Alboran Sea.

1. INSTRUMENTATION

The instrument used for the measurements was a Daystrom Deep Sea Velocimeter, Model V-10 (SACLANT Serial No. 18) with a thermistor taped to the side of the case.

The sound pulse repetition rate, or frequency, was about 7 kHz. This was converted into a square wave (3.5 kHz) to allow for transmission by a lossy cable. The instrument had been previously calibrated at the Centre and the relationship between velocity (V, in m/s) and frequency (f, in Hz) was found to be

$$V = 0.4132\ f$$

Using a dual pre-set counter, recordings were made by counting the time for 1000 cycles of the signal to pass. During this time the output of a 100 kHz crystal (approx. 27000 cycles) was counted and recorded on one channel of a Leeds-Northrup recorder. Temperature was recorded on the second channel. The Y channel (chart drive) was controlled by the output of a Bourns pressure-gauge transducer fitted to the velocimeter. The range of depths over which measurements were made was approximately 0-350 metres.

2. PROCEDURE

It was decided to measure close to one spot for a 24-hr period (the area shown within the circle in Fig. 1) and then to take dips at stations spaced approximately 1 mile apart (profiles AB, A_1 B_1, CD, and C_1 D_1 in Fig. 1).

Recordings were made during both the lowering and recovery of the instrument. The average time for one dip was 8-10 minutes.

For the time-variation study a compromise was reached between the need to take dips as nearly as possible at one spot and the time lost in manoeuvering the ship between dips in an area where surface currents reached 4 knots. A circle of ½ mile radius was drawn on the navigation chart and dips were made, as far as possible, whenever the ship manoeuvered back into this circle after drifting. In this way the average time between dips was half-an-hour.

Two attempts to complete a 24-hour cycle of recordings failed after a few hours because of instrumental faults. On the third attempt a 24-hour period was successfully recorded. The stations spaced 1 mile apart were then completed without incident and repeat measurements were made at these stations three days later.

Navigation was made by taking radar ranges on Europa Point, Ceuta, Carnera Point, and Leona. These ranges were all within 5 to 7 miles of the circle of operation. Fixes were made both on starting down and on recovering the velocimeter. The plotted positions shown in Fig. 1 were taken at the mid-point of these two fixes. During a dip the ship usually drifted about $\frac{1}{4}$ to $\frac{1}{2}$ mile to the west or north-west.

A total of 87 dips was made, giving 174 recordings — of which 4 were unusable due to instrumental failure. Bucket temperatures were taken every second dip so that the thermistor calibration could be checked. After 79 dips the thermistor broke while bringing the instrument inboard, and the last 8 dips were made with a replacement.

3. ERRORS

3.1 Temperature

The calibration error for the first thermistor used was 0.43°C. For the second thermistor the error was zero.

The recording paper was 10 in. wide with 100 divisions. A 10°-20° scale was selected so that one division (0.1 in.) represented 0.1°C. There appeared to be very little effect of hysteresis in the temperature recorder circuit, such as appeared in the sound velocity recordings (described below). The overall error in the temperature recordings was estimated as ± 0.05°C.

3.2 Sound Velocity

Across the 10 in. recording chart the sound velocity "count" scale was chosen to be 27 000-28 000, so that one division represented ten counts or approximately 0.55 m/s. It is estimated that the record could be read to better than half a division, giving an estimated error of approximately ± 0.25 m/s.

The dual traces recorded during lowering and recovery were compared and a systematic difference was observed. This could be more clearly seen in the quasi-isothermal layer beneath the thermocline where the sound velocity gradient is small. In the thermocline and surface layer, possible real changes in the environment obscure any small instrumental error. The various causes of error were considered to be the following:

a. The change in the direction of the water flow past the transducers during lowering and recovery.

b. A slow change in the temperature of the instrument during a dip, due to its being left on deck between dips.

c. Hysteresis of the pressure gauge.

d. Lack of sensitivity of the recorder circuit causing a slight lag analogous to hysteresis.

The records were examined for these effects. No definite conclusions could be drawn from effects a and b. When dual traces were compared there was no apparent constant difference over the profiles, such as might be produced by a. Nor was there evidence of any effect from a slow change of temperature in the transducer, which would produce the largest discrepancy at the surface and very little discrepancy in the deep layer. In fact, the opposite effect was observed.

Hysteresis in the pressure gauge would cause events to be recorded at an apparent depth less than the true depth during lowering and greater than the true depth during recovery. Again, the opposite effect was observed. Measurements of the recorded depth of the 1506.4 m/s isovelocity line were compared for 40 dual traces. The depth recorded during lowering was found to be greater by an average value of 19.8 m than that recorded during recovery.

It is concluded that only effect d could explain the observed behaviour. A loss of sensitivity in the recording of sound velocity means that, during lowering, the reading would lag a little behind the true value. The chart-drive is stopped when the pressure gauge measures 500 lb/in^2, but the winch cannot be stopped instantaneously, so that the meter goes a little beyond the limiting depth. Since the water is quasi-isothermal, the effect will be a slight increase in sound velocity.

When the recorder pen is lifted and the chart moved on for the second recording, the friction on the pen decreases and therefore it is free to move to a higher value of sound velocity. During recovery, the lag in the recording will act in the opposite sense than for lowering; that is, the recorded values will be a little higher than the true values. An actual record with the two traces superimposed is shown in Fig. 2. Near point A on the figure the discrepancy in the quasi-isothermal layer is shown as approximately 20 m, but this large difference in recorded depth arises from a small error in sound velocity in a layer depth with small gradient. In the thermocline (B on Fig. 2) the discrepancy in depth is reduced to 5 m and it is likely that a part of this arises from real environmental changes.

In plotting the isovelocity lines the mean value of the dual recordings was taken for the layer beneath the thermocline. In the thermocline and surface layer no averaging was made.

3.3 Depth

A Bourns pressure gauge was used for monitoring depth. It had an electrical resistance of 5000 Ω and was rated for 500 lb/in^2 maximum pressure. The error of the gauge itself, plus possible calibration errors in the recorder drive circuit (zero shift, etc), is estimated as 2% of full scale. The total absolute error would then be about 7 m.

The pressure gauge had been calibrated in a pressure tank before the cruise and was found to meet the manufacturer's figure of accuracy. Hysteresis caused a maximum difference of 2 m between increasing and decreasing pressure.

A pressure of 500 lb/in^2 is roughly equivalent to 350 m of water depth, the exact value depending on the assumed density of the water. For a σ_t of 23 the equivalent depth would be 344 m. The scale shown for the plotted isotherms and isovelocity lines may therefore be slightly in error.

4. RESULTS

4.1 Time Variation

The plots of temperature distribution are similar in character to the plots of sound velocity so that, in the following discussion, where reference is made to gradients and oscillations of isotherms it may be assumed that the sound velocity structure behaves in the same way.

The results of the 24-hr recordings are shown in Figs. 3 and 4. The thermocline was well-developed during the first 8 hours of recording, with the possible exception of the first hour. The top of the thermocline (layer depth) reaches a minimum depth of 30 m and a maximum of 60 m. The steepest gradient is about 0.15°C/m between the 16.2°C and 14.2°C isotherms.

The large-amplitude internal wave that passed through, started at about 0530 with a gradual deepening of the thermocline and reached its maximum activity between 0650 and 0750. The effect of the passage of this wave on the previously stable thermocline is vividly demonstrated in the succeeding 13 hours of recording. Mixing caused the thermocline to break up, and the temperature gradient measured between the 16.2°C and 14.2°C isotherms fell from 0.15°C/m, recorded 1 hour before the onset of the wave, to 0.04°C/m, recorded 1 hour after its passage.

Towards the end of the recording period small oscillations in the thermocline are observed, the largest occurring at 1930, or about 12 hours after the passage of the internal wave.

Because of the low sampling rate, no conclusions can be drawn on the frequency of oscillation. In Figs. 3 and 4, the internal wave appears to be made up of two cycles, the wavelength of the first apparently much larger than that of the second, but with almost equal amplitude. However, the fact that the second short-period oscillation was recorded with a shorter-than-average time interval between dips indicates that a faster sampling rate would have been required to represent adequately the true character of the oscillations. Figure 5 is a reproduction of the dual traces recorded at one station (no. 39) during lowering and recovery. The total time for the dip was 8 minutes. These traces give some idea of the minimum amplitude of the wave. The temperature of 14°C was recorded at a depth of 152 m during lowering but at 94 m during recovery, a difference of 58 m; for the 15°C isotherm the difference was 57 m.

Figures 6 and 7 show recordings lasting 5 h 20 min, which represent the first attempt to take a 24-hour cycle prior to instrumental failure. It is interesting to compare the character of the isotherms with the 24-hour recording. For the short recording the gradient increases from 0.05°C/m at 2100 (31st) to 0.1°C/m at 0120 (1st). For the 24-hour recording the gradient was 0.07°C/m at 2230 (1st) and increased to 0.1°C/m at 0120 (2nd). All gradients were measured between the 16.2°C and 14.2°C isotherms. The trend for the short recording therefore seems to be similar to that of the 24-hour recording, with the thermocline developing during the evening in both cases.

4.2 Space Variation

Figures 8 and 10 show the temperatures measured along tracks AB and A_1B_1, CD and C_1D_1, respectively. Figures 9 and 11 show the corresponding measurements of sound velocity. During the periods of recording no large fluctuations occurred similar to those in the 24-hr recordings. Along both AB and CD the surface temperature decreased by about 1°C and the same decrease was observed during the repeat measurements. Figure 8 shows the surface layer to have cooled between the evening of the 2nd and the afternoon of the 5th February. Along AB the 15°C isotherm rises from 70 m to 35 m, while along A_1B_1 it starts at 30 m and almost reaches the surface.

Both profiles AB and CD show the surface layer to be stable during the period of observation. Profile C_1D_1 shows some indication of a long-period oscillation of the thermocline, but the number of stations was too small to be able to draw any definite conclusions.

The sound velocity profiles follow very closely the characteristics of the temperature profiles, with the oscillation of profile C_1D_1 slightly more pronounced than for the temperature profile.

In summary, nine stations made in the late evening and early morning of the 2nd-3rd February and repeated during the late afternoon and evening of the 5th contributed very little to the study of internal waves in the Strait. No significant vertical fluctuations were recorded apart from a possible long-period oscillation recorded over C_1D_1 but not over CD. The cooling of the surface water both along AB and CD was confirmed in the repeat observations.

5. CALCULATION OF SALINITY

The velocity of sound in sea-water can be written:

$$V = V_{0:35} + \Delta V_T + \Delta V_P + \Delta V_S + \Delta V_{STP}$$

where $V_{0:35}$ is the velocity of sound at 0°C, 35‰ salinity, and atmospheric pressure: ΔV_T, ΔV_P, ΔV_S and ΔV_{STP} are respectively correction terms for temperature, pressure, salinity, and a term for simultaneous variation of those three parameters.

From experimental results, various workers have provided numerical expressions for the correction terms in the above equation. In the calculations that follow, the formula of Wilson (Ref. 1) has been used.

Sound velocity is most sensitive to changes in temperature and much less so to changes in salinity. In the real ocean, temperature can change rapidly over a few metres, whereas salinity usually shows a relatively gradual change. To a first approximation, a change in sound velocity of 1 m/s would be produced by a temperature change of 0.2°C, a depth change of 60 m, or change of salinity of 0.7‰ . Therefore, a value of salinity calculated from measured values of sound velocity, temperature, and water depth will be subject to substantial error, since, essentially, two large observed values are subtracted to produce a small correction term. However, because of the very large differences in sound velocity and temperature recorded during the lowering and recovery at station 39, it was decided to calculate the relative changes in salinity to see if the difference in the two profiles was significantly greater than the estimated observational errors.

The calculations were made on the computer. As foreseen, the absolute values of salinity were found to be in error (giving a range of 33.5 to 35.5°/oo, instead of the real range of 36.0 to 38.0°/oo), but the relative changes were significant. Plots of the salinity changes for the dual recordings, with the estimated limits of the 95% confidence level, are given in Fig. 12. These plots indicate that over the area of steepest salinity gradient there appears to have been a shift of the order of 60 m from the recordings made during lowering and recovery. Such a result indicates a change in density of the water during the passage of the wave, which is confirmed by the observed mixing and break-up of the previously stable thermocline.

6. CALCULATIONS ON THE SOUND FIELD DURING THE PASSAGE OF THE INTERNAL WAVE

Lee (Ref. 2) calculated the effect of an internal wave on sound propagation using a theoretical three-layer model with assumed velocity gradients of 0/s, -4.8/s and -0.6/s. The internal wave was considered to be a sine wave imposed on the thermocline. A computer study was made on the effect of this wave on sound emitted from a hypothetical, directional source through an angle of ± 8°C. It was shown that refraction caused the rays to be focussed into alternately high and low intensity zones.

Similar computer calculations were made at the Centre for the two observed velocity profiles of station 39. The computer program is designed to trace the rays emitted from a sound source placed at any given depth in the presence of any given sound velocity profile. At present, the program does not allow horizontal variations of the sound velocity profile, so that, in this case, the profile was considered to remain unaltered over a distance of 10 000 m. Bottom reflected rays were neglected.

The results for the two profiles of station 39 are shown in Figs. 13 a and b, the first showing a source depth of 5 m, and the second a depth of 100 m. A beam of ± 5° was chosen and rays were traced every 0.25°.

For both the shallow and the deep sound source the ray diagrams make it clear that the sound field would be greatly altered by the passage of the wave. The most obvious features of the ray diagrams are:

a. <u>For the shallow source</u>

The disappearance of the surface channel and the change in form of the shadow zone.

b. <u>For the deep source</u>

The drop in sound intensity in the area above the source. For the first profile the area was insonified by surface reflected rays; for the second profile, however, most of the rays are bent sufficiently to prevent their reaching the surface.

CONCLUSIONS

The prevalence of large amplitude vertical fluctuations in the Strait of Gibraltar is well-known. They have been studied by Frassetto (Ref. 3) using the towed thermistor chain from R/V CHAIN of WHOI and, more recently, using moored buoys with suspended arrays of thermistors (Ref. 4). Recordings made by these buoys in August 1965 are now being processed and the results should give some idea of the frequency of occurrence and possible mode of formation of internal waves.

More work remains to be done on the relative effects of tides, meteorological conditions, convective processes, etc. In Fig. 3 it is significant that the onset of the large amplitude wave coincided with low tide (0623), but that at the next low tide (1858) there was no comparable effect. Based on no more than a 24-hour recording it would appear then that tidal forces alone do not generate internal waves.

Lafond (Ref. 5), in a review of observations of internal waves, finds a strong correlation between the recorded depth of an isotherm and semi-diurnal tidal periods. He concludes: "while it is not certain to what extent periodic variations are present, there is no doubt that large variations in temperature of a quasi-periodic nature close to the semi-diurnal frequency are present in the sea".

More observations are required in the Strait of Gibraltar and surrounding areas in order to follow the progress of waves through the Strait and to study in more detail the mechanism of their formation. What is clear from the recordings shown in this report is that their presence can considerably alter the sound field in a matter of minutes, thereby making environmental prediction extremely hazardous.

ACKNOWLEDGEMENTS

The author would like to acknowledge his debt to Dr. J. Ziegenbein for his help in carrying out the measurements and for several helpful discussions on the results. Mr. R. Frassetto and Dr.R.Pesaresi also gave useful advice.

REFERENCES

1. W. Wilson, "Speed of sound in sea water as a function of temperature, pressure and salinity", J. Acoust. Soc., Vol. 32, p. 641, 1960.

2. O.S. Lee, "Effect of an internal wave on sound in the ocean", J. Acoust. Soc., Vol. 33, pp. 677-680, 1961.

3. R. Frassetto, "Short-period vertical displacements of the upper layers in the Strait of Gibraltar", SACLANTCEN T.R. 30, November 1964, NATO UNCLASSIFIED.

4. R. Frassetto, "Report on the oceanographic cruise GIB V, 7-15 April - 8 May 1965 and some preliminary results on temperature and sound velocity measurements", SACLANTCEN T.R. 45, July 1965, NATO CONFIDENTIAL.

5. E.C. LaFond, "Internal waves", Chapt. 22 of The Sea, Vol. 1, Gen.ed.M.N. Hill, 1962.

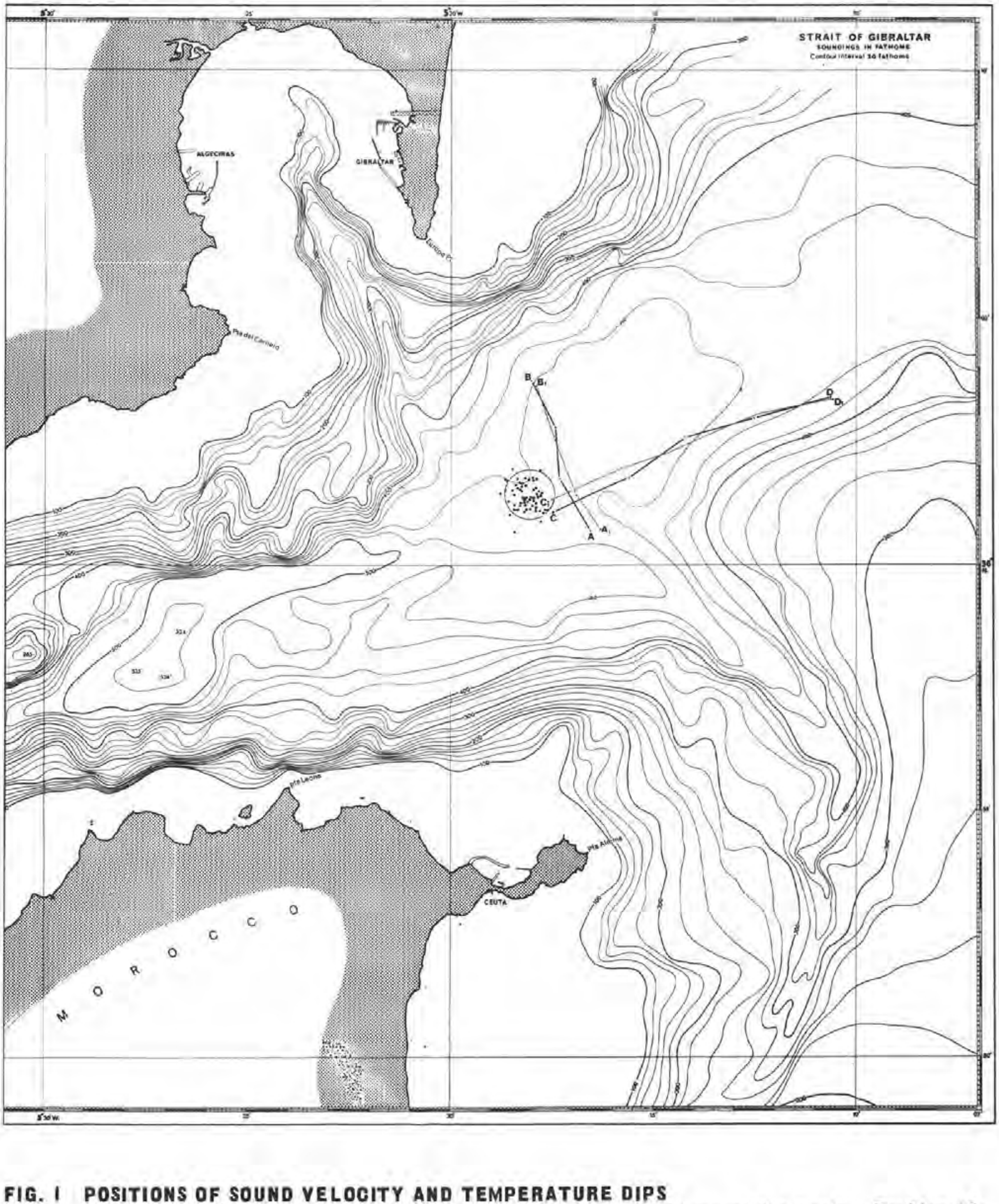

FIG. I POSITIONS OF SOUND VELOCITY AND TEMPERATURE DIPS
The 5–hour and 24–hour series of measurements were made in and around the circle. Profiles AB and CD were repeated after three days and are shown as A_1B_1 and C_1D_1.

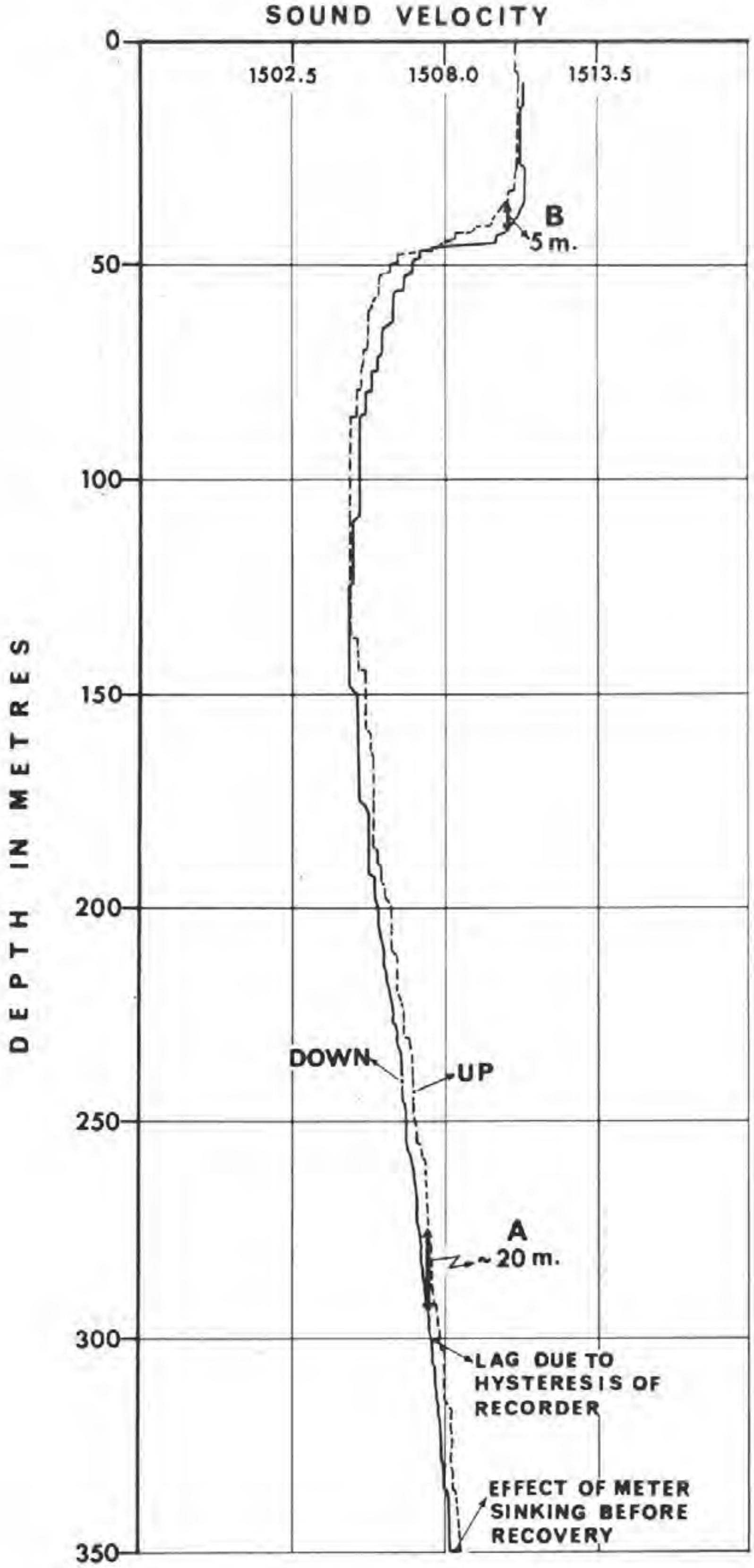

FIG. 2 DUAL RECORDINGS OF SOUND VELOCITY DURING LOWERING AND RECOVERY
Point A illustrates the error of 20 metres in depth in the quasi-isothermal layer. In the thermocline, at Point B, the difference is 5 metres. Note the slight increase in sound velocity at 350 metres due to sinking of the meter prior to recovery.

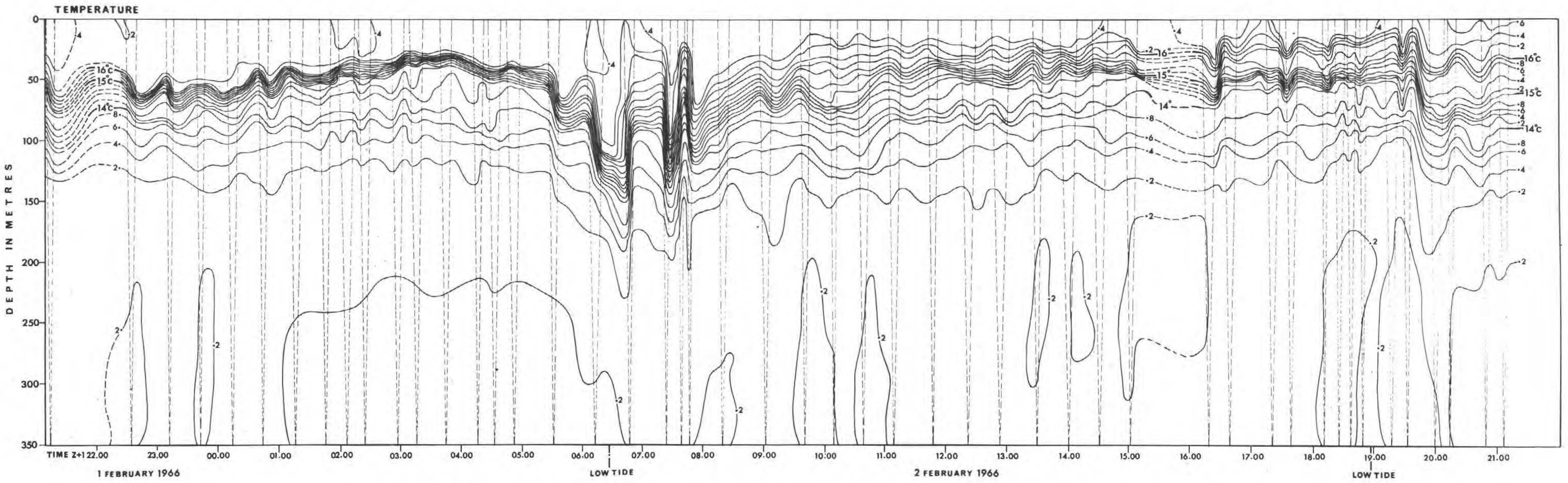

FIG. 3 ISOTHERMS PLOTTED OVER A 24–HOUR PERIOD AT THE POSITIONS SHOWN AS DOTS IN FIG. 1
The dips are represented above as dashed lines (both lowering and recovery). Contour interval is 0.2°C.

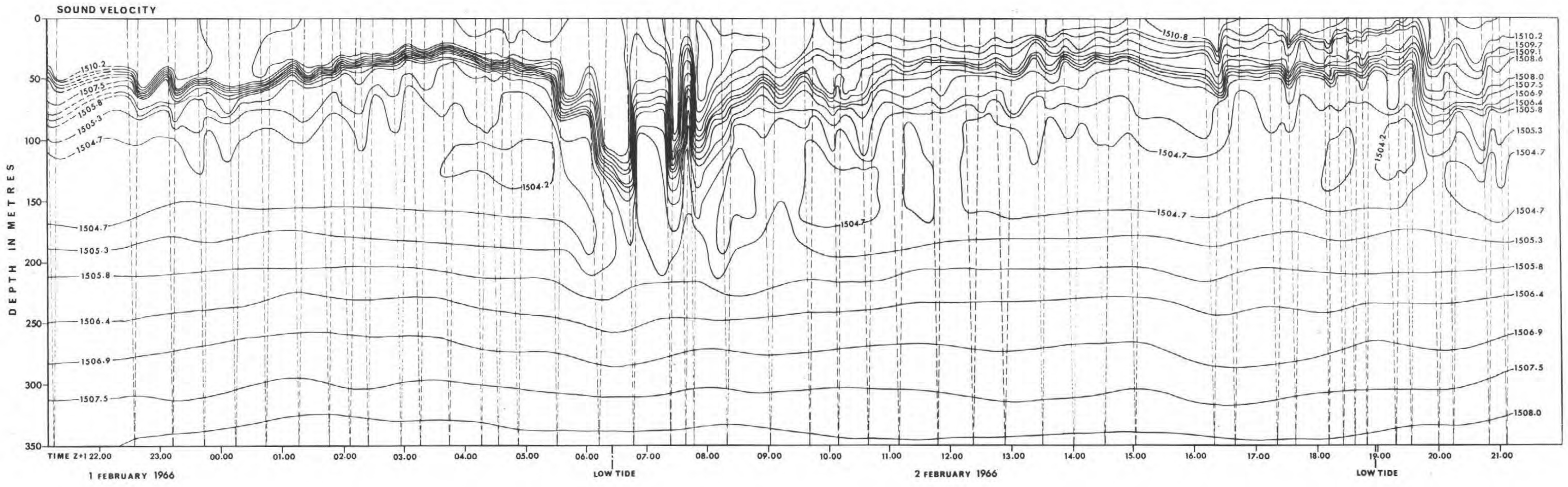

FIG. 4 LINES OF ISOVELOCITY PLOTTED AS FOR FIG. 3
Contour interval averages 0.55 m/s

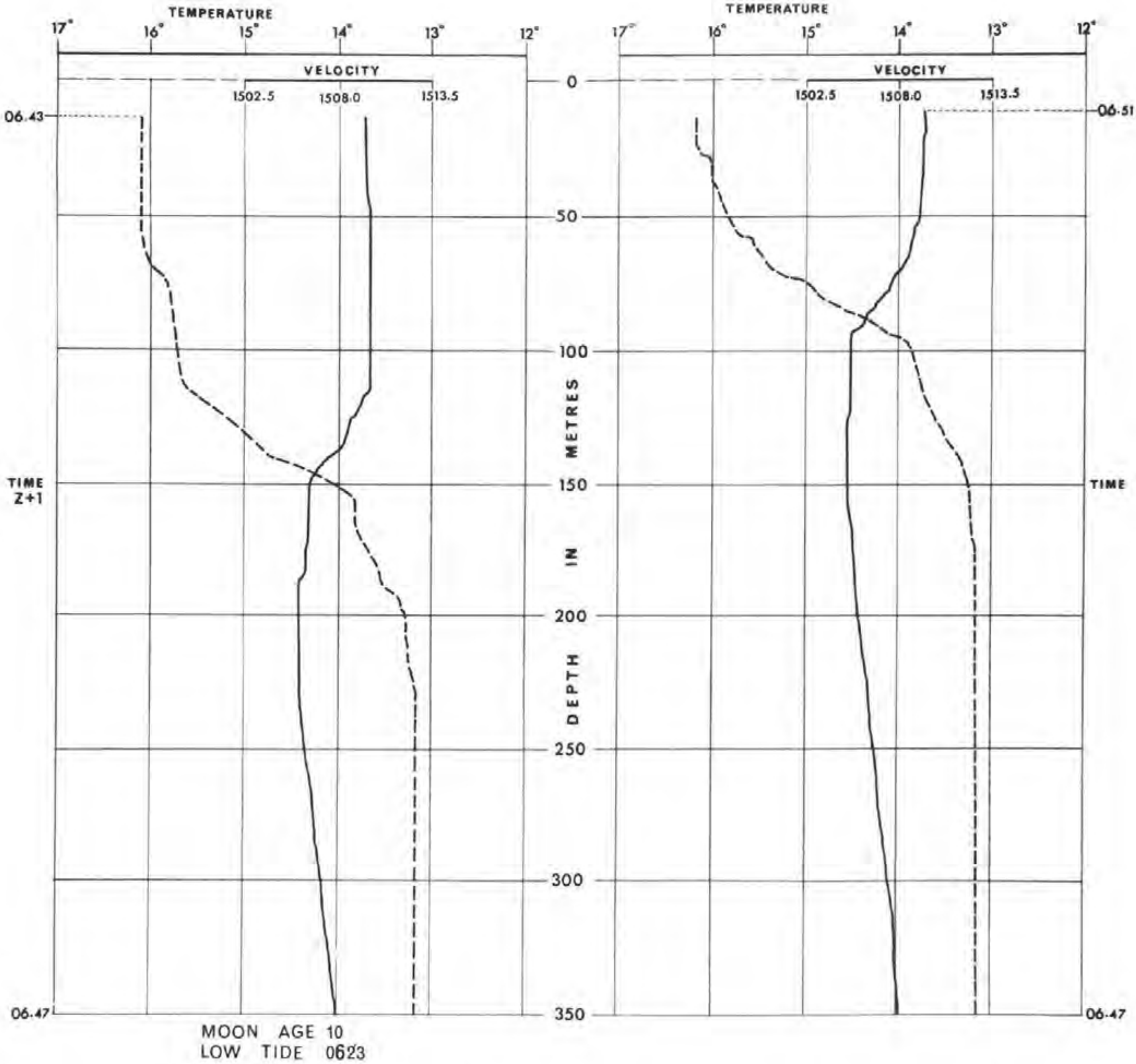

FIG. 5 THE TWO PROFILES OF TEMPERATURE AND SOUND VELOCITY RECORDED DURING LOWERING AND RECOVERY AT STATION 39

The temperature profiles are shown dashed. Note that the total time for the dip was 8 minutes.

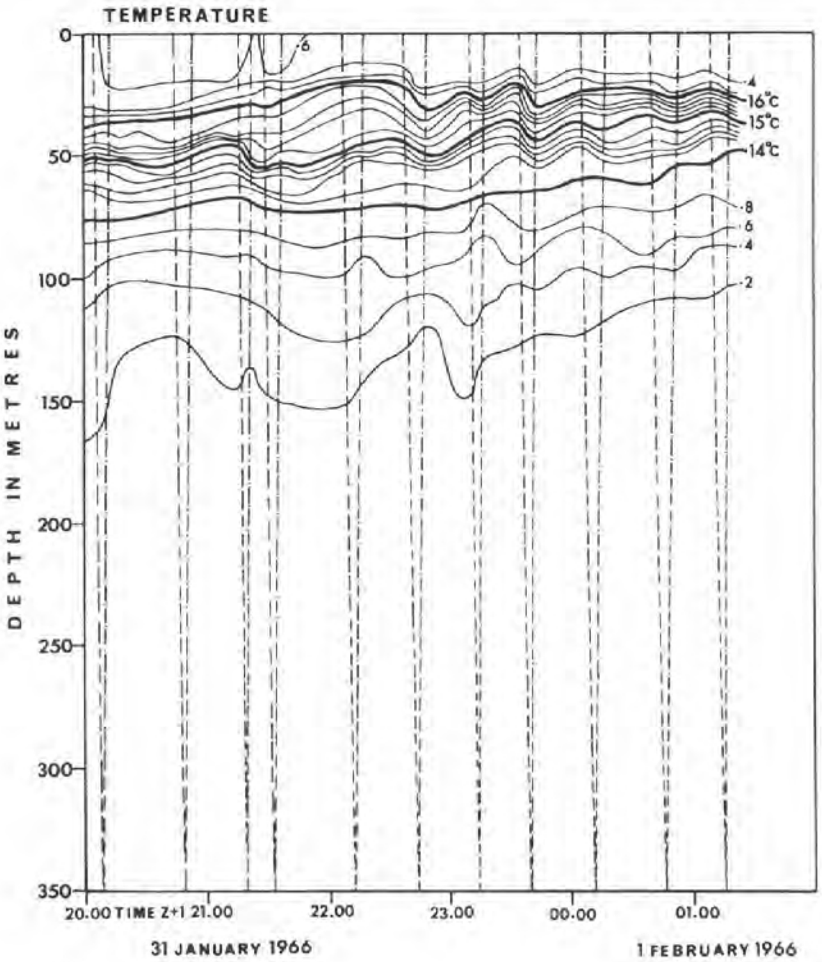

FIG. 6 ISOTHERMS PLOTTED AT THE POSITIONS SHOWN AS CROSSES IN FIG. 1
Period of 5 hr. 20 min. Contour interval is 0.2°C

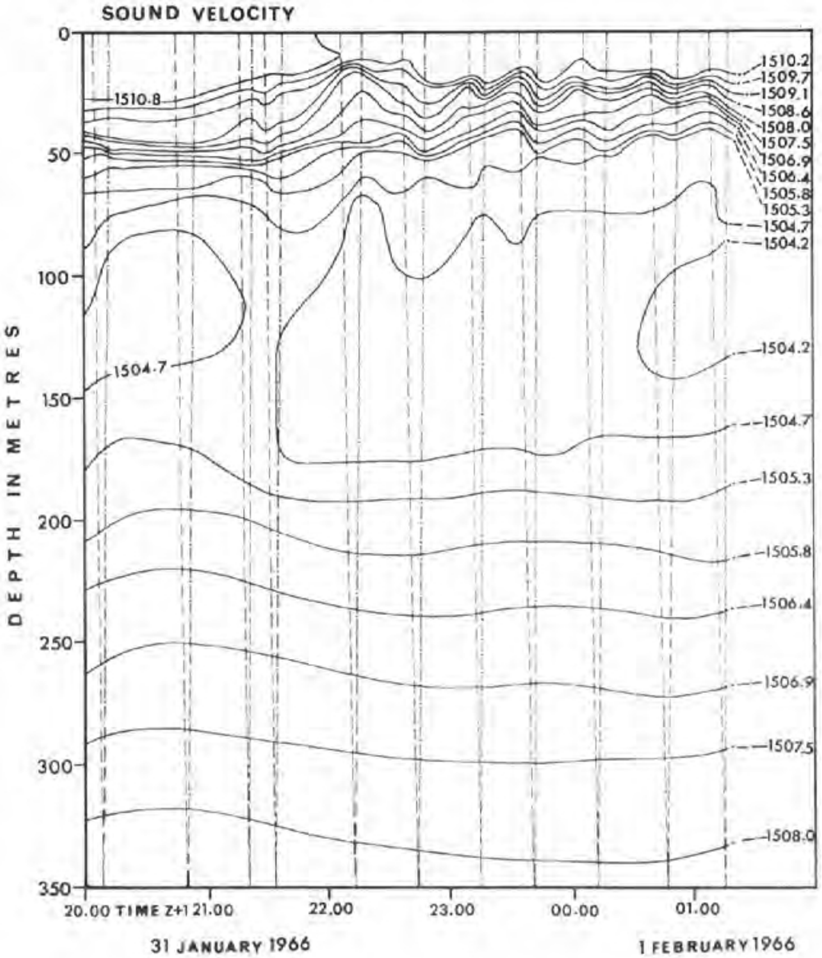

FIG. 7 LINES OF ISOVELOCITY PLOTTED AS FOR FIG. 6
Contour interval averages 0.55 m/s

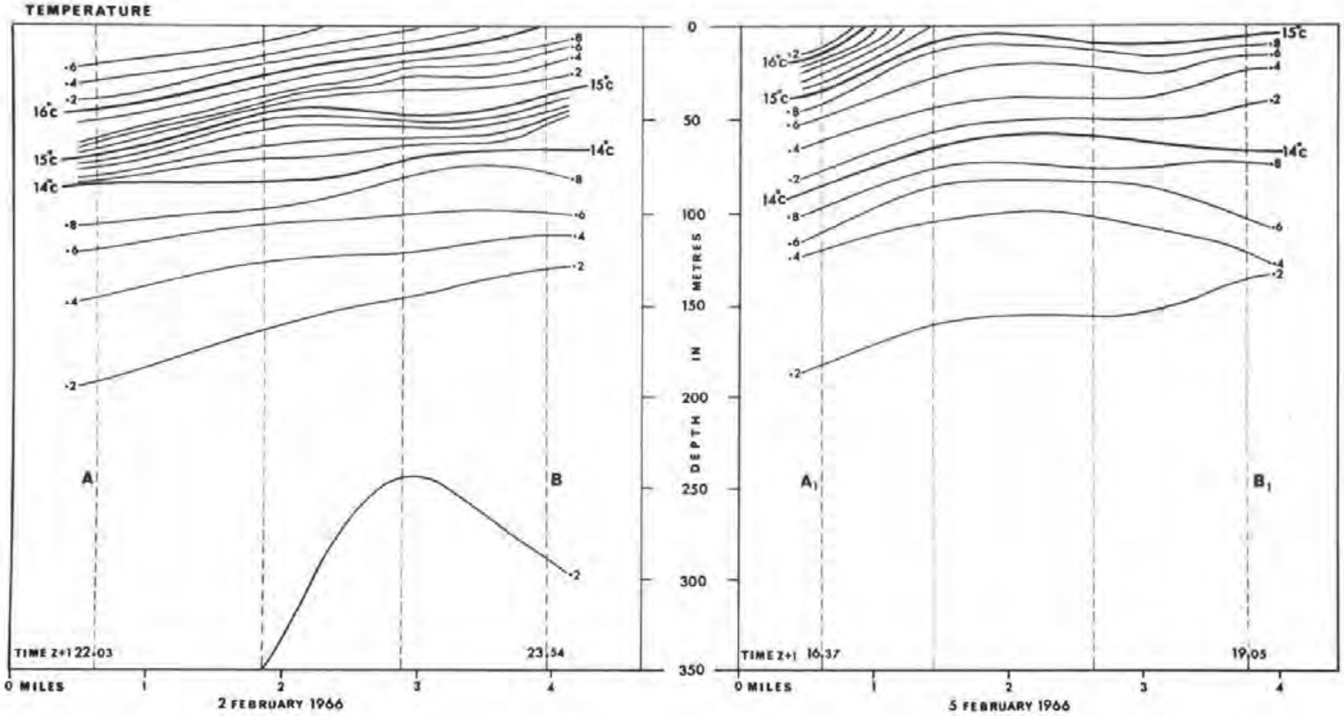

FIG. 8 ISOTHERMS PLOTTED AT THE STATIONS ALONG AB AND A₁B₁

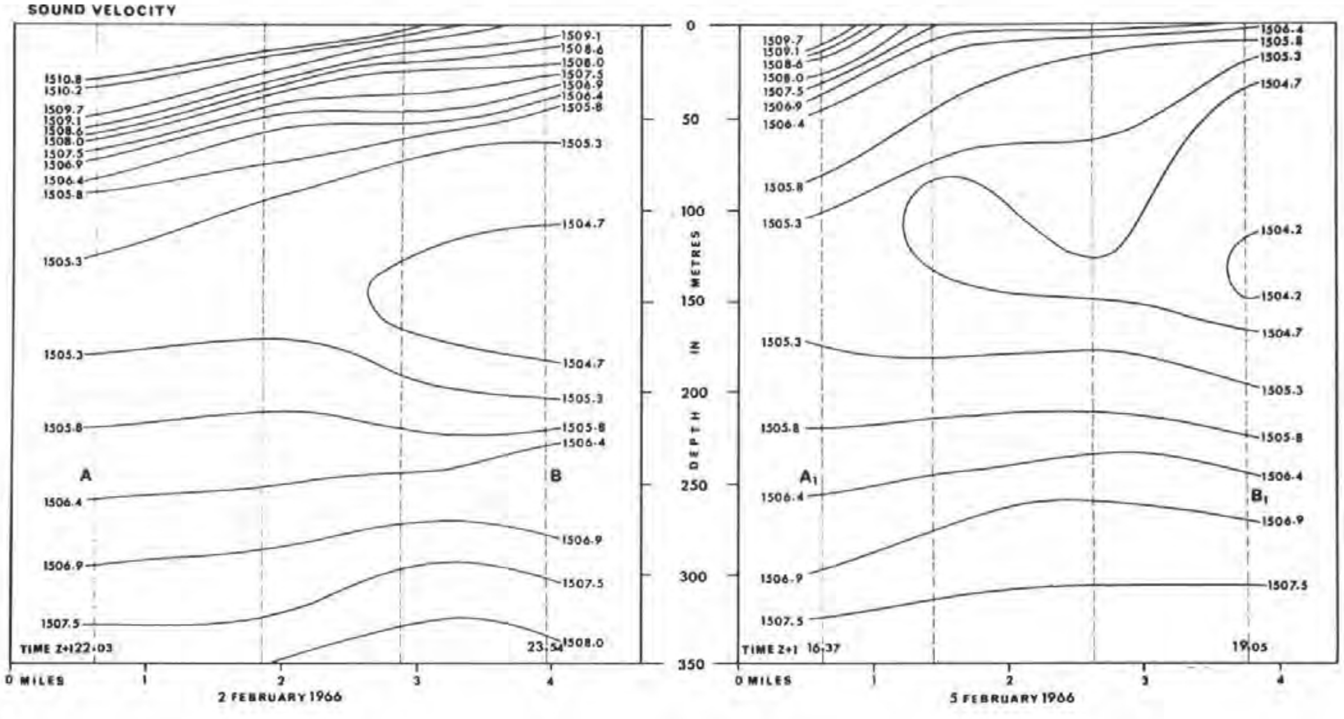

FIG. 9 LINES OF ISOVELOCITY AT THE STATIONS ALONG AB AND A₁B₁

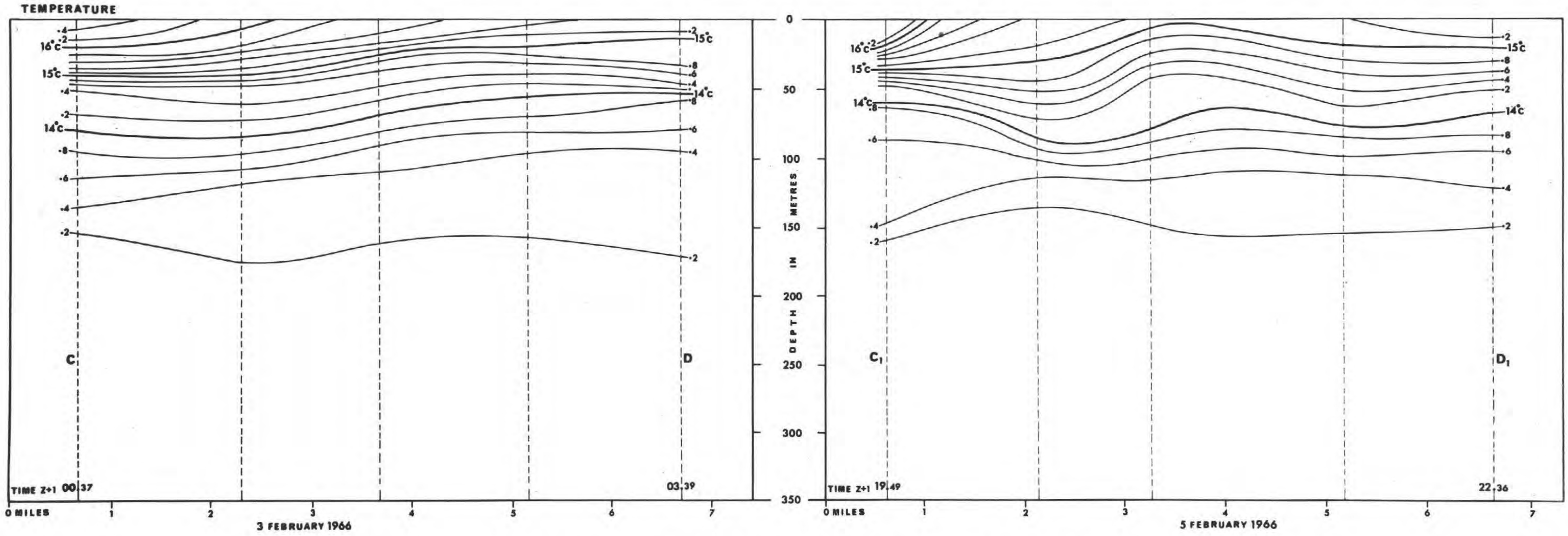

FIG. 10 ISOTHERMS PLOTTED AT THE STATIONS ALONG CD AND C₁D₁

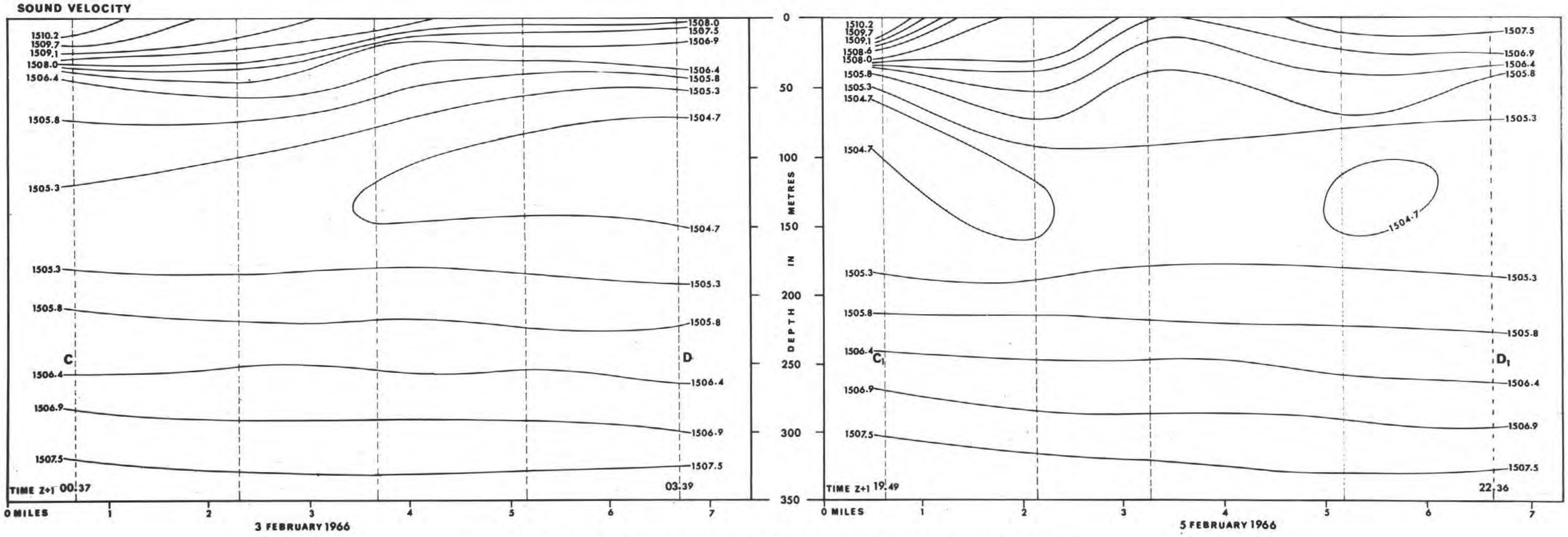

FIG. 11 LINES OF ISOVELOCITY AT THE STATIONS ALONG CD AND C₁D₁

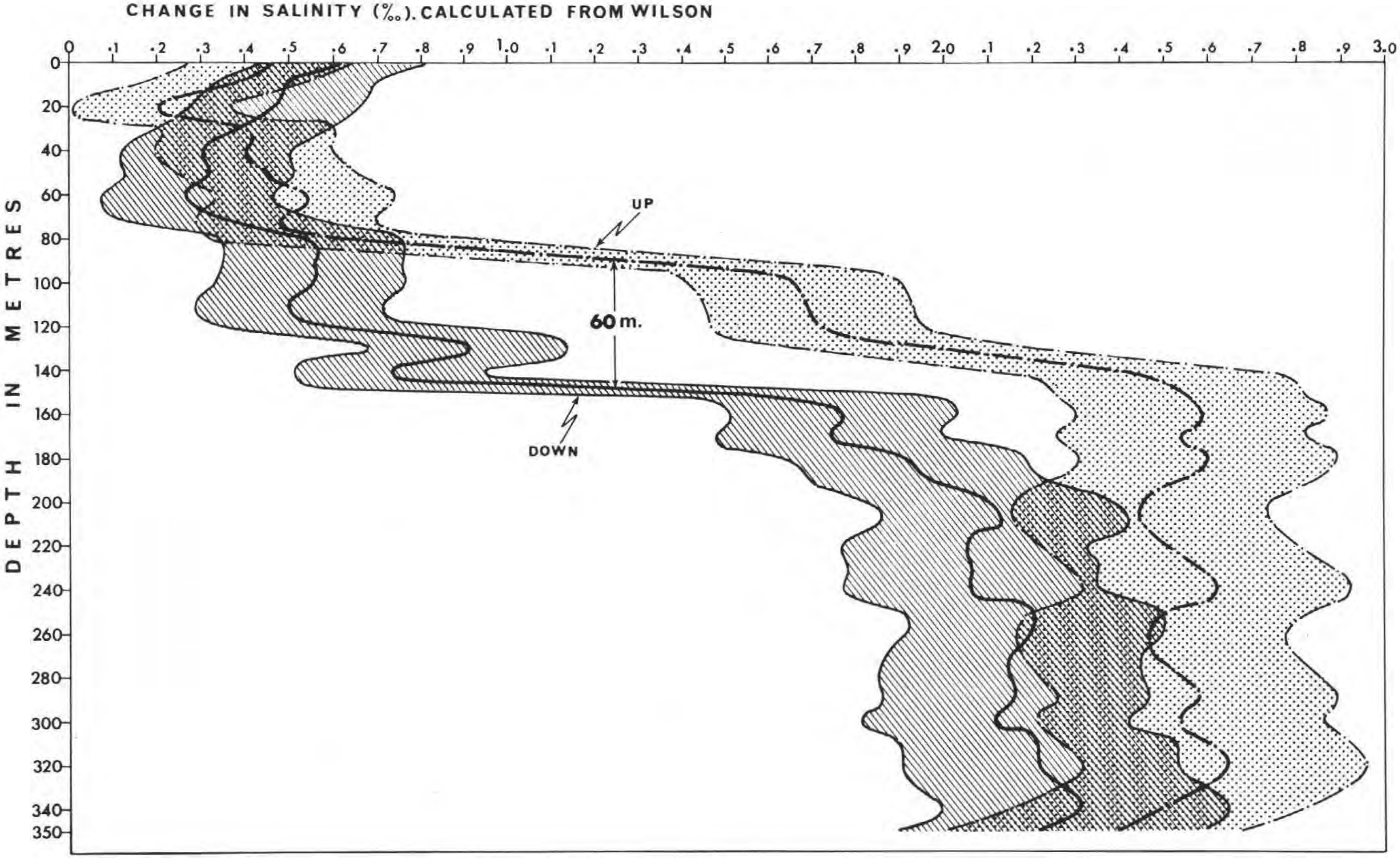

FIG. 12 SALINITY CHANGES AS CALCULATED FROM THE OBSERVED TEMPERATURE AND VELOCITY PROFILES RECORDED AT STATION 39 (see Fig. 5)

The shaded areas represent the estimated 95% confidence limit of the observational errors. Calculated changes are relative to an arbitrary value of 33.4‰

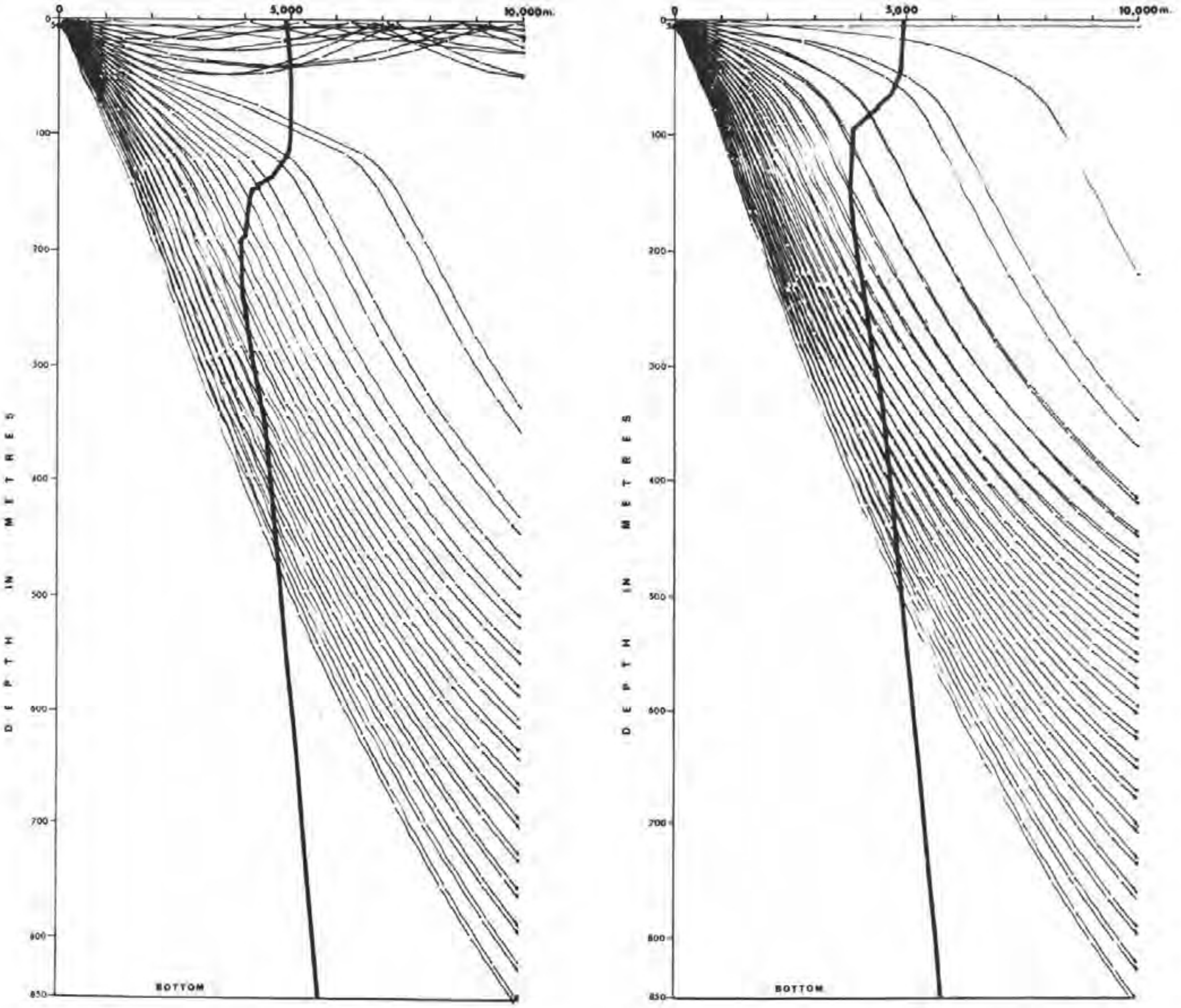

FIG. 13a RAY TRACING FOR A BEAM OF ± 5° PLOTTED EVERY ¼° FROM SOURCE DEPTH OF 5 m
The depth of water is 850 m and the horizontal distance 10 km. The left–hand diagram is calculated for the velocity profile recorded during lowering at station 39; the right–hand side for the velocity profile recorded during recovery (see Fig. 5).

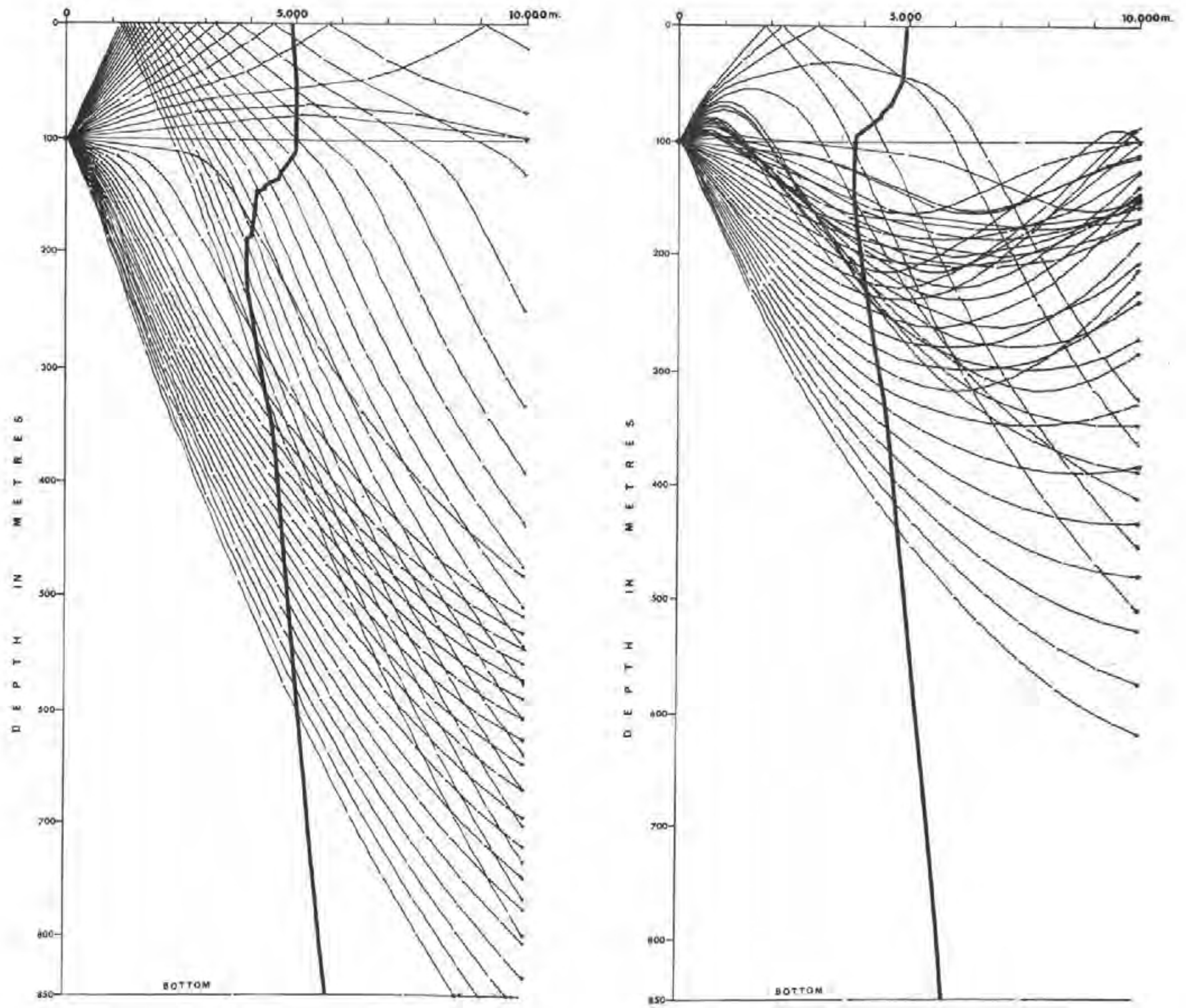

FIG. 13b RAY TRACING FOR A BEAM OF ± 5° PLOTTED EVERY ¼° FROM SOURCE DEPTH OF 100 m
The depth of water is 850 m and the horizontal distance 10 km. The left–hand diagram is calculated for the velocity profile recorded during lowering at station 39; the right–hand side for the velocity profile recorded during recovery (see Fig. 5)

DISTRIBUTION LIST

MINISTRIES OF DEFENCE

Minister of Defence Brussels, Belgium	10 copies
Department of National Defence Ottawa, Canada	10 copies
Chief of Defence Copenhagen, Denmark	10 copies
Minister of National Defence Paris, France	10 copies
Minister of Defence Federal Republic of Germany Bonn, Germany	12 copies
Minister of Defence Athens, Greece	10 copies
Minister of National Defence Rome, Italy	10 copies
Minister of National Defence The Hague, Netherlands	10 copies
Minister of National Defence Oslo, Norway	10 copies
Minister of National Defence Lisbon, Portugal	10 copies
Minister of National Defence Ankara, Turkey	10 copies
Minister of Defence London, England, U K	20 copies
SECDEF United States (through USNLO to SACLANTCEN, ONR, London)	70 copies

NATO AUTHORITIES

SECGEN NATO (through MCREP) Paris, France	5 copies
NATO Military Committee Washington D.C. 20301	3 copies
ASG for Scientific Affairs NATO Paris, France	1 copy
SACLANT Norfolk, Virginia 23511	3 copies
SACEUR Paris, France	7 copies
CINCHAN Ft. Southwick, Fareham England	1 copy
SACLANTREPEUR Paris, France	1 copy
COMAIRCHAN Northwood, England	1 copy
CINCAFMED Malta G.C.	1 copy
CINCEASTLANT Eastbury Park Northwood, England	1 copy
CINCWESTLANT Norfolk, Virginia 23511	1 copy
COMMAIREASTLANT Northwood, England	1 copy
COMSUBEASTLANT Ft. Blockhouse Gosport, England	1 copy
COMCANLANT H.M.C. Dockyard Halifax, Canada	1 copy
COMOCEANLANT Norfolk, Virginia 23511	1 copy
COMEDCENT Naples, Italy	1 copy
COMEDSOUEAST Malta G.C.	1 copy
COMSUBACLANT Norfolk, Virginia 23511	1 copy
COMSUBMED Malta G.C.	1 copy
Commander TASK FORCE 442 FPO, N.Y. 09521	1 copy
SHAPE T.C. The Hague, Netherlands	1 copy

SCIENTIFIC COMMITTEE OF NATIONAL REPRESENTATIVES FOR SACLANTCEN

SCNR Belgium	1 copy
SCNR Canada	1 copy
SCNR Denmark	1 copy
SCNR France	1 copy
SCNR Germany	1 copy
SCNR Greece	1 copy
SCNR Italy	1 copy
SCNR Netherlands	1 copy
SCNR Norway	1 copy
SCNR Turkey	1 copy
SCNR United Kingdom	1 copy
SCNR United States	1 copy

NATIONAL LIAISON OFFICERS FOR SACLANTCEN

NLO France	1 copy
NLO Italy	1 copy
NLO Portugal	1 copy
NLO United States	1 copy

NATIONAL LIAISON REPRESENTATIVES TO SACLANT

NLR Belgium	1 copy
NLR Canada	1 copy
NLR Denmark	1 copy
NLR France	1 copy
NLR Germany	1 copy
NLR Greece	1 copy
NLR Italy	1 copy
NLR Netherlands	1 copy
NLR Norway	1 copy
NLR Portugal	1 copy
NLR Turkey	1 copy
NLR United Kingdom	1 copy