

THE FINNISH SURVEY VESSEL "AIRISTO"

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GENERAL

The survey vessel *Airisto* was built by the Rauma - Repola shipyard in Savonlinna and was delivered to the Finnish Board of Navigation on the 14th June 1973. The vessel is constructed for "echo sweeping" as well as for ordinary single echo sounding. When planning the vessel and her equipment valuable experience obtained from the survey vessel *Särkkä* was taken into account. The *Särkkä*, also constructed for echo sweeping, was delivered in 1966 and has been in use since then.

Main particulars of the *Airisto*

Length	30.7 m
Breadth	8.9 m
Draft	3.0 m
Engines	2 × 290 HP
Propellers	2 Ulstein variable pitch
Speed	8.5 knots
Speed (sweeping)	4.0 knots
Crew	13

General arrangements

On board the vessel there is accommodation for 16 persons; all cabins except two are singles. The vessel also has an office, three messes, a Finnish sauna and a laundry with automatic washing machine.

Crew

In addition to the master, there are three officers on board: the junior surveying officer, the radio technician and the chief engineer. The main duty of the radio technician is operating and maintaining the electronic measuring equipment. The rest of the crew members are: boatswain, carpenter, motor man, stewardess, cook and four deck hands.

Auxiliary craft

The vessel has two motorboats embarked, which are used for material transport and for shifting the shore based position fixing equipment. Both craft are equipped with echo sounders and can be used for minor surveying tasks.

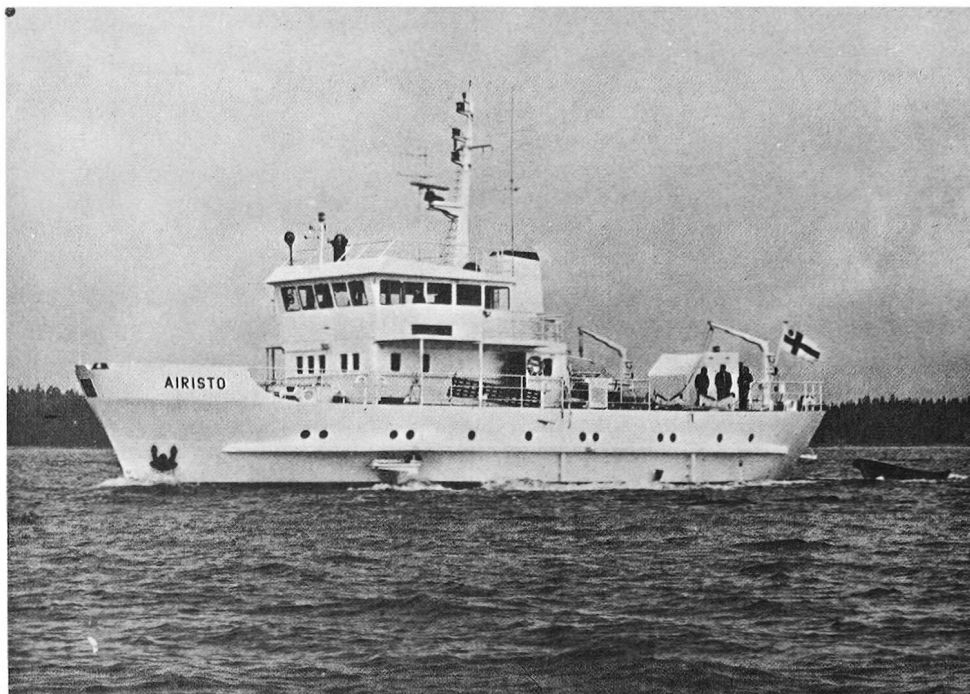


FIG. 1

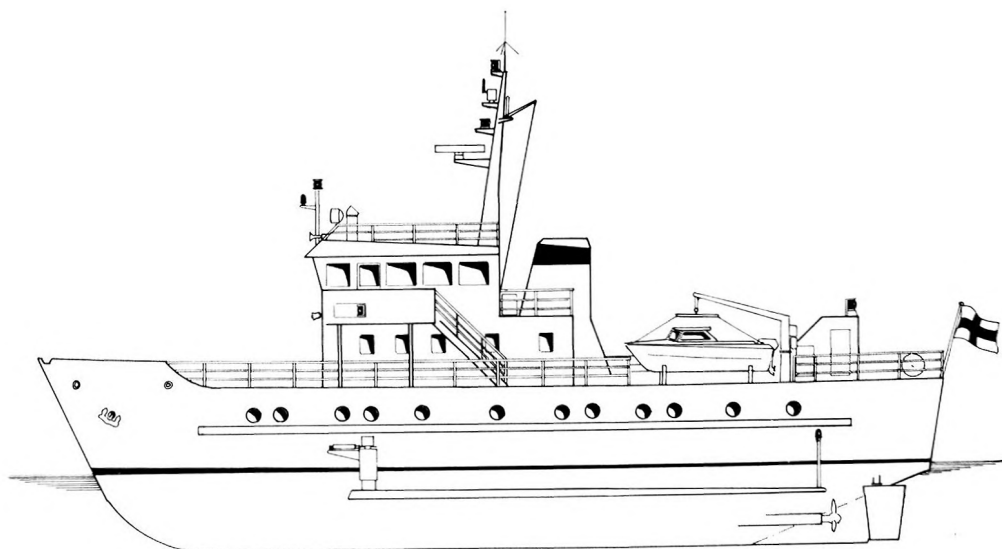


FIG. 2

Measuring equipment

The *Airisto* is equipped with a "Slocum waterway measuring system" [1], which allows fully automatic recording and processing of depth figures and position data. Even the steering of the vessel can be done fully automatically.

The bridge arrangement

The panel-mounted equipment for manoeuvring and navigation, such as engine throttles and controls for the adjustable propellers, radar unit, gyro compass, autopilot and log display, is in the fore part of the bridge. Here also are digital and analogue displays indicating position data and steering instructions for the helmsman.



FIG. 3. — Inside the bridge.

The control panel for the measuring and positioning system is located at the rear of the bridge. Here are mounted, from left to right : an Atlas DESO-10 echo sounder, Slocum operating console, KSR-teleprinter, Wang 600 electronic calculator, Decca Trisponder display, steering generator, and Decca Navigator digitizer with displays. Above the panel is mounted a monitor showing sounding and position data. In front of the panel there is a Wang x, y plotter which is connected to the Wang 600 calculator.

The central electronic unit is situated at the aft bulkhead of the bridge. The central unit comprises Dr. FAHRENTHOLZ'S 40-channel echo sounder [1]

and the Slocum central processing unit (CPU) in which a magnetic tape recorder is mounted.

Measuring wings

The two measuring "wings" are located one on each side of the hull at a depth of 1 metre. They are hydraulically operated from the bridge. When sweeping, the wings are fixed at an angle of 90° to the hull. When not in use, they are positioned along the hull, secured with clamps. In the wings, and in the hull between the wings, there are 39 ultrasonic transmitter-receiver pairs built in with an interval of 1 metre between each pair. The length of the wings is 16 metres and the width of the area swept is 40 metres.

THE SLOCUM SYSTEM

The system is based on 39 simultaneous soundings concurrent with continuous position fixing. The depth figures and the position data are recorded and protocolled at the same time.

Sounding

The actual soundings are performed by means of the FAHRENTHOLZ echo sounder [1]. The sounding interval is 0.1 sec. and a frequency of 110 kHz is used for the sounding pulse. The echo sounding apparatus has built-in time delay circuits to correct the level difference between the wing-based and the hull-based oscillators, the reference level of the sounding pulses being that of the centre hull-based oscillator. The receivers also have delay circuits manually adjustable to eliminate false echoes obtained from fish or muddy water between the transmitters and the sea bottom. The delaying of the hull-based receivers also eliminates the risk of interference between the wing transmitters and the hull receivers.

Simultaneously with the triggering of the echo sounder crystals, 39 electronic counters (one for each channel) start in the Slocum CPU. The counters are stopped by the returning echo corresponding to each channel. The echo sounding channels are divided in the CPU into pairs, every two adjoining channels forming a pair. The centre channel forms pairs with the two adjoining channels. The lesser of the depth values measured by each pair is recorded and protocolled. The protocoling interval on the magnetic tape unit and on the monitor is, at its fastest, 1 sec. The fastest protocoling achieved by the teleprinter is every 5 sec. The protocoling period can be manually set on the operating console from 1 to 99 sec. Each channel's lowest depth value obtained during the period is then protocolled. The data recorded on the tape unit can later be read by means of the monitor for further examination.

Variable conditions such as water temperature and salinity influence the velocity of sound in water. Corrections for these variables are computed

on the operating console. Reference depths can also be set on the operating console to achieve a protocolling pattern drawing attention to depth values above or below the reference level.

The KSR-teleprinter is connected to the tape unit and is used to write preliminary data on the tape, such as the coordinates of the points used for the shore-based position-fixing equipment, the number and name of the area surveyed and the prevailing water level. These data are important when post-processing the tape by computer.

Position fixing and steering

Of course, knowing the exact position where the values are obtained is as important as the measuring of accurate depth values. In order to meet these needs, the *Airisto* has three different position fixing devices connected to the measuring system : Decca Trisponder, Sea-Fix, and Decca Navigator.

Decca Trisponder

The Decca Trisponder equipment provides range information from two remote units, usually shore-based, to the shipboard base unit. When using the Trisponder, the two distances A and B are automatically protocollated. Furthermore the x and y coordinates are available separately by ordering the Wang calculator to evaluate them. The equipment works on frequencies of 9325 — 9480 MHz. The ranging accuracy is ± 3 metres according to the manufacturer. Fixes are available every 1 second.

Before starting the measuring (surveying) the remote units are transported to their stations. The preliminary work usually takes $\frac{1}{2}$ - 1 hour, depending on the distances to be travelled. Before using, the system should be allowed to warm-up for 20-30 minutes.

When setting up the stations the following factors should be taken into account :

Line-of-sight must be maintained between the remote stations and the base unit.

The directional antenna of the remote unit has opening angles of 89° in the horizontal and 5° in the vertical planes, and must therefore be pointed towards the surveying area.

Practice has, however, shown that even low obstructions — rocks and skerries — may cause loss of signals although line-of-sight is maintained.

The base unit antenna is situated in the mast of the vessel, at a height of about 12 metres above the water level. Thus the radar horizon is about 7 nautical miles from the vessel. In the Finnish archipelago greater distances can seldom be obtained because of the many islands, and therefore this equipment serves our purpose.

Sea-Fix

The Sea-Fix system provides position-lines in the form of circles (range measuring) or hyperbolas, depending on whether the master station is based

on board the ship or all stations are shore-based. The Sea-Fix system does not necessarily need line-of-sight between the vessel and the stations. The maximum range of the system is quoted as up to 150 km, which can be considered quite sufficient for surveying in the Finnish archipelago and coastal waters. The system's weak point is the relatively long time needed for setting out and calibrating the equipment. In the archipelago this time can exceed one week.

Decca Navigator Mk 12

The Decca Navigator Mk 12 is fitted with a separate digitizer unit through which the lane values are fed into the central electronic unit for protocolling.

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For the present no position fixing system other than the Decca Trisponder has been in use on the *Airisto*. This is because no Sea-Fix equipment has been available and the accuracy of the Decca Navigator is insufficient for use in the archipelago. The following therefore deals principally with the use of the Decca Trisponder.

Guidance system

The vessel can be steered by means of the guidance system either by an autopilot or manually. Three different modes of guidance are available : — 1. Circular mode, 2. Hyperbolic mode, 3. Straight-line mode. Straight-line mode can be used only when using a position fixing system based on ranging.

Sea-Track

The Sea-Track unit is used to mix the signals of the guidance generator and the gyro compass. The rate gyro of the Sea-Track unit maintains the curving movement when using circular or hyperbolic modes. The Sea-Track must always be connected when the autopilot is used for steering.

Steering generator

The reference value referring to the guidance mode desired is set on the steering generator. Either range or lane value or right-angular range can be pre-set. The generator has three analogue displays from which deviations from the pre-set values can be read. When using auto-guidance, the deviations from the pre-set values cause error pulses which are fed into the Sea-Track and thus to the autopilot and steering gear.

When using circular or straight-line modes, the indicators show the deviation from the pre-set line directly in metres. In the hyperbolic mode the deviation is indicated in fractions of a lane.

Straight-line mode

When using the straight-line mode the Wang 600 calculator is used to evaluate the right-angular range s_1 and the distance s_2 . The program performs a continuous loop unless stopped manually or by lack of data (ranges A and B). An $\alpha - \beta$ filter is included in the program in order to even out incidental ranging errors.

The Wang calculator is fitted with two digital displays indicating the current s_1 and s_2 values. The computed s_1 value is fed continuously into the steering generator for comparison with the pre-set value.

Steering the vessel

When steering manually, the helmsman keeps the steering indicator at zero. In straight-line mode, the gyrocompass also facilitates line holding. A well-trained helmsman is able to keep the vessel on the pre-programmed line with an accuracy of about ± 3 metres, assuming that weather conditions are favourable.

When using automatic steering, the Sea-Track unit must be switched on. The autopilot selector-switch is set to "remote". In the circular and hyperbolic mode, the selector-switch of the Sea-Track has to be in the position "rate"; in straight-line mode the "compass" position is selected. The approximate gyro-course of the line has to be set on the autopilot in this case.

Usually a few test-lines have to be run, in order to trim the equipment. On the Sea-Track the relative strengths of the line-guidance and the gyro-guidance can be adjusted in order to achieve a smooth track.

In good weather conditions the auto-steering provides better accuracy than manual steering. Bad weather conditions decrease the accuracy to $\pm 5-8$ metres.

The turns between lines are always carried out manually by the helmsman. When the ship has been turned round and settled on the new line, the auto-steering may be switched on again.

SURVEYING

General

The vessel can be used to estimate the amount of material to be dredged, for localizing desired depth curves, for surveying in connection with underwater construction work, and other hydrographic surveys.

The equipment is used in the most efficient way when the results are post-processed by a computer. This is usually done when dealing with underwater fairway construction work of all kinds.

In the following paragraphs, echo sweeping in combination with the Decca Trisponder is explained. When using other position fixing equipment the procedure is essentially the same.

Preliminary preparations

Planning the summer's surveys (due to ice and weather conditions, the surveying season in Finland starts in May and ends in October) is mainly carried out during the previous winter. The necessary depth charts are copied, information about existing triangulated fix-points is gathered, time schedules are made up, and so on. Before use, the Decca Trisponder is calibrated using a Distomat or some similar distance measuring device. This calibration is repeated a few times during the season.

The preliminary work in the field comprises the choice of locations for the Decca Trisponder remote units, and setting up the equipment. If there are no suitable points already available, auxiliary points will have to be established. These points can be triangulated afterwards and their coordinates fed into the computer for post-processing of the results. However, if line guidance equipment is used, the distance z (the distance between the points) has to be known approximately.

Calibration of the echo sounders

The echo sounders are calibrated before commencing each day's surveying; for this purpose a place where the sea bottom is as flat as possible is needed. The depth values obtained from the echo sounders are then compared with hand lead soundings. Another way of checking the echo sounders is to submerge an iron ball under the transmitters at a known depth; by moving the ball along the line of transmitters each channel can be checked.

The position fixing equipment is also checked daily — a rough check being performed by comparing fixes obtained electronically with fixes based on optical methods.

The depths and distances used for calibration should correspond as closely as possible to the depths and distances in the actual surveying area.

After the calibrations have been carried out, the line guidance and protocolling systems are fed with the necessary information such as coordinates of the remote units (if they are not known, the distance z) and the angle coefficient k which is relevant to the direction of the sounding lines. These data, in addition to the base data for the x, y plotter, are fed into the Wang calculator. The desired s_1 value is set on the steering generator.

Now surveying may commence. The first line is caught 200-300 metres before the point where measuring starts. This distance is normally enough to get the vessel stabilized on the line and to get the automatic steering system trimmed. On reaching the start point, the protocolling device is started; at the end of the run, the device is stopped. The steering is now switched to manual, and the helmsman continues a further 100 metres along the line; then he turns the vessel round and aims for the new line which is set on the steering generator. When the vessel is stabilized on the new line, automatic steering may be switched on again. This procedure is continued until the entire survey area is covered.

An interval of 30 metres is used between the lines. This allows deviations up to 10 metres from the track with the coverage still remaining intact. The track-plotter enables the surveying officer to spot loss of coverage immediately.

When choosing the direction of the sounding lines attention should be paid to wind and wave conditions. If results are to be post-processed by computer, the lines should be chosen as close to the south-north or east-west directions as possible. This is because the automatic chart-drawing programme being used at present processes an area limited in the x and y axes.

When surveying a shoal ending up at the shore, or a dangerous shoal where risk of grounding may occur, double coverage is used. This means that an interval of 15 metres between lines is used. In this case the vessel moves in an area already swept by the shore-side wing. As a rule the vessel is not used for sounding in areas where depths may be less than 5 metres. This may however be done if the area is quite safe, as revealed by mechanical sweep or some other reliable equipment.

The speed when sweeping is usually kept at 3.5-4 knots. It is not essential to keep the speed extremely stable because the position fixing is continuous.

If during measuring a certain point has to be marked, spar buoys are used. The spar buoys are fitted with automatic anchors and may be laid from the vessel during measuring. Simultaneously with the laying of the spar buoy, an order is given to the calculator to mark the current s_1 and s_2 values on the plotting sheet. If a more accurate position of the spar buoy is necessary the line is sounded a second time, and when reaching the position of the buoy the vessel is stopped for positioning. The x and y coordinates of the point are obtained by ordering the Wang to evaluate them.

PROCESSING OF THE DATA GATHERED

The final processing of the data is done in three alternative ways :

1. Depth and positioning data are post-processed by computer using the mag-tape, automatically drawing depth contour charts.
2. Depth values and position data are manually selected from the KSR-teleprinter output.
3. Position data only are selected (manually) to obtain the area surveyed. In this case no depth values are processed.

Computer post-processing is done by means of a Univac 1108 computer. Charts are drawn by an automatic Kongsberg Kingmatic plotter.

CONCLUSIONS

Although no thorough examination of the measuring accuracy of the system has yet been carried out, experience already obtained suggests an

accuracy of 10-15 centimetres in the depth values and better than 6 metres in positioning.

The vessel has now been in use for two full seasons, and during that time a lot of improvements have been made. Nevertheless the results of surveying have turned out to be quite satisfactory for evaluating dredging masses and for planning in connection with underwater construction work.

With more ships like *Airisto* we can look forward to building up a library of magnetic tapes which could be used in the planning of new fairways and when redrawing sea charts. This data can also be extremely useful when calculating the costs of dredging.

REFERENCE

- [1] FAHRENTHOLZ, S. (1963) : Profile and area echograph for surveying and location of obstacles in waterways. *Int. Hydrog. Rev.*, XL (1), pp. 23-37.

EARLY THOUGHTS ABOUT ECHO SOUNDING

"Though in theory the depth is easily to be arrived at, yet to obtain it practically is exceedingly troublesome, requiring much time as well as favorable opportunities.

... Few are aware that it requires from two to three hours for a well appointed vessel to make a sounding to a depth of 1 500 or 2 000 fathoms, for which opportunities seldom occur: calms or light winds and a smooth sea are requisite.

... It will thus be seen that it is out of the power of an ordinary vessel to make experiments; in order that this interesting enquiry may advance ..., it becomes necessary that some new mode of sounding be adopted whereby both the time may be lessened and the opportunities multiplied. It has been suggested to obtain an echo from the bed of the ocean by the explosion of a shell just beneath the surface, the depth to be measured through the propagation of reflected sound."

Written by Rear Admiral Charles Wilkes, U.S.N., circa 1870 when referring to the paucity of soundings taken during the United States Exploring Expedition which, as a Lieutenant, he had led round the world in the years 1838-42.

From *A History of Oceanography* by Susan Schlee, published by Robert Hale & Company in London in 1975 and recently received in the Bureau Library.