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UNDERWATER ACOUSTICS AT SCANDINAVIAN AND DUTCH DEFENSE RESEARCH LABORATORIES

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21 August 1967

UNITED STATES OF AMERICA

TABLE OF CONTENTS

	Page
INTRODUCTION	1
THE RESEARCH INSTITUTE FOR NATIONAL DEFENSE, STOCKHOLM, SWEDEN	2
NORWEGIAN DEFENSE RESEARCH ESTABLISHMENT, DIVISION FOR UNDERWATER WARFARE, HORTEN, NORWAY	4
DANISH DEFENSE RESEARCH BOARD, COPENHAGEN, DENMARK	5
NATIONAL DEFENSE RESEARCH ORGANIZATION RVO-TNO, THE HAGUE, NETHERLANDS	6
DIRECTORY OF LABORATORIES COVERED IN THIS REPORT	8

UNDERWATER ACOUSTICS AT SCANDINAVIAN AND DUTCH DEFENSE RESEARCH LABORATORIES

INTRODUCTION

A great deal more than underwater acoustics research is going on in these four defense research establishments. The Research Institute for National Defense in Stockholm has research effort in medicine, physics, chemistry and engineering, most of it in one complex of buildings. The Norwegian Defense Research Establishment has six divisions with its Division for Underwater Warfare at Horten. Denmark has recently reorganized its military research establishment, and in September the Defense Research Institute will be composed of six divisions covering chemistry, operations research, applied physics, electronic communication, instrumentation, and special projects. Underwater acoustics comes under the Electronic Communication Division. The most complex group of all is the TNO in the Netherlands, in English, the Netherlands Organization for Applied Scientific Research. Within the TNO are 25 institutes under the Organization for Industrial Research, four institutes under the Organization for Nutrition and Food Research, seven institutes under the Organization for Health Research, five institutes under the National Defense Research Organization, and seven institutes and three committees under the Central Organization TNO. There are 35 research centers under the National Council for Agriculture Research TNO. The total personnel within TNO runs over 5000.

The five institutes under the National Defense Research Organization are referred to by the initials RVO-TNO. These five are Physics Laboratory, Medical Biological Laboratory, Chemical Laboratory, Technological Laboratory, and the Institute for Perception. The Assistant Director of the Physics Laboratory, Ir. M.W. van Batenburg, is now the Director of the SACLANT ASW Research Centre at La Spezia, Italy. He replaced Dr. Henrik Nødtvedt of Norway this summer. In this report I shall limit the discussion of underwater acoustic research to the areas of propagation, transducer design, and transducer calibration facilities.

These four defense research laboratories have one problem in common--underwater sound propagation in shallow, stratified water. The average depth of the Baltic Sea is 100 m and the maximum depth is 400 m. Salinity varies from 2 - 3 ppm in some areas, 10 - 12 ppm in the southern part, and 35 ppm in the western region. The bottom temperature is 4 - 5°C and the surface temperature in summer gets

up to 20°C. In summer sound waves are refracted from the surface to the bottom in 0.5 to 1 km. A sound channel exists in winter at a depth of 50 m. There are six types of bottom in a general direction of west to southeast in the order of rock with clay pockets, rock, sandstone, lime rock, sand and clay, and sediment. Norway has had the cooperation of Hudson Laboratories in their studies of propagation in a west coast fjord area, and they have a propagation range in the Oslo Fjord. Larry Gregory of Hudson Laboratories has been working with them and will return to the US in October of this year. In these fjords there are irregular currents, the water ranges from fresh to salt, and the depth is less than 200 m. Denmark is studying propagation in the Baltic in a two-week cooperative effort with SACLANT and Woods Hole Oceanographic Institute. The Netherlands has been studying shallow water propagation in the Rotterdam channel, in fresh water during the outgoing tide.

THE RESEARCH INSTITUTE FOR NATIONAL DEFENSE, STOCKHOLM, SWEDEN

There are four departments in the Institute: Department 1 does basic and applied research in chemistry and medicine; Department 2, the Department of Physics, covers explosives, rockets, optical instruments and X-ray photography; Department 3, the Department in Electronics, covers communication, radar, navigation and underwater acoustics; and Department 4 is active in nuclear chemistry and physics. The last three Departments are housed on the eastern side of Stockholm in an area that covers the equivalent of eight blocks. Over 250 graduate scientists are on the staff of the four Departments. Only the Institute for Acoustics in Department 3 will be dealt with in this report. Sigfrid Wennerberg heads the Institute for Acoustics. He has been to the US twice; the last time was in 1959. Lars Götherström is interested in propagation. Harald Haegermark, in the same section as Götherström, visited the US in 1964. Ake Hallbäck and Claes Runborg are in the second section that deals with transducer design and calibration.

The Institute for Acoustics has worked in air acoustics, speech and geoacoustics. The underwater sound work in the 1950's consisted of the development of a sound velocity meter and a doppler indicator. In 1960 they began studies in shallow-water propagation and signal processing. They produced spark and air piston boomer sources that were used by the Geology Department of the University of Stockholm in a cooperative study of the bottom characteristics of the Baltic Sea. The Geology Department was interested in prospecting for oil and iron, while the Institute for Acoustics was interested in the bottom in connection with underwater sound propagation. Data obtained since 1900 show that the water at the bottom

of the Baltic has increased in salinity and decreased in oxygen content. This water is trapped by the shallow entrance from the North Sea. Sonar conditions can be seasonally predicted in a macroscopic sense. Low salinity means low sound absorption. In much of the Baltic attenuation is on the order of $\frac{1}{4}$ dB/km at 10 kHz. The low absorption means that they can use 300-kHz sound for mine location.

In signal processing they have been interested in frequencies up to 1 mHz. In the early work on signal processing the Dimus system was used. Now they have a micro-circuit correlator of their own design that uses 2000 transistors in a chassis a little larger than one's hand. Data from six hydrophones fed into the correlator give 32 points on the correlogram. The six hydrophones are used either in a towed line array or in the helicopter-dropped star configurations they have developed. The first star had a maximum hydrophone separation of 15 m; the latest model is 45 m across. One hydrophone is in the center. The sound velocity meter that they developed measures the delay between quartz crystals that act as source and receiver. The meter scale reads to 0.1 m/sec. They have developed an electrodynamic projector for the frequency range of 200 to 2000 Hz to produce up to 50 W of acoustic power. A very thorough analysis went into this development in order to obtain 10% efficiency, neglecting the power for dc polarization. The diaphragm has a radius of 15 cm, and the suspension of the diaphragm is a ring of rubber 3 mm wide. An input power of 200 W raised the temperature to 65°C with a $\frac{1}{2}$-rise point reached in 30 min. Thus, 500 W can be used for a few minutes.

They showed me the curves used in the development of this projector. The relation of mass reactive radiation load vs. mass of coil and radius of the piston had been analyzed, all with respect to frequency. For a coil mass of $\frac{1}{4}$ the total acoustic circuit mass, the curve is fairly flat from 200 to 2000 Hz with about 10% efficiency. The diameter of the coil is maximum for diaphragm size. Round wire is used and inductance is reduced by a copper layer on the magnet gap. The driving and magnetizing coils are consolidated in epoxy.

In some of their early signal correlation tests they used 10-in ceramic lines in cone reflectors. The reflectors were foamed polyvinyl encased in fiberglass-reinforced plastic. Transmission loss measurements on a plane reflector at 27.6 kHz showed no transmission at 42°. This angle was then used to produce the cone, but the null is dependent on the frequency and I suspect it is also a function of the panel size and shape.

Calibration facilities consist of a small tank which uses the two-projector null method at low frequencies, a reciprocity and comparison calibration tank 5 x 2.5 x 2.5 m deep and a torpedo tube that is used for comparison calibrations up to 600 psi hydrostatic pressure. The open tank is concrete, about 6 inches thick, and the water can be circulated and cooled to about 2°C. A motor stirrer keeps the temperature uniform. Calibrations are made point by point versus frequency or orientation, using continuous or pulsed sound. The level is read on a calibrated scope or vacuum tube voltmeter. The torpedo tube is slightly offset from a vertical position and is mounted through the floor. Meyer-type sound absorbing wedges, 2 inches long, are cemented to the tube wall and at the ends.

NORWEGIAN DEFENSE RESEARCH ESTABLISHMENT, DIVISION FOR UNDERWATER WARFARE, HORTEN, NORWAY

The Norwegian Defense Research Establishment was organized in 1946. Its headquarters is at Kjeller per Lillestrøm, east of Oslo. There are about 250 on the staff, with research in X-ray, nuclear physics, aerodynamics, chemistry, communications, explosives, and rockets. Research is done in six laboratories that are referred to as divisions. The Division for Underwater Warfare is located in Horten. Dr. H. Nødtvedt, Superintendent, returned to Horten this spring after a term as Director of the SACLANT ASW Research Centre, La Spezia, Italy. Mr. I. Engelsen is Superintendent in charge of the work in underwater sound. Under him are Ole Fr. Harbek, senior scientist; Per Heimdal; A. Aubell, in charge of transducer calibration; and E. Kjellsby.

For some time they have had a propagation range in the Oslo Fjord where the range traverses a depth of 200 m. Measurements of variability in sound propagation off the western coast are in progress over a range of 6 kyds with a source depth of 65 m, hydrophone depth 95 m and maximum water depth of 152 m. These measurements have been made at 1.4 and 3.7 kHz.

A towed line array is being constructed for propagation studies. The elements are ceramic cylinders that are capped with O-ring seals between the cylinder and caps. An electrodynamic sound source is also being built for use in the frequency range 2 - 15 kHz. An air-piston calibration chamber is under construction for calibrating hydrophones at low frequencies. The piston is motor driven. A 6 x 15-m barge is being installed in the bay at Horten in water 20 m deep for transducer calibration.

DANISH DEFENSE RESEARCH BOARD, COPENHAGEN, DENMARK

In 1965 the Danish Minister of Defense requested of the Defense Research Board a proposal for the organization of a high level defense research laboratory. In a report of 27 April 1967, the Board advised the Minister on the organization of the Defense Research Institute covering the responsibilities of the Director, facilities and funds. By August or September of this year, it is planned to set up the Institute with six divisions and to reduce the number of military personnel in engineering training positions from the present 55 to not more than 20. The total complement of the Institute is planned for 190 people in the next five years. The six Divisions as planned will cover Chemistry, Operations Research, Applied Physics, Electronic Communication, Instrumentation, and Special Projects. Under Electronic Communication there will be sections of hydroacoustics, electromagnetic radiation at low frequencies in water, and radar propagation. In the Applied Physics Division there will be an optical section, radioactive and radiation physics and shock and vibration. Under Instrumentation, there will be data processing and a computer laboratory. The only special project referred to was an IFF system. The new Institute is to be kept informed and to advise or do research required by all defense activities. No other laboratories are to be organized under the individual arms of the military--air, army, or navy. If the Institute does not have the capabilities, they can contract for research.

Sv. Falck Larsen is the Head of Communications and Electronics Division with responsibility for research in hydroacoustics, electromagnetic radiation in water at 10 - 30 Hz, and radar. This summer there was a cooperative research effort on sound propagation in the Baltic with SACLANT and Woods Hole Oceanographic Institute. Other work includes acoustic control and classification of underwater craft.

The Danish fishing fleet has been very slow in equipping their boats with sonar. The Navy has used UK sonar, but they stopped installing this a year ago and a decision on future Navy sonar is to be made by 1969. They have a 10-m-long vertical line for propagation studies that consists of five American TR127 transducers. Daily salinity profiles have been made from data taken for 32 years. These data are on 16 mm film that is projected to show the movement of water from the North Sea to the Baltic, where it is trapped by the shallow water barrier between.

Calibration facilities use a wooden tank 1½ x 1½ x 2½ m. Mr. I. Gilberg, an electronic engineer, does the calibration. Two other electronic engineers under Larsen are A.M. Terkelsen and O.V. Olesen, both working on the salinity measurements, sound propagation, and data processing.

NATIONAL DEFENSE RESEARCH ORGANIZATION RVO-TNO, THE HAGUE, NETHERLANDS

The Physics Laboratory of the National Defense Research Organization has divisions in Microwaves, Radio Communication, Arithmetic Computers, Operations Research, Radar, and Sonar. Ir. M.W. van Batenburg was in charge of Sonar until he became the Director of SACLANT ASW Research Centre at La Spezia, Italy, this summer. The two sections of the Sonar Division are Electronics under B.C. Reith and Acoustics under H.A.J. Rijnja. No one is acting in place of van Batenburg.

Reith recently reported at a meeting here at ONRL on the propagation studies in the Rotterdam channel. Propagation over a range of 6000 to 7000 m during the out-going tide, to give them sweet water, have been made with a 100-msec pulse of 5 kHz every 2 sec. The channel is 1500 m wide and the receiver is installed on a ship in the inlet.

The work under Rijnja consists in transducer development and calibration. Beginning in 1948 they used Rochelle crystals obtained from Philips at Van der Heen. Later, they built sonar with ADP operating at 20 kHz. More recently, a magnetostrictive transducer has been produced, operating at 11 kHz and powered with 10 kW. Listening square-arrays have been built with a cosine pattern. A large series of small transducers varying in size from ¼ in. to 1 in. across the active face are now in development for flush mounting in flow noise measurements. These are ceramic Tonpilz units; some have very smooth response while others seem to show anomalies due to a slight misalignment of stress in relation to the center of mass. Calibrations in the frequency range from 1 to 40 kHz are made in a lake at Nootdorp from a floating pier in 16 m of water. A 1/3-octave band of noise is used in point-by-point measurements. A 1-octave band is used up to 100 kHz. On the pier they are currently installing a 60-kW power amplifier operating at 5 kHz for calibrating a panoramic transducer. A small laboratory tank, 1 m deep and 3.5 m long, is used for calibrations of 100 to 1000 Hz using a hydrophone to maintain a constant output from a J9 projector. They can also calibrate at the higher frequencies, 30 to 200 kHz, in this tank. Ir. K. Posthuma is making the noise investigations, C.C. van de Rint and

G.C. Lenterman are producing the transducers, and C. de Mos and J. Kromjongh calibrate in the lake. H.A.J. Rijnja spent three years at SACLANT ASW Research Centre, returning to the Hague in 1965.

APPENDIX

DIRECTORY OF LABORATORIES COVERED IN THIS REPORT

Stockholm, Sweden

Research Institute for National Defense, Dept. 3
Institute for Acoustics
Linnégaten 89
Stockholm 80 Tel: 63-15-14

Ing. Sigfrid Wennerberg	
Lars Götherström	Propagation
Harald Haegermark	
Ake Hallbäck	Transducers
Claes Runborg	Calibration

Horten, Norway

Norwegian Defense Research Establishment
Division for Underwater Warfare
Karl Johansvern
Horten Tel: Horten 2081

Dr. H. Nødtvedt, Supt.	
I. Engelsen, Supt.	
Ole Fr. Harbek, Senior Scientist	Transducer Design
A. Aubell, Senior Scientist	Transducer Calibration
E. Kjellsby	
J. Johnsen	Propagation
K. Söstrand	Propagation

Simonsen and Mustad Co.
Division of Simonsen Radio A.S.
Standgete 31
Horten Sonar and Echo Sounders

Copenhagen, Denmark

Danish Defense Research Board
Østerbrogades Kaserne
Copenhagen, 8 Tel: TRIA-5707

S. Falck Larsen, Head, Communications and Electronics Division	
A.M. Tenkelsen	Propagation and Noise
O.V. Olesen	Propagation and Noise
I. Gilberg	Calibration

The Hague, Netherlands

Physics Laboratory of the National Defense Research Organization TNO
Vlakte van Waalsdorp
The Hague Tel: 24-43-60

Ir. H.A.J. Rijnja	Sonar Acoustics
Ir. K. Posthuma	Noise
C.C. Van de Rint	Transducer Design
G.C. Lenterman	Transducer Design
C. de Mos	Calibration
J. Kromjongh	Calibration

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13. ABSTRACT

Organization of the defense research laboratories in Norway, Sweden, Denmark, and The Netherlands, is described with a discussion of underwater acoustics in the areas of propagation, transducer design and calibration facilities. One sonar manufacturer in Norway was also visited and a description of products and calibration facilities is included in this report.

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