OBSERVATIONS OF THE OPERATIONAL CHARACTERISTICS OF EUROPEAN CONSOL BEACONS

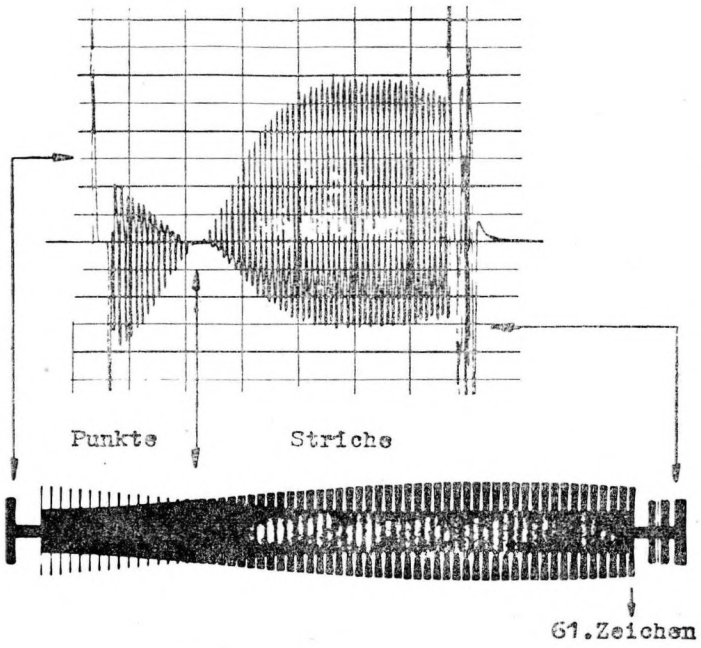
by Dipl. Ing. W. FAUST.

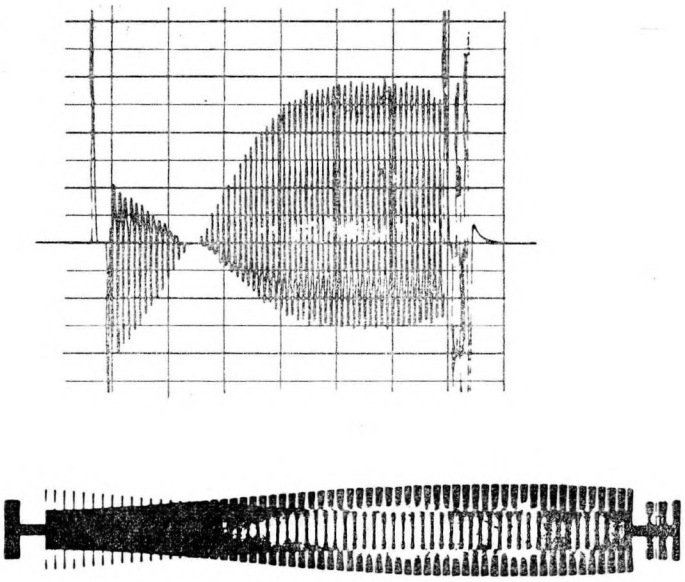
The work of the German Hydrographic Institute, commenced in 1953 on the systematic observation and precision measurements of the European Consol beacons, after a period of four years shows one substantial fact. Such factors that are of interest to the navigator : accuracy and stability of bearings provided by the Consol method, are primarily determined by the operational condition of the transmitter. Propagation phenomena play a subordinate role in this case. Thus the authorities in charge of such installations may draw practical conclusions, and we are in a position to inform the navigators of the knowledge obtained and the progress made.

For the purpose of our observations we developed a recording device, which gives objective results in the form of a document, i.e. the well-known difficulties of headphone reception will be avoided. Its design is relatively simple : we added to a highly selective receiver an amplifier stage and a sensitive line recorder with a moving coil system and zero position of the stylus in the scale centre. The recorder was specifically designed by Messrs. Metrawatt and is of the shock-proof type, which supplies information independently of any acceleration due to swell. It has been applied most successfully in many thousands of measurements made on board ship. The design of the amplifier permits a specially favourable reproduction of changes in condition. Thus the keying cycle, which is of great importance, can be recorded accurately. The equisignal in particular can be read with an accuracy that can be defined unambiguously. The requirements as to accuracy of the equipment may easily be specified : the position line must be capable of being determined to within the unit of an integral number, i.e. the equisignal must be capable of being determined precisely to one character. Or, in other words : if, for instance, the position line indicates 15, then the reading is required to be so unambiguous that it may not be mistaken for either 14 or 16.

With the slow-rotation Consol beacons this was achieved early, but the fast-rotation beacons have been under our control with the same « absolute » accuracy only since August of this year. The correctness of our assertion can now be proven by our records and by the oscillograms with the Siemens bifilar oscillograph taken simultaneously with the recording of the transmitters. Besides, we have devised a pilot transmitter that permits the reproduction in the laboratory of the keying cycle close to the equisignal. Thus the definite interpretation of the full-scale oscillograms has become possible.

Attempts were of course made to utilize the circuit arrangement for an automatic counter. At present we only can say that we have not yet succeeded in covering all the requirements of a commercial counter. I mention this in order to avoid any misunderstanding : our recording equipement is not a counter. It is designed for scientific research and operational control purposes.





DHJ VI	Registrierschrieb und Oszillogramm aufgenommen in Hamburg Consol-Funkfeuer Stavanger "langsam"	Bild 1

Punkte : dots. Striche : dashes. 61. Zeichen : 61st character. Registrierschrieb und Oszillogramm... : Record and Oscillogram, taken at Hamburg, « slow » Stavanger Consol beacon.

Fig. 1 presents a keying cycle as obtained from our recording equipment of a dot sector of the Consol beacon at Stavanger. Below is the oscillographic representation. The oscillogram represents photographically the output voltage of the receiver, i.e. the dots and dashes as received by the navigator's headphones. The time scale is slightly different owing to different paper or film feed. In each of the lower oscillograms there can be seen : the beginning and termination of the long dash, keying cycle with equisignal, call signal LEC and the beginning of the following long dash together with the intervals. The absolutely constant passage through the equisignal should especially be noted ; it can also be seen that it has the same amplitude as the long dash.

The record contains certain peculiarities that nonetheless easily allow the connexion with the natural transmission cycle to be obtained :

1. Long dash and radiation of the central aerial during the keying cycle are not indicated, since they have a constant amplitude.

2. All switching-in operations — long dash, radiation of the central aerial, beginning of all dots and dashes — result in a current pulsation in the same direction (here downwards), since they constitute a change of condition.

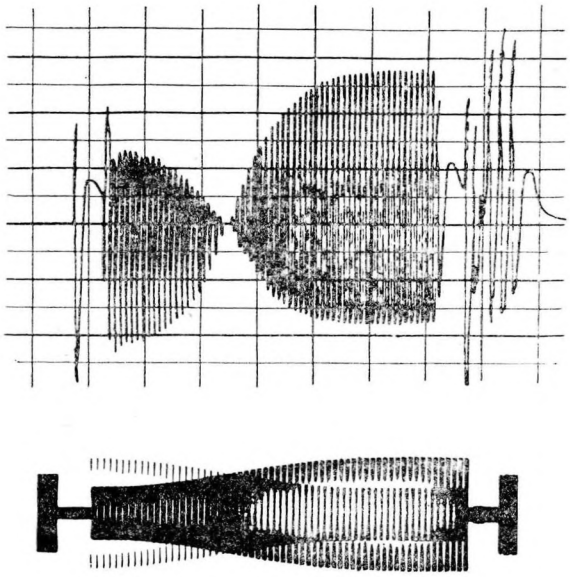
3. Consequently, all switching-off operations, and the end of all dots and dashes, will result in a current pulsation in the opposite direction (here upwards). Thus, during the keying cycle an additional upward record is obtained.

4. The call signal, being an aperiodical operation, is recorded in a mutilated form. In order to understand the illustration, it was necessary to discuss briefly these operations of secondary importance.

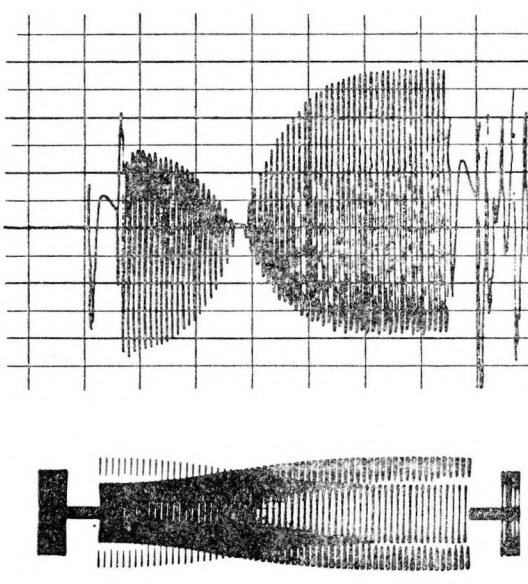
It is important to know how the time is represented, which is of interest to the navigator, and which is the important feature in the Consol method : between the dots and the dashes there appears the clearly defined equisignal, i.e. with steep sides in contrast with the flat passage of the natural process shown by the oscillogram. Its upper portion (A) is characterized by the absence of one character only. Thus we have obtained the optimum indication which, according to our previous discussion, corresponds to an absolute accuracy of one character.

The evaluation of such a record is very simple : one should count the dots from the beginning of the keying cycle ; in our example their number is 16. The next step is the equisignal and thus the count of the position line 17. Thus one reads off from the beginning and need not continue the recording after the equisignal. By applying a millimetre scale, reading is facilitated. The central arrow is intended to indicate that during the recording and the oscillogram observation, the indication and the electrical zero of the transmitter are defined analogously : where the one character is missing on the record neither dots nor dashes will be heard in the headphone. As you know, however, things are not so ideal in practical operation and frequently more than one character gets lost in the headphone (although this should not happen).

The following remarks must be made as regards the lower portion (B) : this type of picture is encountered in our series of measurements as frequently as the upper picture. Although two characters of the equisignal are seen to be missing, this record represents the case where the intersection of the sine envelope curves coincides with the middle of the cycle. It can be proven mathematically that



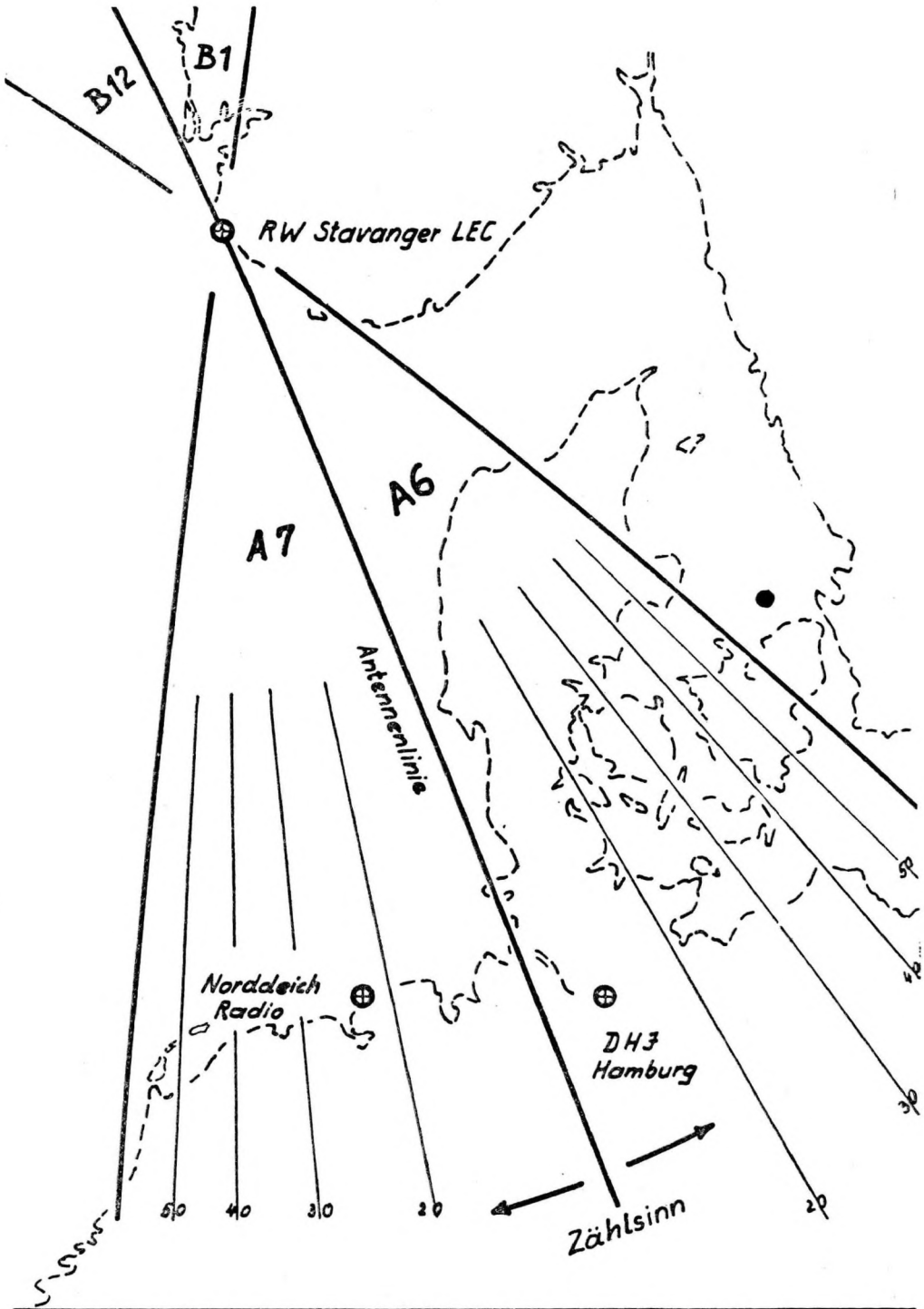
A)



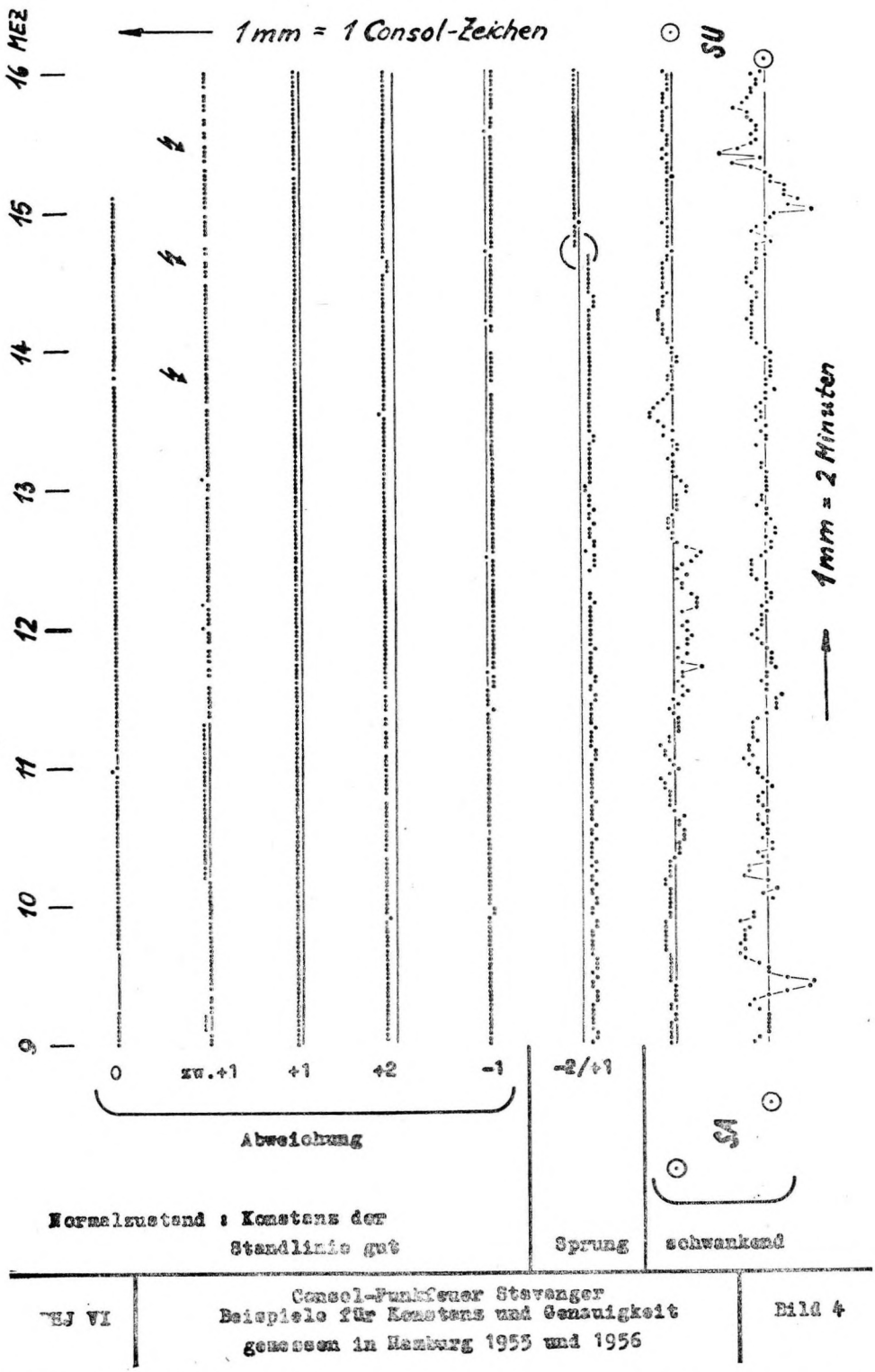
B)

DHJ VI	Registrierschrieb und Oszillogramm Ankerstation Lerwick/Shetlands Consolfunkfeuer Stavanger "schnell"	Bild 2

Registrierschrieb und Oszillogramm... : Record and Oscillogram, Anchoring Station Lerwick/Shetlands. « Fast » Stavanger Consol beacon.



Antennenlinie : line of antennas. Zählsinn : direction of count, Consol beacon, Stavanger, Layout of Synoptical Observations.



1 mm. 1 Consol-Zeichen : 1 mm. 1 Consol character. Abweichung : deviation. Sprung : jump. Schwankend : unsteady. Normalzustand... : Normal state : stability of position line satisfactory. Consol Beacon Stavanger, Beispiele... : Examples of Stability and Accuracy, taken at Hamburg, 1955 and 1956.

this finer picture grading corresponds to the absolute accuracy, i.e. this picture is equivalent to the other one with respect to the accuracy requirements.

A final remark as to Fig. 1 must be made. In the meantime, it has gained some fame with respect to the 61st character case. When counting precisely the number of the received characters, we were surprised to find that one more character was received. Since no navigator thinks of using a stop-watch when counting Consol characters, it had not hitherto been observed that we had miscounted or, strictly speaking, had obtained a wrong bearing.

On August 1st 1956, the radio beacon of Stavanger was changed to the rapid keying cycle. Previously, the Norwegian authorities had been given an oscillogram showing the 61st character. As you will see from Fig. 2, which was taken during a test mission in August, the Norwegians eliminated this mistake when they changed the station. You will also see clearly that we succeeded in obtaining an even more distinct presentation of the equisignal. Sections (A) and (B) correspond to those of Fig. 1.

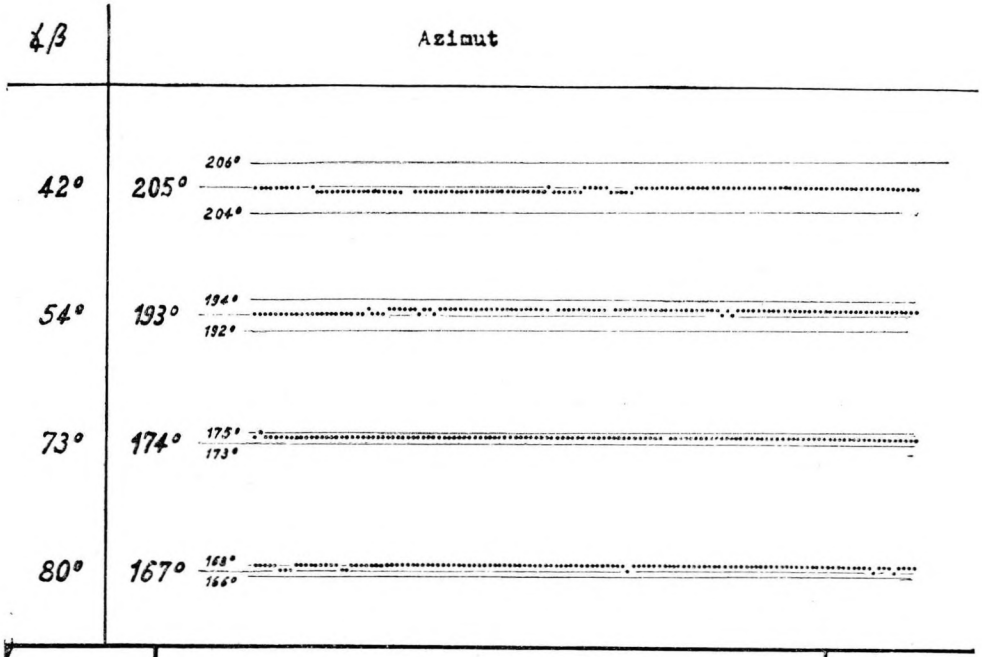
Curiously enough, the two Spanish beacons of Lugo and Sevilla also transmitted this 61st character. But based on our observation, also in this case the prescribed 60 characters are now being transmitted. In this respect there is uniformity among the five European transmitters, supposed to have existed for quite some time. It is evident that this 61st character was an actual mistake in that it influenced the navigator directly and also affected azimuth tables and charts based on the 60 - characters graduation.

The beacons at Ploneis and Bushmills have always transmitted the correct number of 60 characters. I shall exclude these two stations from my present report. The data available are too few. Besides, it is almost impossible for us to obtain useful measuring data in the area east of those two beacons, since there is substantial interference from broadcasting stations.

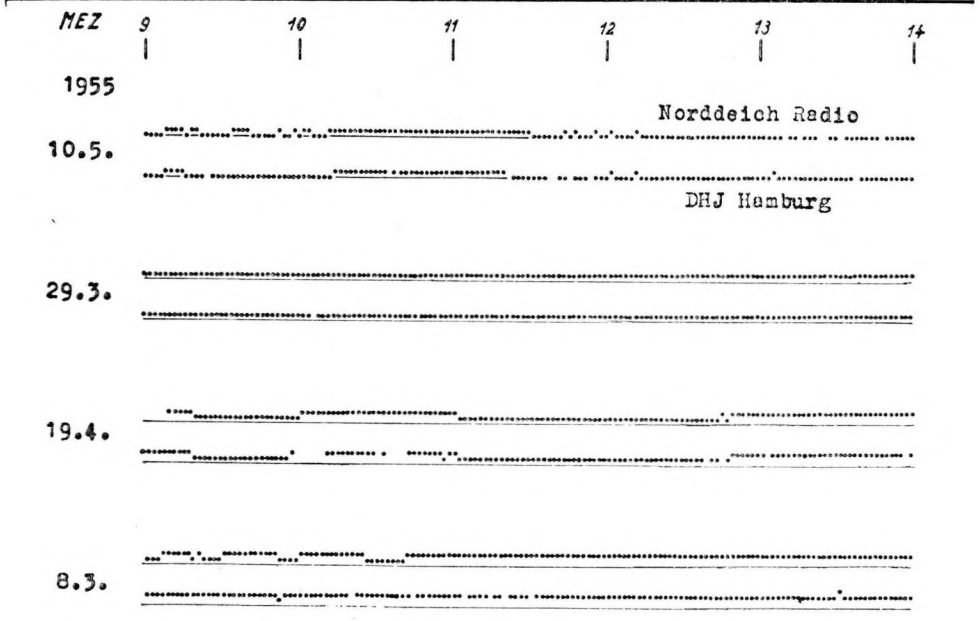
There is more information available regarding the Stavanger beacon ; more than 40.000 individual measurements were made. There is, therefore, a certain foundation for the experience obtained. This particular Consol beacon has proven to be a suitable object for nautical and scientific measurements, and many of the basic problems could be applied also to other Consol beacons.

A considerable portion of the observations were made by the Institute in Hamburg. The geographical situation and a section of the pattern of this transmitter are presented in Fig. 3. The coastal radio station of Norddeich-Radio assisted us greatly by synoptical observations for several months early in 1955. We thus very soon succeeded in proving that some irregularities were due exclusively to the operation of the transmitter. Thus we started a year-round measuring schedule with one day of measuring per week. This program was concluded in October 1956.

Fig. 4 from this program, which contains about 10,000 measurements, presents everything the navigator ought to know with respect to accuracy and stability of the position obtained ; typical examples of ranges of measurement are presented herein. It can be seen immediately that the normal stability is very good. On closer examination it is surprising to notice that it is obviously difficult to obtain the correct precalculated positon of the bearing pattern, and to keep it without deviation. The desired value is represented by the solid line. It happens that the number of the position line deviates from the desired value by an amount of $\pm$ 2 characters. Occasionally, deviations of 3 characters are also observed. The orienta-

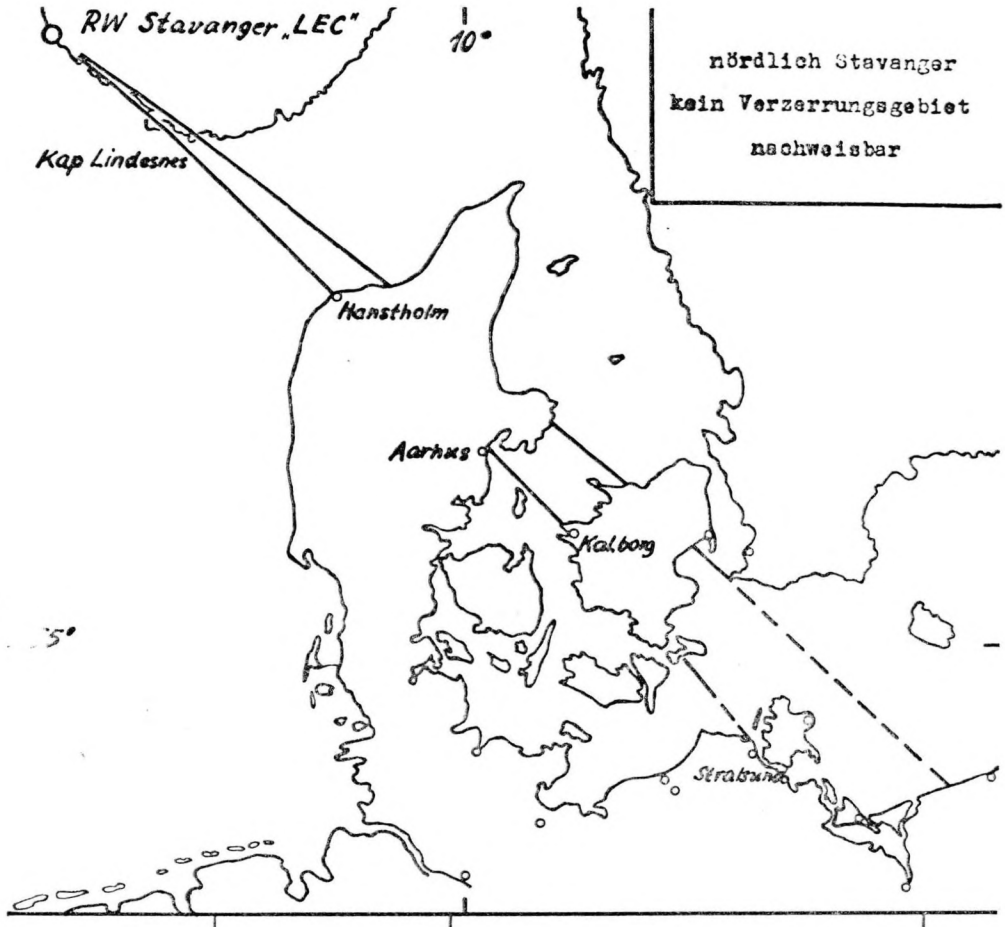


DHJ VI	Consol-Funkfeuer Stavanger Auswirkung der Zeichentoleranz auf das Azimut gemessen auf verschiedenen Ankerstationen	Bild 5A



DHJ VI	Consol-Funkfeuer Stavanger Beispiele aus den synoptischen Messungen	Bild 5B

Azimut : Azimuth, Consol Beacon, Stavanger. Auswirkung der Zeichentoleranz... : Rate of Deviations of Characters against Azimuth, taken at different Anchoring Stations. Consol Beacon, Stavanger, Beispiele... : Examples of Synoptical Measurements.



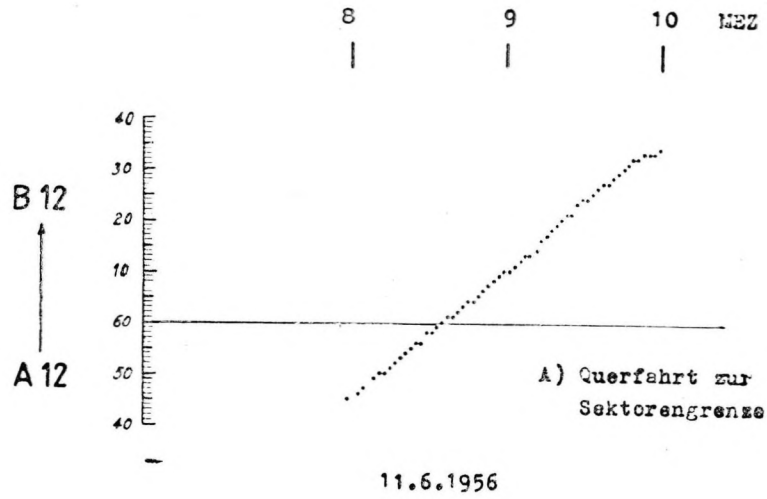
Jahr	Seegebiet	gemessene Fehler in Consolzeichen auf den Standlinien im Sektor A6 / in B6 40 42 44 46 48 50 52 54 56 58 60 2 4 6 8	max. Fehler in sm
1953,1954	südl.Lindesnes	o o 1 2 4 6 4	3
1955	Hanstholm	o o o o 2 2 4 5 6 5 2 o o o o	5
1955	Grosser Belt	2 2 4 6 6 6 4 o o o o	8
1955,1956	Sund	o 3 4 6 o 2 6 2 o	14

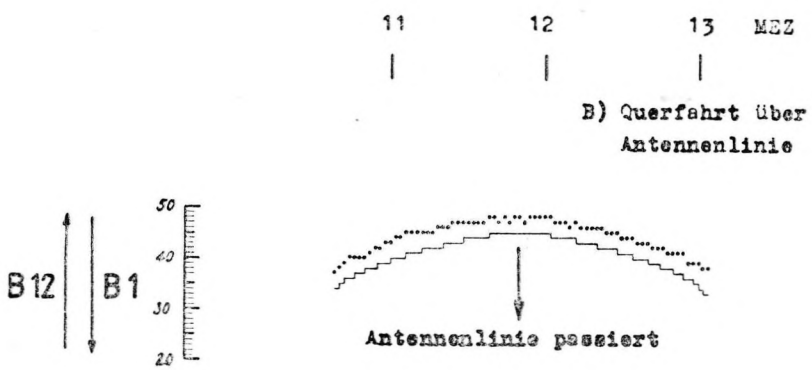
alle Fehler positiv im Zählsinn

Vermerk: die Fehlerbeträge können nicht als Korrekturwerte dienen

DHI VI	Consol-Funkfeuer Stavanger Verzerrungsgebiet im Peilschema	Bild 6

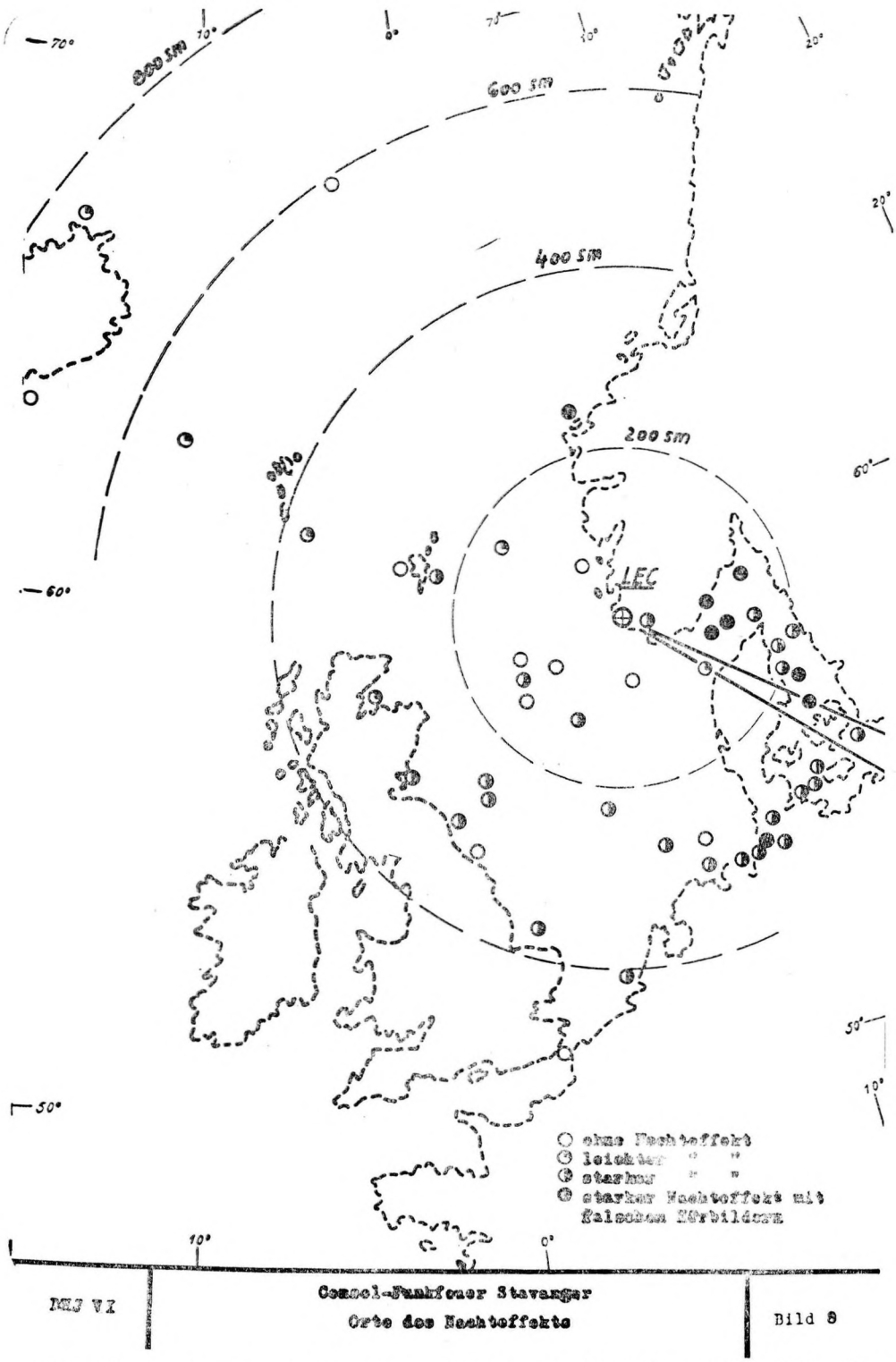
Nördlich Stavanger kein Verzerrungsgebiet nachweisbar : North of Stavanger no distortion to be found. Jahr : year. Seegebiet : sea area. Gemessene Fehler : Errors taken in Consol characters on the lines of position in sector A6, B6 : südlich Lindesnes : South of Lindesnes. Hanstholm : Hanstholm. Grosser Belt : Great Belt. Sund : The Sound. Alle Fehler positiv im Zählsinn : all errors are positive in direction of count. Vermerk... : Notice : The amounts of errors should not serve for correction. Consol Beacon Stavanger, Verzerrungsgebiet... : Area of distortion in the Bearing Pattern. Max. Fehler in sm : Max. error in naut. miles.



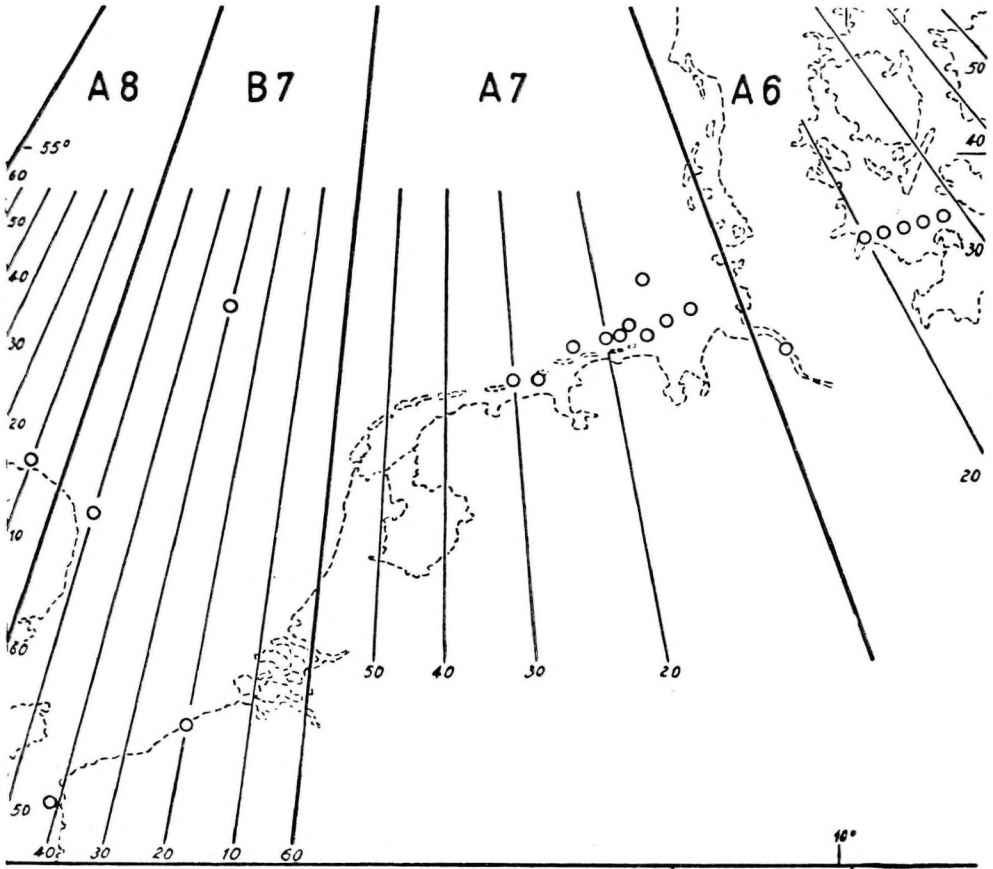


IHJ VI	Consol-Funkfeuer Stavanger Suchfahrt Verzerrungsgebiet Nord	Bild 7

A) Querfahrt... : Way across to edge of sector. B) Querfahrt... : Crossing line of antennas. Antennenlinie passiert : line of antennas is crossed. C) Fehlerdarstellung... : Display of errors from the area of distortion, series of measurements near Hanstholm. Consol Beacon Stavanger, Suchfahrt... : Crossing around North of Stavanger for distortions.



Ohne Nachteffekt : no night effect. Leichter Nachteffekt : slight night effect. Starker Nachteffekt : heavy night effect. Starker Nachteffekt mit falschen Hörbildern : heavy night effect with abnormal indications. Consol Beacon, Stavanger, Orte der... : Spots of night effect.



Ankerstation	Standlinie	1955
Tonne 3 bei FSch Elbe 2	15 A7	17.4.
Tonne Westertill Nord	16 A7	"
Wangerooge Tonne C	17 A7	18.4.
Tonne JE 12	18 A7	"
12 sm vor Norddeich Radio auf gleichem Azimut	23 A7	19.4.
vor Boulogne	41 B7	26.4.
Hafen Ostende	20 B7	28.4.
FSch Cross Sand	50 B7	30.4.
vor Cromer	10 A8	"
Tonne S 2	30 B7	1.5.
Hubert Gat Tonne HE	30 A7	2.5.
Randzel Gat Tonne W 10	27 A7	"
Langeoog Tonne W 3 J	20 A7	3.5.
Tonne Otzumer Balje	19 A7	"
Tonne Kiel 3	20 A6	14.6.
Weg 1 zwischen Tonne 2 und Tonne 3	22 A6	15.6.
Weg 1 " " 4 " " 5	24 A6	"
Weg 1 " " 5 " " 5a	26 A6	16.6.
FSch Fehmarn	28 A6	"
Hanstholm	40 A6	19.6.
Hafen Helgoland	16 A7	27.6.
Krautsand	15 A7	28.6.

DHJ VI — Consolfunkfeuer Stavanger
Zur Frage "unsichere" Sektoren — Bild 9

Fig. 9.

Ankerstation :	anchoring station.
Standlinie :	position line.
Tonne 3... :	Buoy 3 near light vessel Elbe 2.
— Westertill Nord :	Buoy Westertill North.
Wangerooge Tonne C :	Wangerooge Buoy C.
Tonne JE 12 :	Buoy JE 12.
12 sm vor Norddeich... :	near Norddeich Radio on the same azimuth.
vor Boulogne :	near Boulogne.
Hafen Ostende :	Ostende Harbour.
FSch Cross Sand :	Light Vessel Cross Sand.
vor Cromer :	near Cromer.
Tonne S2 :	Buoy S2.
Hubert Gat Tonne HE :	Hubert Gat Buoy HE.
Randzel Gat Tonne W 10 :	Randzel Gat Buoy W 10.
Langeoog Tonne W 3 J :	Langeoog Buoy W 3 J.
Tonne Otzumer Balje :	Buoy Otzumer Balje.
Tonne Kiel 3 :	Buoy Kiel 3.
Weg 1 zwischen Tonne 2 und Tonne 3 :	Way 1 between Buoy 2 and Buoy 3.
	d° 4 5.
	d° 5 5a.
FSch Fehmarn :	Light Vessel Fehmarn.
Hanstholm :	Hanstholm.
Hafen Helgoland :	Heligoland Harbour.
Krautsand :	Krautsand.
Consol Beacon Stavanger, Zur Frage unsichere Sektoren :	Re « unreliable » sectors.

tion of the pattern thus is not always absolutely correct. Such errors of a magnitude of several times the theoretical accuracy must be regarded as being inadmissible, and they should be eliminated if possible.

The series of measurements in Fig. 4 containing the jump, indicated by a circle, convincingly proves that in this instance a change-over of the transmitter or some such operation must have been effected, for this cannot be produced by a propagation effect. Furthermore, the arrows of the second series show that the bearing remained unchanged in spite of a thunderstorm.

New information, at least considered as a measuring document, can be derived from the two fluctuating measuring series. They were made on days in winter when the altitude of the sun is minimum. Not only the count fluctuates, but the respective records show a deformation normally typical for night effect only. There is a thorough night effect during the daytime ; this may most impressively be observed if the sun is not covered by clouds. One may say that on individual days in winter conditions of propagation prevail that are equal to an ionospheric condition, which normally occurs at dawn only. This dependency of the radiation of Consol transmitters has to be investigated further. But we are content that the causes are known now, for this was a problem in 1951 when the same observation was reported. The cause is not the passage of a cold front ; this assumption of a meteorological cause is now recognized as having been incorrect.

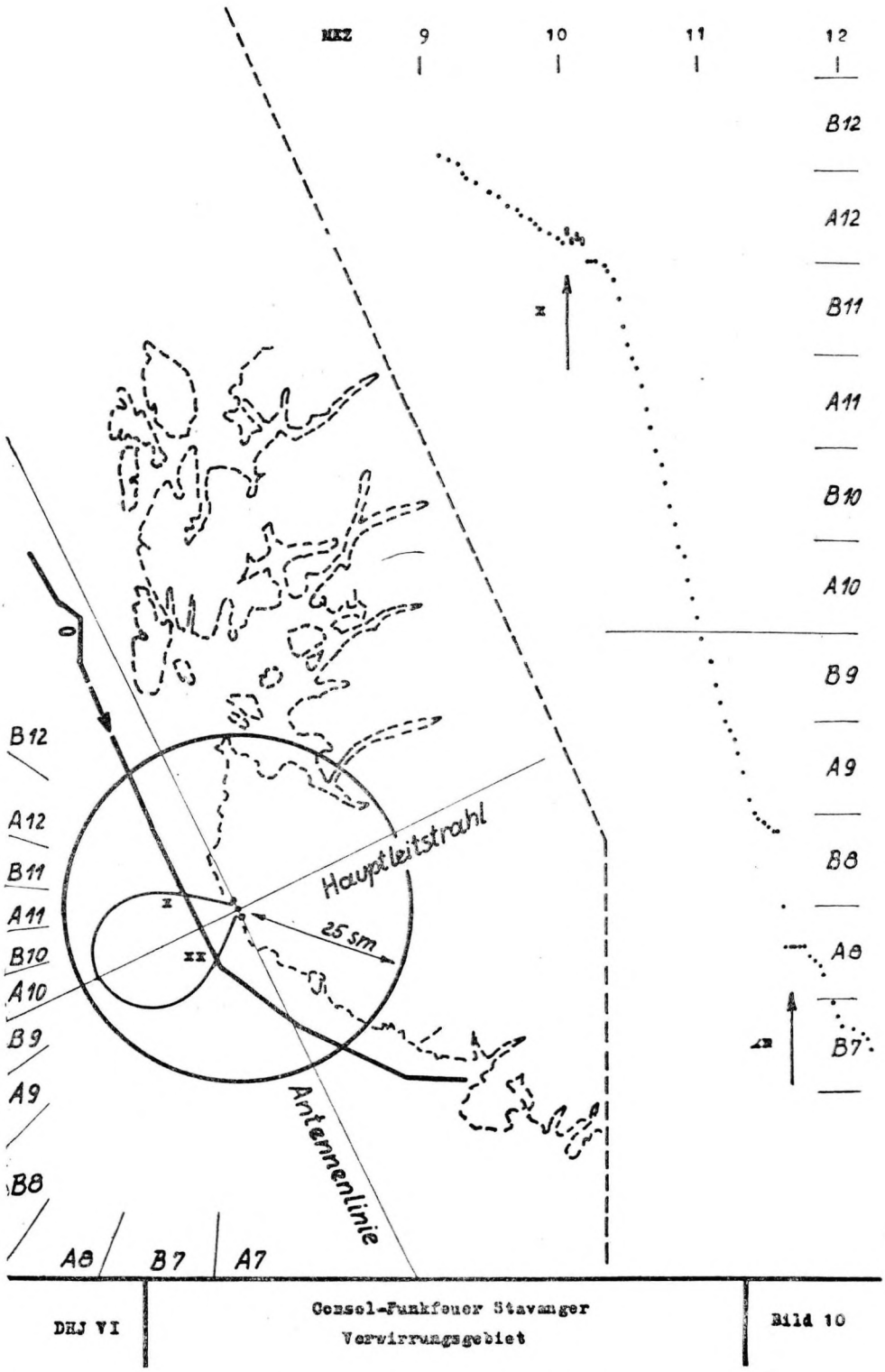
Now it is necessary to explain the practical importance of the tolerances and fluctuations observed. Fig. 5A shows the great surplus of accuracy of the Consol method. Compared with other means of navigation, a tolerance of 2 or 3 characters, computed in angular degrees, is still small. Only if the angular distance from the centre beam (angle β) is 80°, a deviation by one character would mean an azimuthal shift of 1°. Fig. 5B gives some examples of the correspondence obtained from synoptical measurements made with Norddeich.

In order that you may understand Fig. 6, I must inform you that we measured repeatedly all the sea sectors of the beacon at Stavanger, at distances of up to 1000 nautical miles. The results showed no anomalies in the bearing pattern, with one exception, as shown on the diagram. The sector of 4.5° shows a constant distortion, whose magnitude, direction and value, computed in nautical miles, may be gathered from the table. We have announced this area of shipping in our Notices to Mariners.

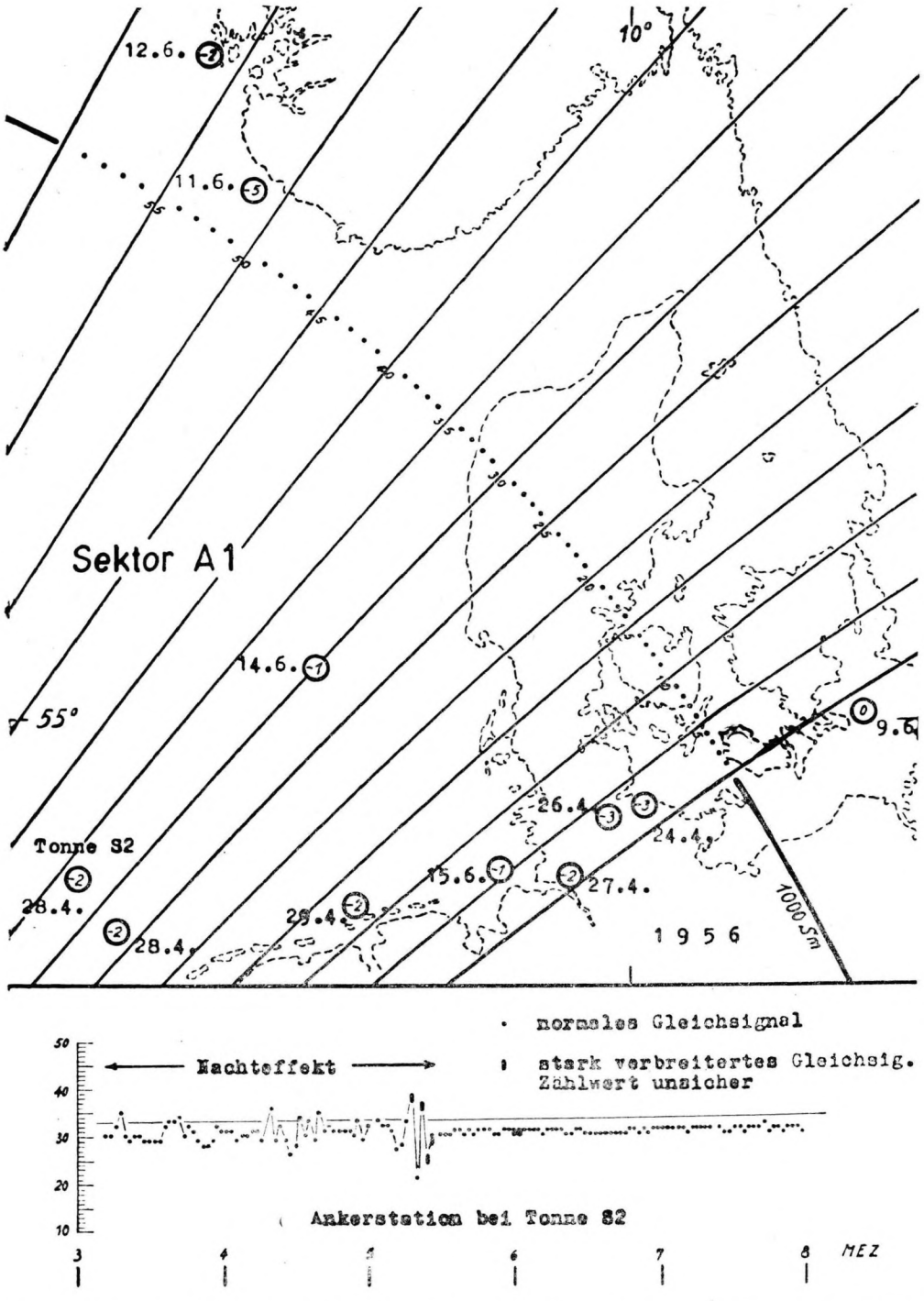
Here was proven by measurements for the first time a problem that had arisen in connection with hyperbolic systems : could distortions of the pattern be due to geographical features ? We could not observe distortion North of Stavanger. The measuring data of two special test missions, represented in Figs. 7A and 7B, follow a continuous course. If there were anything present, some system as in part C would have been observed.

We have transferred the area of distortion on the chart showing night effects. In Fig. 8 the causal connexion is established with the strong night effect in the area of the ground wave in the Skagerrak and the Kattegat in geographically complete orientation.

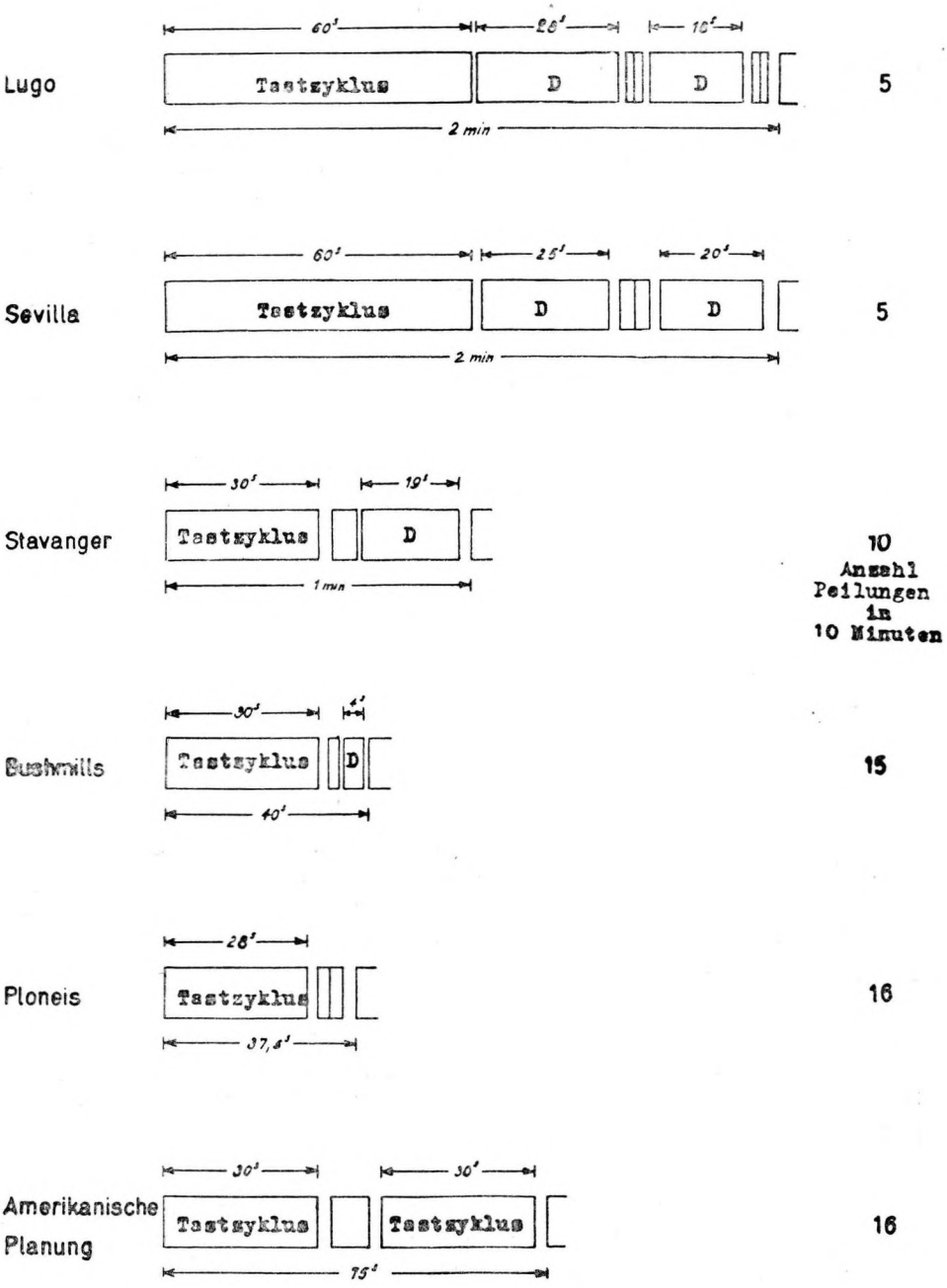
The problem of the so-called « unreliable » sectors proved to be a fertile subject. The use of this notation, as so far practised in Germany, in the course of the first preliminary tests of a more qualitative nature soon appeared to be doubtful. In 1955 on a series of anchoring stations sufficient quantitative measurements were



Hauptleitstrahl : centre line. Antennenlinie : line of antennas. Consol Beacon Stavanger, Verwirrungsgebiet : Area of Confusion.



Tonne S2 : Buoy S2. Nachteffekt : Night Effect. Normales Gleichsignal : normal equisignal. Stark verbreitertes Gleichsignal : strongly broadened equisignal. Zählwert unsicher : counting unreliable. Ankerstation bei Tonne S2: Anchoring Station near Buoy S2. Consol Beacon Lugo, Control of accuracy of the bearing pattern.



Tastzyklus : keying cycle. D : long dash. Anzahl Peilungen : numbers of bearing in 10 minutes. Amerikanische Planung : American scheme. Sendefolgen der... : Transmission cycles of the European Consol Beacon, Key-Date September 1956.

made during half days and whole days, which are shown in Fig. 9. It proved that the notation « unreliable » is not justified. Therefore, this notation was omitted in the picture at sectors A6 and A7, as in the previous Fig. 3, where the sectors B1 and B12 also belonged to the « unreliable » sectors. This experience was transferred to the other Consol beacons in the same nanner. In the official notices on Consol at the German Hydrographic Institute, as in the Nautischer Funkdienst, Consol charts and tables, the world « unreliable » was removed once and for all so that now correspondence is reached with the method practised in other countries.

Another precept also was tested as to its correctness. In passing the transmitter station of CFF Stavanger sited near the coast of Varhaug, empirical proof was obtained that there is an area of confusion. Therefore, the area of 25 nautical miles around the transmitter, in which it is forbidden to take bearings by Consol, not only appears to be justified but also properly assigned in extent. Details are shown in Fig. 10. The interchange taking place in the characters of the dot and dash sector upon crossing the clover are clearly perceptible.

Fig. 11 represents the result of an observation of the Spanish Consol beacon of Lugo after the erroneous orientation of the pattern, which became known some years ago, was repaired. The series of measurements presented in the diagram, made near the buoy S 2 shows that it is possible to make unambiguous measurements even at such great distances. The few observations show that there is a great similarity with the Stavanger beacon with respect to stability and accuracy, the only difference being the *negative* error of 2 to 3 characters.

In Fig. 12 we have grouped together the transmission cycles of the five Consol beacons with respect to time. Without going into details, it can easily be seen how different the forms of operation are, when it is intended to design an automatic counter which should be simple and economical.

German ships have lately reported the existence of two unknown Russian Consol beacons in the Polar Sea. Aboard the research vessel « Gauss », it was possible to receive one of these beacons by headphone on the 8th and 9th October 1956, shortly before midnight in the southerly North Sea and in the Channel near the Thames estuary in a dot sector, i.e., at an estimated distance of at least 1500 nautical miles. It was the transmitter of Cap Kanin Noss with the call-sign « KN » on a frequency of 270 kc/s. The structure of the cycle on the whole was similar to that of Stavanger, i.e. keying cycle 30 seconds — that is rapid, — slow call-signal, after that long dash, duration in all one minute, for the rest normal equi-signal transmission. The reception was, sad to say, not good enough for recording and oscillogram purposes.

There is no doubt therefore that the Russians have contrived to build a Consol beacon according to the operational method so far tested, and to work it under geographically rather unfavourable conditions.