Developments of Hydroacoustic Measurement Technology

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Japan is surrounded on all four sides by the ocean, with the coastline of her territories spanning more than about 35,000km, which is equivalent to about 90% of the linear distance around the globe. People of this nation have always had a deep relationship with the ocean and the rivers since ancient times while the domain of measurements under the sea or in the water can also be described as playing an important role. Oki Seatec Company Limited was founded in 1987 and its establishment can be traced back to its forerunner, the Marine Laboratory of Oki Electric Industry Company Limited, which started operations in 1962. Throughout its existence, the organization has served a wide range of clientele including the Defense Agency, various shipbuilding companies, sound navigation and ranging (SONAR) device manufacturers, universities as well as research institutions and consistently performed duties relating to measurement technologies, primarily performing tests and evaluations in the sea that are essential for the development of hydroacoustic equipment and oceanographic equipment. The kind of measurement service that can respond to a diverse range of demands from customers can only be provided through a triune measurement technology, environment and testing facility. This paper will first describe the measurement technology, environment and testing facilities used. Further, although we are engaged in the provision of products based on the hydroacoustic measurement technology, such as various transducers, acoustic analyzers and measuring devices, we are also involved with developments in other fields through such efforts as the commercialization of underground tank inspection devices that use acoustics. This paper will also describe a part of such efforts.

Hydroacoustics and measurement technology

It has been known for a long time that sound travels a long way under water. The incident that gave momentum to the progress in the field of hydroacoustics was the “shipwreck of the Titanic”. The luxury liner Titanic struck an iceberg in the North Atlantic Ocean during her maiden voyage in April 1912. This resulted in a tragedy that caused the death of many people. The nations of Western Europe and the United States began research to prevent such a tragedy from occurring again, which led to the development of sound navigation and ranging (SONAR) devices. In later years during both world wars SONAR was emphasized as an effective means for detecting submerged vessels, which led to the evolution of hydroacoustic technologies. SONAR research was instigated in Japan by the former Imperial Navy around 1930. The Acoustic Research Department was established at the Naval Institute of Technology in 1940 with research, development and evaluation tests commencing in Suruga Bay and a base at Numazu. Hydroacoustic technologies are no longer limited to their application in SONAR devices, but are currently implemented in positioning systems for seabed exploration as well as for deep-sea submersible research vessels and are also widely used in the field of marine structure studies on a global scale (for research into the generation mechanism of El Nino Effects, etc.). The domain of their applications is growing.

In terms of assuring quality and improving productivity, it is essential that research and development, as well as the product evaluation tests of SONAR devices, oceanographic survey and observation equipment be based on measurements taken at sea. Signal and noise levels, frequency characteristics and directivities, as well as propagation characteristics are subject to hydroacoustic measurements for the purpose of evaluation tests. Therefore, it is necessary to have an advanced understanding of the acoustic characteristics of transmitters (devices emitting sounds) and receivers (devices receiving sounds). A number of methods are used for calibrating the sensitivity of transducers, with reciprocity calibration and comparison calibration most widely used[1),2)] and stipulated by the Defense Agency Standards (NDS)[3)].

Although there are a few considerations to keep in mind for improving the measurement quality during actual measurement operations, it is vital that adequate care be taken, in particular with the signal-to-noise ratio (SN ratio). Noise factors that deteriorate the SN ratio include ambient noise, mechanical noise and electrical noise (Figure 1).

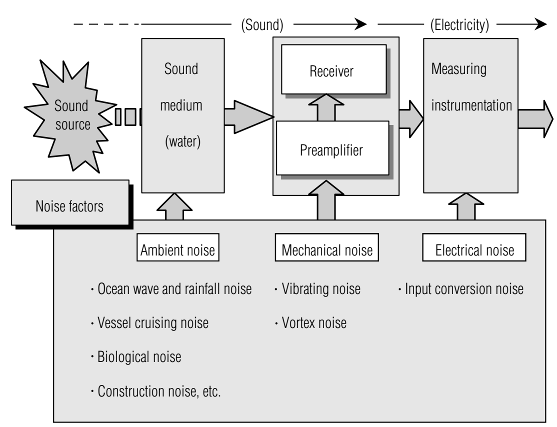


Fig. 1 Noise factors relating to hydroacoustic measurements.

The level of ambient noise is dependent on the “location used for measuring”, therefore, when taking measurements at sea ocean waves as well as rainfall noise, vessel cruising noise and biological noise need to be taken into consideration. When measurements are taken on land (in water tanks, etc.), manufacturing plants in the vicinity, cruising motor vehicles and civil engineering work all tend to have an impact on the readings. In general, ambient noises have characteristics that include a raised level of noise in the low frequency range. In order to obtain favorable measurement results it is necessary to understand the ambient noise in advance and to examine the testing conditions, such as the signal level settings.

Mechanical noises are vibrating and vortex noises, detection of which usually depends on the “method used for measuring”. Ordinarily transducers and receivers are attached to measuring instruments and suspended in water in order to take measurements. Prevention of the transmission of vibrations to the receiver, originating in transmitters and other sources of mechanical vibrations via the instrumentation, is required. It is, therefore, necessary to design measuring instruments with consideration for preventing the transmission of vibrations by using structural and material means in accordance with a measured frequency range. Further, when a flow of fluids exist, a design that incorporates a consideration for preventing the occurrence as well as the magnification of noise due to a vortex using structural and contour means is necessary.

Electrical noise depends on the “equipment used for measuring”. The design and selection of equipment, therefore, must be carried out in such a way as to ensure that the input conversion noise of the preamplifier, in particular, is adequately lower than the signal level of the subject for measurement.

We have at our disposal a wealth of technological know-how relating to “locations used for measuring”, “methods used for measuring” as well as “equipment used for measuring” and we have established various acoustic measurement technologies, including sensitivity calibration, as our core competence.

Environment and testing facility supports measurement quality

An environment (a location used for measuring) suitable for taking measurements and a testing facility that can accommodate a diverse range of demands are essential for offering a favorable measurement quality, which can achieve a high level of customer satisfaction.

(1) Environment of measurement sea area

The topography at the Uchiura Bay Cove area on the eastern section of the Suruga Bay has a flat seabed and in the proximity of a region where the water reaches a depth of 500m to over 1,000m. This makes implementation easy for performing tests ranging from shallow to deep. This “location” was chosen, primarily by the Naval Institute of Technology of the former Imperial Navy starting from the early Showa Era (late 1920s), as a place for conducting various acoustic tests.

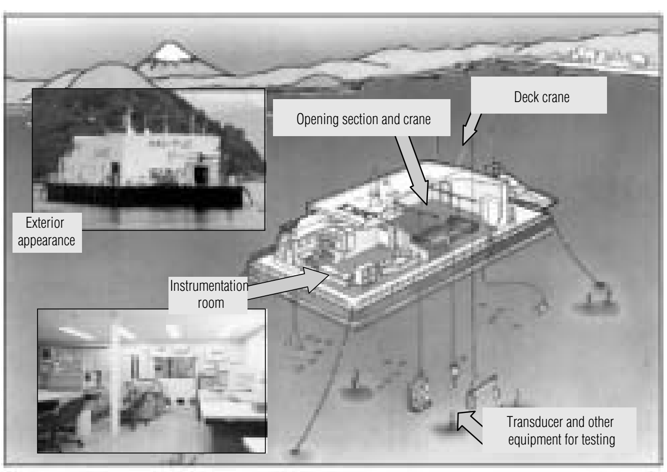
We use the Uchiura Cove area as our location to maximize the site conditions that are suitable for measurement operations at sea. Further, we have been fortunate enough to be able to conduct smooth operations and establish extensive testing facilities through the understanding of members of the local fishing community who use the same “ocean”. These site conditions and the favorable relationship we share with the local community are intangible assets that we cherish.

(2) Testing facility

A broad range of customer requirements are needed for evaluating hydroacoustic devices and oceanographic devices. The applicable frequency range, for example, may be anything from low to high, while the articles subject to measurement can range from compact items to large items, which can also be a device or even a whole system. Test items included as a part of the evaluation test are highly diverse, ranging from the acoustic characteristics of a transducer (sensitivity frequency characteristics, directivity, etc.) to the reflective and permeability characteristics of acoustic materials or the overall evaluation tests of equipment and systems. We have at our disposal a number of test facilities (both at sea and on land) to respond to such customer requirements. A summary of the main facilities is provided below.

◆ Marine instrumentation barge: Seatec II

Various acoustic measurements are taken aboard this marine instrumentation barge, which is permanently moored in the testing sea area (Figure 2). It is our understanding that this is the only dedicated facility of its



Specifications	
Overall length	30m
Overall width	13m
Aggregate tonnage	300 tons
Mooring method	Four-point mooring
Opening dimensions	7.5 x 3m
Opening section crane	2 x 1-ton
Deck crane	1 x 2.9-ton
Water depth	32m

Mooring location: Uchiura Bay Cove, Numazu City, Shizuoka Prefecture.

Fig. 2 Marine instrumentation barge (Seatec II).

kind within the private sector of Japan.

An opening (7.5 × 3.0m) at approximately the center of the vessel allows the test subjects to be suspended in the water with the help of a crane. The necessary data is obtained in the instrumentation room, where equipment, such as calibration equipment, is permanently installed. By installing electronic equipment dedicated to the use of test subjects in the instrumentation room, it is possible to conduct an overall evaluation test of the entire system at sea. Further, because Seatec II is moored at four separate points the waves of the ocean do not impact its operations very much, thus there is hardly any movement of the vessel. For this reason it is possible to conduct stable measurements that are reproducible, as there is very little increase in the fluctuation of data or noise resulting from movement of the test subject.

Furthermore, large test subjects can be suspended and salvaged safely and, making it possible to implement tests in an efficient manner.

◆ Test Vessel: Ikoi-maru II

The test vessel "Ikoi-maru II" and a few other test vessels are used for tests that require mobility, such as offshore towing, laying and salvaging operations, suspensions at great depth and drifting buoy testing. The structure of the hull of these test vessels have been designed to minimize the vibration emitted from the engine so that the measurement quality is not impacted. They are also equipped with instrumentation rooms and A-frame cranes for suspending test subjects (Figure 3). Further, several vessels that include floating cranes are operated to conduct tests involving large test subjects.

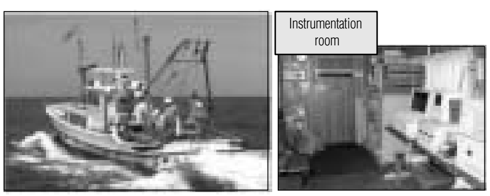
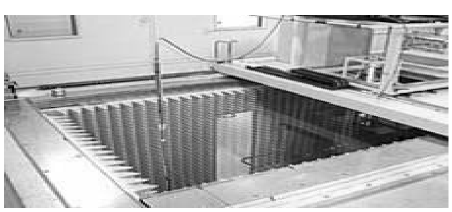
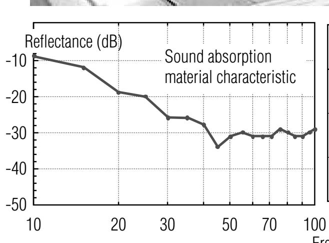


Fig. 3 Test vessel (Ikoi-maru II).

◆ Anechoic water tank

An anechoic water tank is used as a land-based facility for hydroacoustic instruments to take measurements of the sensitivity and directivity of high frequency transducers (Figure 4). Wedged-type sound absorbing resin materials are attached to the internal surface of the water tank, which makes it possible to conduct measurements in conditions where no reflections from the internal surface of the water tank exist for frequencies of approximately 30KHz and above.





Specifications	
Length	5m
Depth	2.5m
Width	3.5m

Fig. 4 Anechoic water tank.

By using hydroacoustic measurement technologies we have accumulated based on our characteristic testing environment and testing facilities we are able to offer a measurement quality that can satisfy our customers.

Products created from hydroacoustic technologies

We are aiming to improve our corporate value through the creation of new products, such as various transducers, acoustic analyzers and instruments resulting from the horizontal development of our hydroacoustic measurement technologies, which constitute our core competence.

A part of such developments are described below:

(1) Hydroacoustic analyzer: OST4100

Ordinarily hydroacoustic measurements involve composing an instrumentation system made up of general-purpose instruments, such as an oscilloscope, frequency analyzer (FFT) and decoder, as well as a transducer. The hydroacoustic analyzer is a compact and easy-to-use instrument analyzer, which resulted from the extraction of only those functions that are necessary and based on the hydroacoustic measurement technologies we have amassed over the years (Figure 5 and Figure 6).

Fig. 5 Configuration of hydroacoustic analyzer.

◆ Compact, light-weight and battery operable for outdoor use.

◆ Offers four functions in a single unit:

(1) Waveform observation function (2) Frequency analysis function

(3) Analysis display function (4) Data recording function

◆ Measurable frequency range : 20Hz to 20kHz

◆ Frequency resolution : 0.5Hz to 25.0Hz

◆ Data recording time : 30 minutes continuous (maximum)

Fig. 6 Major functions and performance of hydroacoustic analyzer.

An oscilloscope display, spectrum display, spectrographic display and level recorder display are provided simultaneously by the display processor, making it possible to conduct multifaceted measurements and analysis at the same time (Figure 7)

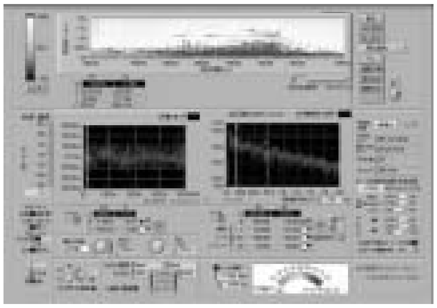


Fig. 7 Display screen of a hydroacoustic analyzer.

(2) Sonic Tester: OST4200.

The Sonic Tester is a device used for inspecting underground tanks that are laid under the ground at service stations for the purpose of detecting the existence of minute pinholes and cracks on the wall's surfaces.

The product was developed and commercialized in response to a commission received from a customer (Kodama Industry Co., Ltd.) and complies with the new standard for underground tank inspections that has been enforced since April 2004. The device is composed of a receiver section and display processing section (Figure 8).

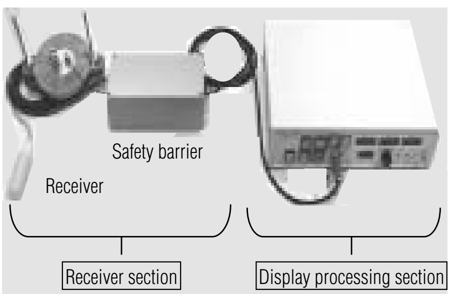


Fig. 8 Configuration of a Sonic Tester.

The operation summary of the device is described below (Figure 9).

- The receiver is installed in the liquid phase section and a depressurizing pump is used to reduce the tank's internal pressure to a prescribed pressure.
- Air outside the tank is drawn in and bubbles are generated if a pinhole or crack exists on the walls in the liquid phase section of the tank.
- Using the receiver this air bubble-generating sound is detected, which determines whether a pinhole or a crack exists.

This device detects the sound of air bubbles being generated inside underground tanks, which takes us into an application field that is quite different from conventional hydroacoustic measurements. The fact that the sound inside a body of liquid can be measured presents us with a segment that is technically similar to hydroacoustic measurements. Commercialization of this product was realized by first gaining a good understanding of the air bubble-generating sound characteristics using our internal experimenting equipment and the test equipment of our customer. Further, the receiver section (receiver + safety barrier) was required to be designed in compliance with the "Intrinsically Safe Construction" as defined by the Electrical Machinery and Apparatus Explosion-proof Construction Standard. The product passed the type test (No. TC16962 of the Technology Institution of Industrial Safety) as the design of the receiver, parts and circuit patterns were of an explosion-proof construction.

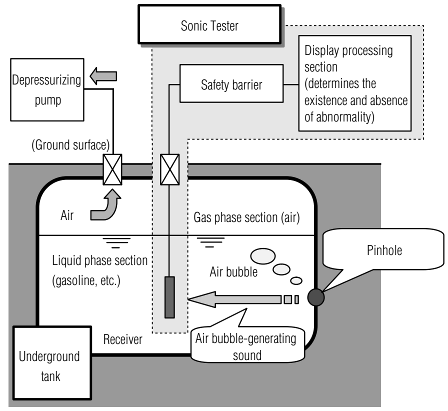


Fig. 9 Summary of an inspection with a Sonic Tester.

Conclusion

Oki Seatec aims to improve the customer satisfaction in the field of hydroacoustic measurements, which require triune manipulation of a testing environment, testing facilities and measurement technologies. Further, our company is aiming to improve our corporate value through the creation of new products resulting from the horizontal development of the hydroacoustic measurement technologies.

Even though this paper did not get into details, issues have become evident regarding environmental problems in coastal regions in recent years, stemming from concerns of the negative impact on marine life and the fish in fish preserves, from noise generated by construction that often resulted in the implementation of environmental evaluations. We have been dispatching our instrumentation personnel with measuring instruments to such locations, equipped with measurement technologies that we have accumulated over the years, to assist in conducting hydroacoustic measurements to evaluate the environmental impact.

We intend to continue striving to polish our skills to respond to a diverse range of customer requirements and to ensure that our customers are satisfied.

References

1) R.J. Urick (translated by Akira Tsuchiya), "Principles of Hydroacoustics", Kyoritsu Shuppan, 1978.
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