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Manuel d'installation et de maintenance d'un thermosalinographe embarqué

Users guide for thermosalinograph installation and maintenance aboard a ship

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ABSTRACT

Ocean temperature and salinity distributions are important features for understanding the effects of the oceans upon global climate. Since 1990, the ECOP group (*Etudes Climatiques de l'Océan Pacifique tropical*, former SURTROPAC group), IRD/Nouméa, has been operating temperature and salinity measurements on board merchant vessels using thermosalinographs. Since 1998 and thanks to an eight-year experience, the group has considerably developed and improved installation procedures and automation of the system, i.e. automatic measurements, GPS positioning, real time data transmission through satellites.

On the occasion of the 26-30 October 1998 SOOPIP (Ship Of Opportunity Program Implementation Panel) meeting in Nouméa, New-Caledonia, it was recommended that the ECOP group compile a users guide describing TSG installation on board ships. The present guide describes the implementation and use of such a system, and the various mechanical and electronic techniques that have been developed.

1. INTRODUCTION

Temperature and salinity fields play a crucial role in the ocean circulation and therefore in the distribution of water masses. Thus, the description and analysis of the Sea Surface Salinity (SSS), the Sea Surface Temperature (SST) and their seasonal to interannual variability are essential for understanding the influence of oceans on the global climate. In order to obtain such data, a large observation network has been developped during the recent decades. Commercial vessels, in particular, proved to be an efficient way to monitor SSS and SST distributions along their routes. Moreover, the numerous routes make it possible to plot SSS and SST maps at global time/space scales.

The Noumea-based IRD center has coordinated such a network since 1969. Initially the group selected merchant ships to provide surface water samples using meteorological buckets. The watch officer collected these samples four to six times a day, hoisting up to the bridge an insulated bucket equipped with a thermometer. The water sample was then placed in an airtight container to be analysed later in laboratory. However, measurements taken in these conditions were liable to be inaccurate due to several hard-to-assess parameters, such as loss of heat through evaporation, heat gain through solar radiation, influence of ambient air temperature or of apparent wind and of remaining salt deposit. The preservation of the samples also became questionable.

In order to reach the aims of the TOGA (Tropical Ocean Global Atmosphere array) program, it became obvious that our original manual sampling method needed to be upgraded. A study undertaken thanks to CORDET (Commission de Coordination de la Recherche dans les départements et Territoires d'Outre Mer) financing obtained in 1990, showed the feasibility of installing automatic thermosalinographs (TSG) on merchant ships. This new system would provide greater simplicity, accuracy and frequency than prior observation methods.

Since 1990, numerous vessels have been equipped with TSGs by the IRD group (*cf*. Appendix 1). The first systems were installed without GPS, so positions could only be established by reference to the ships' logs. Today, many improvements have been achieved, and now satellite systems make it possible to recover data in real time.

However, the installation of TSGs is still subject to a large number of compromises and requires careful attention to obtain reliable measurements. This document is designed to serve as a TSG guide based upon the experience of the IRD group which equipped 18 different ships with TSG between 1991 and 1998.

2. BRIEF SUMMARY OF THE SYSTEM

The core of the system is an SBE-21 thermosalinograph, manufactured by Seabird Inc. (Bellevue, Wa, USA), located as close as possible to the engine water-intake. A conductivity cell and a thermistor cell provide conductivity and temperature measurements. Salinity is deduced using an algorithm loaded within a computer, usually located on the bridge. The ship's position is given by a GPS, whose antenna is usually fixed on the deck. Data are recorded on the computer using the "*Thermo*" software developped by B. Buisson and J. Grelet (Grelet *et al.*, 1992). Reduced data are then transmitted by a GOES satellite system whose antenna is on the bridge as well.

3. SELECTING THE SHIP

3.1. Selecting the route and the shipping line

The scientific group chooses the routes according to the studies they run.

The choice of the company, among those operating suitable routes, is more complicated. The shipping routes should be regular and unlikely to change. We happened to equip ships that, immediatly after the TSG installation, changed routes or did not come back to Noumea. We thus wasted much time in both equipping ships and bringing back instruments from remote harbours.

The ports of call should also be taken into account. It is preferable to choose vessels that call at ports where correspondent technicians may undertake possible repairs.

Before applying to a shipping line for an official installation, the operators should definitely visit the ship to evaluate the installation facilities.

3.2. Inspecting the ship

As a matter of respect, one should not go against the best interests of the staff on the issues of safety, comfort, or personal wishes.

The bridge must afford enough space for the computer and the tansmitter. An open room is needed, and the GPS and satellite antennae must be able to be easily connected.

In the engine room, the configuration of the sea water circuit must allow the connection of inlet and outlet pipes at suitable spots (refer to the chapter "Installation"). But remember to follow the engineer's advice. A preliminary inspection will also point out the technique you will have to use for the connections (welding or tapping), and thus the tools you will need. There must also be an accessible place for the TSG itself.

Finally, the electrical link between the engine room and the bridge must be easy to install. On recent ships, spare cables are generally available. If there are not any, it is prudent to foresee how you will manage to link the TSG with the computer sometimes located more than 25m higher. Here, you will obviously have to consult the electrician on board.

3.3. Applying and explaining

If the vessel looks well adapted, you will have to initiate the agreement procedure and to argue the value of such TSG network.

Note that the agreement of the company is far more reliable than the captain's approval, because crews, and therefore the ways they view the scheme, often change, and thus the installation may be called into question again.

Companies are usually very appreciative of these scientifically intented installations, which are actually user-friendly and do not place a great burden on the crew. Always try to put forward the importance of the scientific studies (oceanography, climatology, …) deriving from the data, and stress the interest of the program.

4. INSTALLATION

Usually, installation of the whole system takes up to two or three days at least. In case of too short a stopover, it can be completed the next time the ship calls. A shipboard technician can sometimes complete the installation aboard. We successfully experienced such a situation in the past.

Do not forget to manufacture your own accesories (TSG water jacket or bubble trap) prior to the ship’s call and anticipate the time of delivery of ordered equipment.

Before proceeding to the site, check the parts and tools package you will need in order to avoid any waste of time. A list of the indispensable elements is shown in Appendix 2.

To begin with, the TSG water circuit has to be connected to the sea water circuit of the ship.

Dividing the fitters into two teams, one in the engine room and the other on the bridge, usually appears very efficient; the ideal team seems to be made up of two technicians. Indeed, it may be useful to have a team-mate who can help his partner or undertake unexpected errands. Then, having at one’s disposal a car or even a mobile phone can often prevent wasting time.

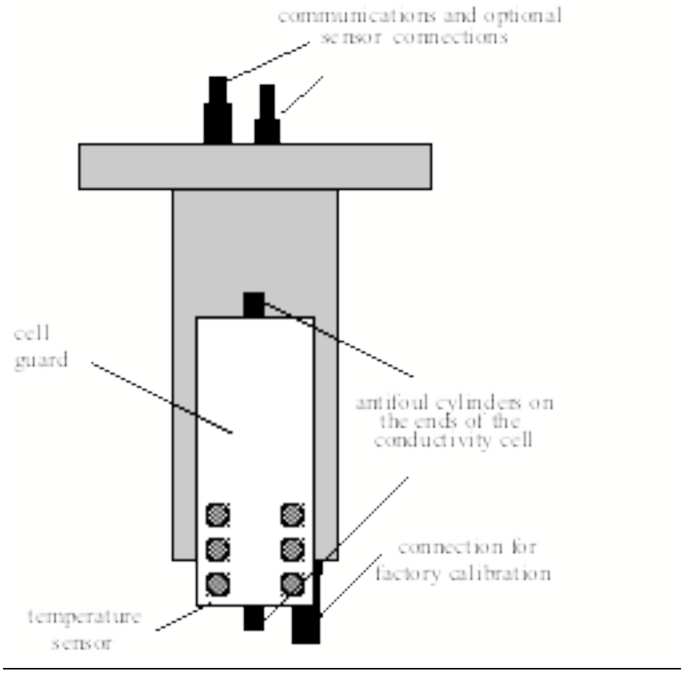
One has to understand that the quality of the measurements greatly depends on the installation. The rest is only a matter of cable-laying.

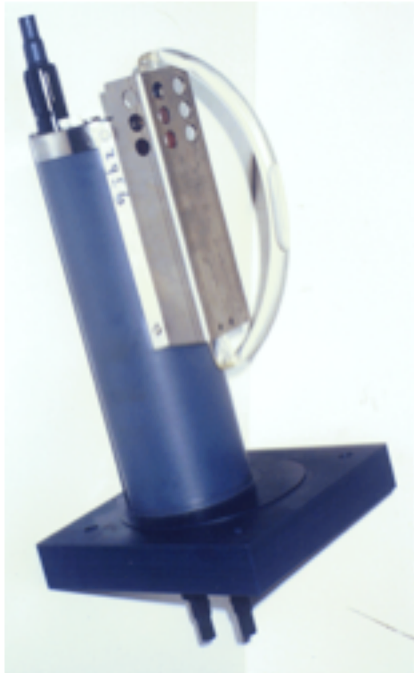
4.1. Engine room

4.1.1. *TSG*

- <u>Description</u>

Having examined various available TSG systems, we chose the SBE-21 thermosalinograph, manufactured by SeaBird Electronics Inc. The main specifications of this model are shown in Appendix 3.





Electronics and sensor module of the SBE-21 thermosalinograph

- *Water jacket*

Stainless TSG water jacket

Ordinarily, the housing of the TSG is made of PVC and available from the manufacturers. Nevertheless, we noticed various defects on the PVC jackets on some installations. The material proved to be very sensitive to temperature variations and to vibrations. PVC paste also cracks when pressure exceeds 3.5 bars. Hence, we have replaced original water jackets by home-made stainless steel ones which do not present such drawbacks and which cost much less (500 US$ instead of 1800). Yet, we noticed galvanic reactions that corroded the stainless jacket. We have not met these problems on installations made using flexible hoses.

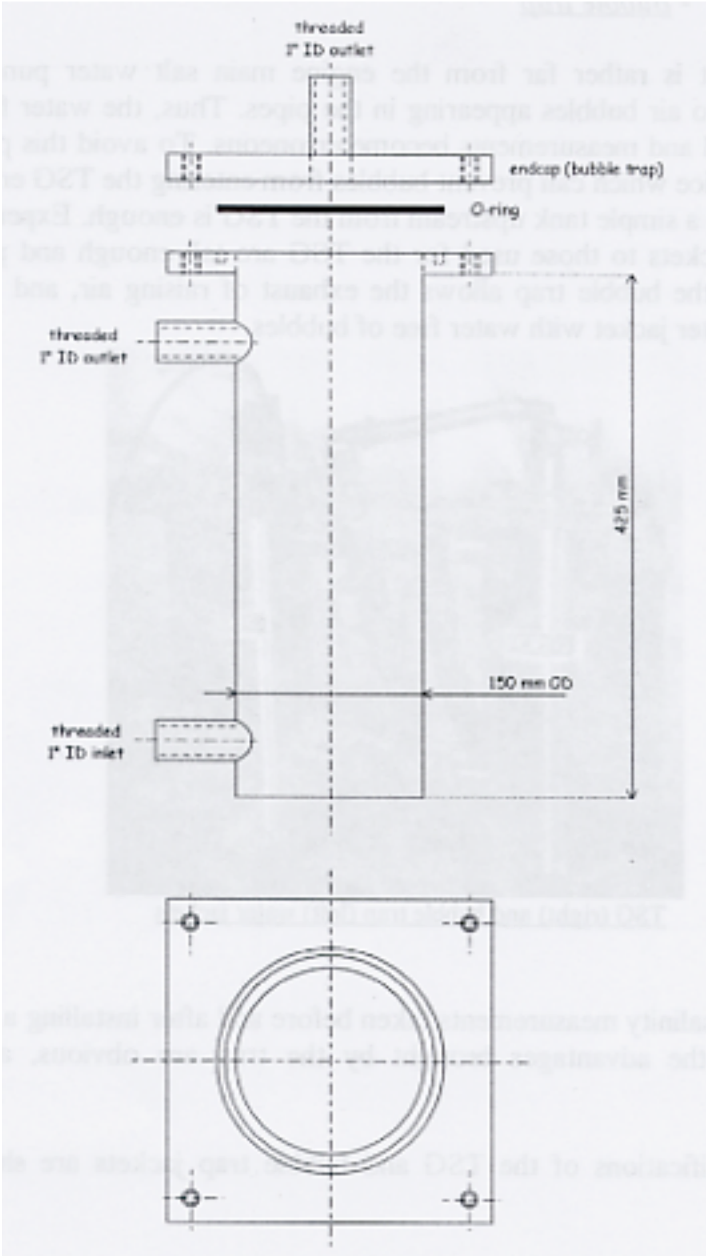
- *Bubble trap*

When the inlet is rather far from the engine main salt water pump, drops in pressure often lead to air bubbles appearing in the pipes. Thus, the water flow through the TSG is perturbed and measurements become erroneous. To avoid this problem, it is advisable to fit a device which can prevent bubbles from entering the TSG enclosure. For that purpose, placing a simple tank upstream from the TSG is enough. Experience shows that similar water jackets to those used for the TSG are tall enough and practical. An outlet at the top of the bubble trap allows the exhaust of raising air, and a low outlet supplies the TSG water jacket with water free of bubbles.

TSG (right) and bubble trap (left) water jackets

We compared salinity measurements taken before and after installing a bubble trap. Results prove that the advantages brought by the trap are obvious, as shown in Appendix 4.

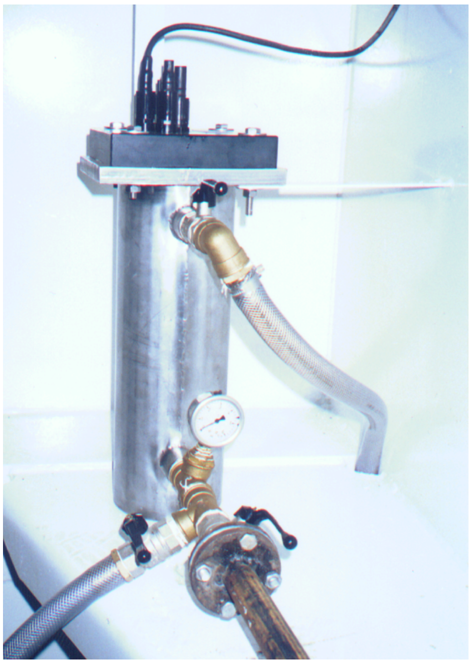
Technical specifications of the TSG and bubble trap jackets are shown on the following figure :



Schematic diagram of the TSG water jacket and/or bubble trap tank

- *Installation*

The TSG has to be easily accessible to allow for any intervention. Thus a clearance of 20 cm at least must be left between the jackets and the ship's bulkheads for removal of the sensor module and cleaning. The equipment has to be solidly fixed to restrain vibrations which can damage many parts. There is no universal technique : each TSG fixing depends on the facilities the ship offers. Here are some pictures of typical TSG installations using different techniques.



Examples of TSG fixings

- *Pressure gauge*

A pressure gauge can be inserted between the feed-pipe and the TSG inlet, to monitor the inflow pressure. Remember that this pressure must not exceed 3 bars.

Placing a pressure gauge after the TSG may also allow to detect possible bad circulation, characterized by an increasing pressure. Remember that maximum pressure outflow is around 0.5 bars.

- *Flowmeter*

Although our group has never actually done this, it is advisable to check the water flow when ships call. The technique consists of inserting a fresh water flowmeter in the system, which will later be thoroughly rinsed. The manufacturer indicates a minimal discharge of about 1 L/s. This value actually corresponds to the entire water renewal of the water jacket prior to a new sampling (minimum sampling intervall : 6s). Obviously, the higher the discharge, the better the temperature measurements will be (the water temperature will be less influenced by the pipe's length).

4.1.2. ***Water flow circuit***

- Inlet and outlet

Inlet and outlet sites greatly depend on the facilities the ship's salt water circuit offers in the engine room. The inlet must be located as close as possible to the cross-pipe feeding the engine cooling system. This prevents water from getting warmer and bubbles from appearing. Comparisons with CTD data have shown that differences could reach 0.2°C (Hénin and Grelet, 1996). Nevertheless, an optional remote thermometer may be installed at the hull intake. But the cost of both Seabird instrument and its installation led us to opt for the technique which consists of installing the system as near as possible to the hull intake. The ideal solution lies in connecting the pipes just downstream of the vessel's main pump.

These connections to the cooling circuit may be achieved in several ways. However, we no longer install an auxiliary pump. As a matter of fact, such a pump usually remains unrepaired by the crew when it breaks down, whereas ship's own pumps are always well kept up. Thus, after losing much data by using our own pump, we now recommend connecting the TSG just downstream of existing ship's pumps.

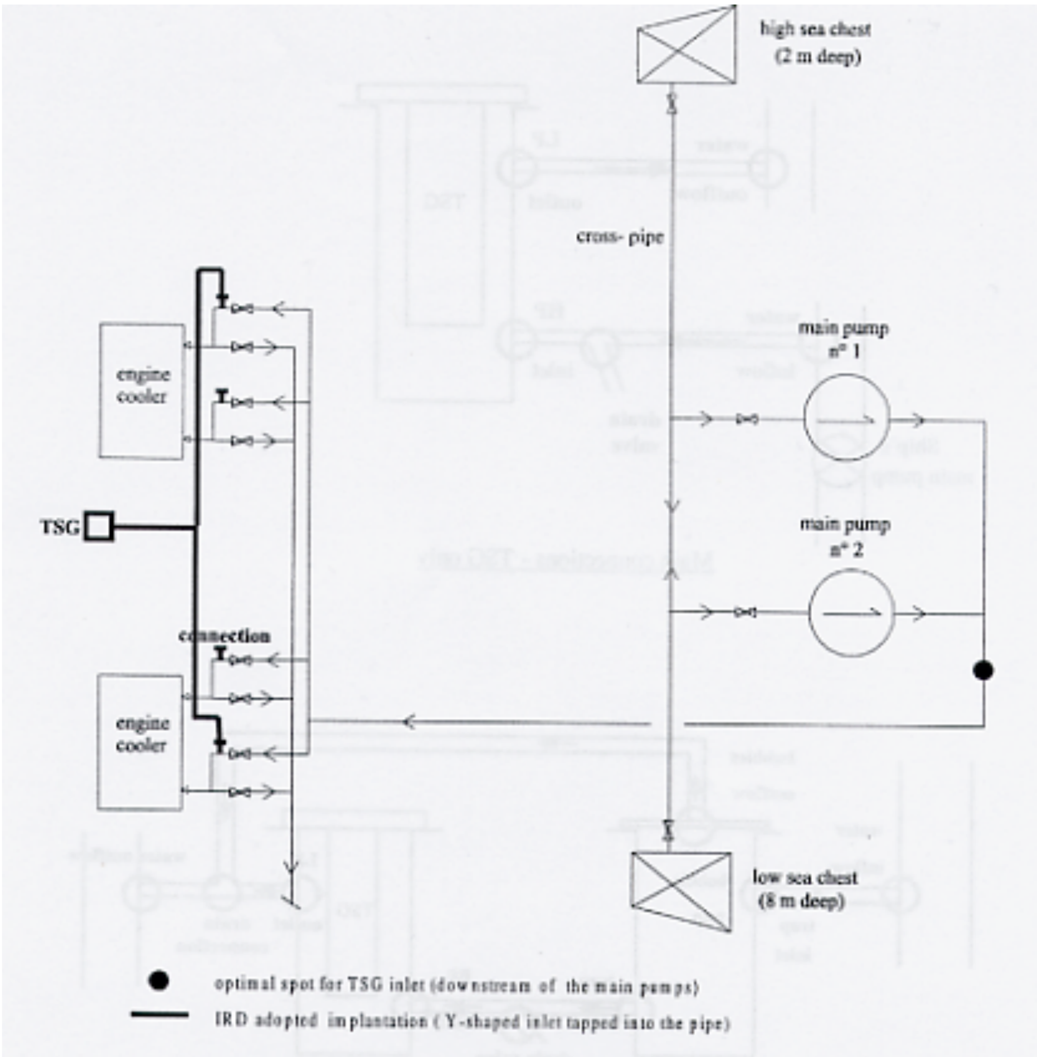
In most cases, blind outlets are already available. If they are not, a technician will have to weld and shape a connection by himself. Although crews often prove to be helpful, this latter technique is far more tedious and requires more equipment.

Connecting techniques : pre-existing blind outlet (left) and welded connections

Note that, aboard certain vessels, the water circuit is divided into two branches which are not fed simultaneously. In that case, a Y-shaped inlet must be made.

The water outlet downstream of the TSG must be connected to a low pressure main, such as the ship's waste pipes. The outlet connection is made with the same techniques as those employed for the inlet.

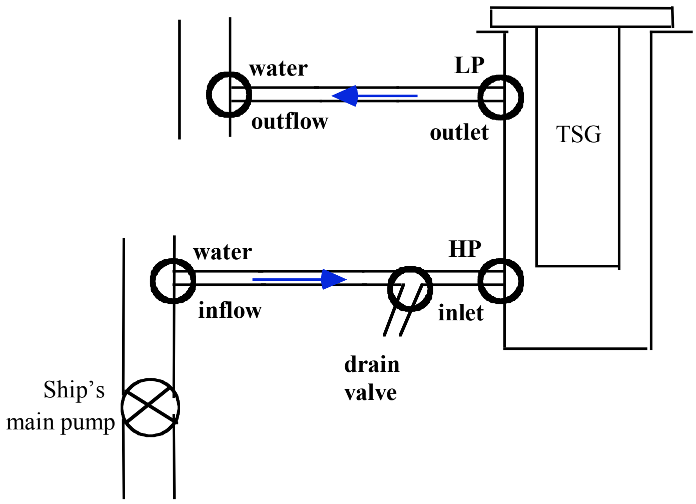
The TSG drain valve is exclusively used to clean the system or to collect water samples. Concerning water sampling, we noticed untimely manipulations of the drain valves and that such samples, which were also often poorly logged, resulted in measurements too inaccurate to test the good operation of the TSG through cross-comparisons (Hénin and Grelet; 1996).



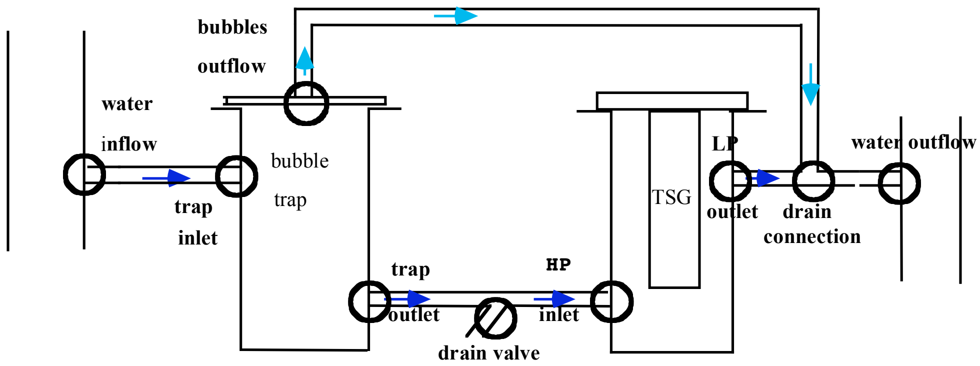
TSG implantation aboard the M/V Rome

- *Piping and connecting*

The following diagrams show out the different links and connections along the circuit surrounding the TSG, with and without bubble trap.



Main connections - TSG only



Main connections - TSG and bubble trap

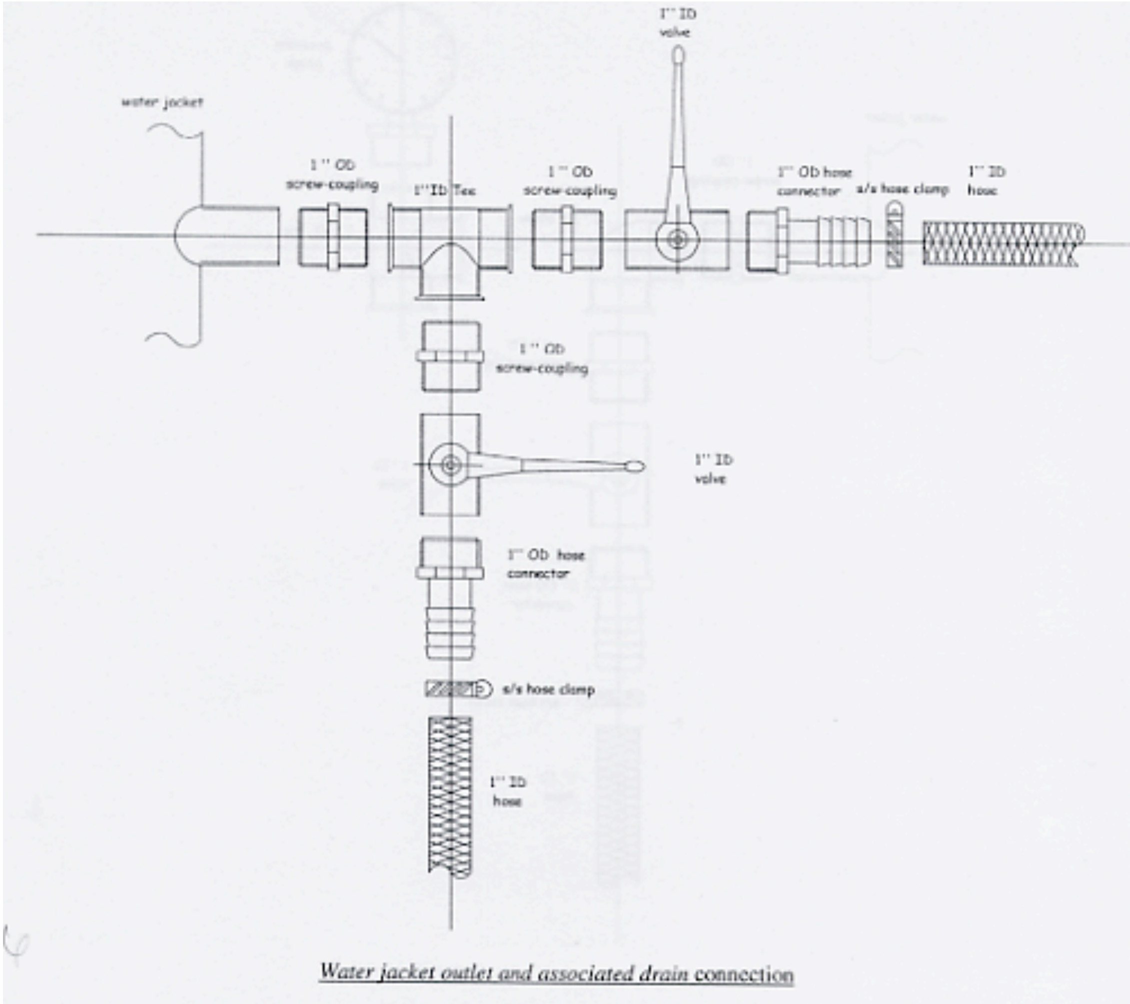
To keep the system consistent, every component of the connections are 1″ ID. We propose three main connecting methods:

- "*water jacket outlet and associated drain*" connection which includes :
  HP inlet and **drain valve** (case TSG only)
  HP inlet and **drain valve**, **LP outlet** and **drain connection** (case TSG and trap)

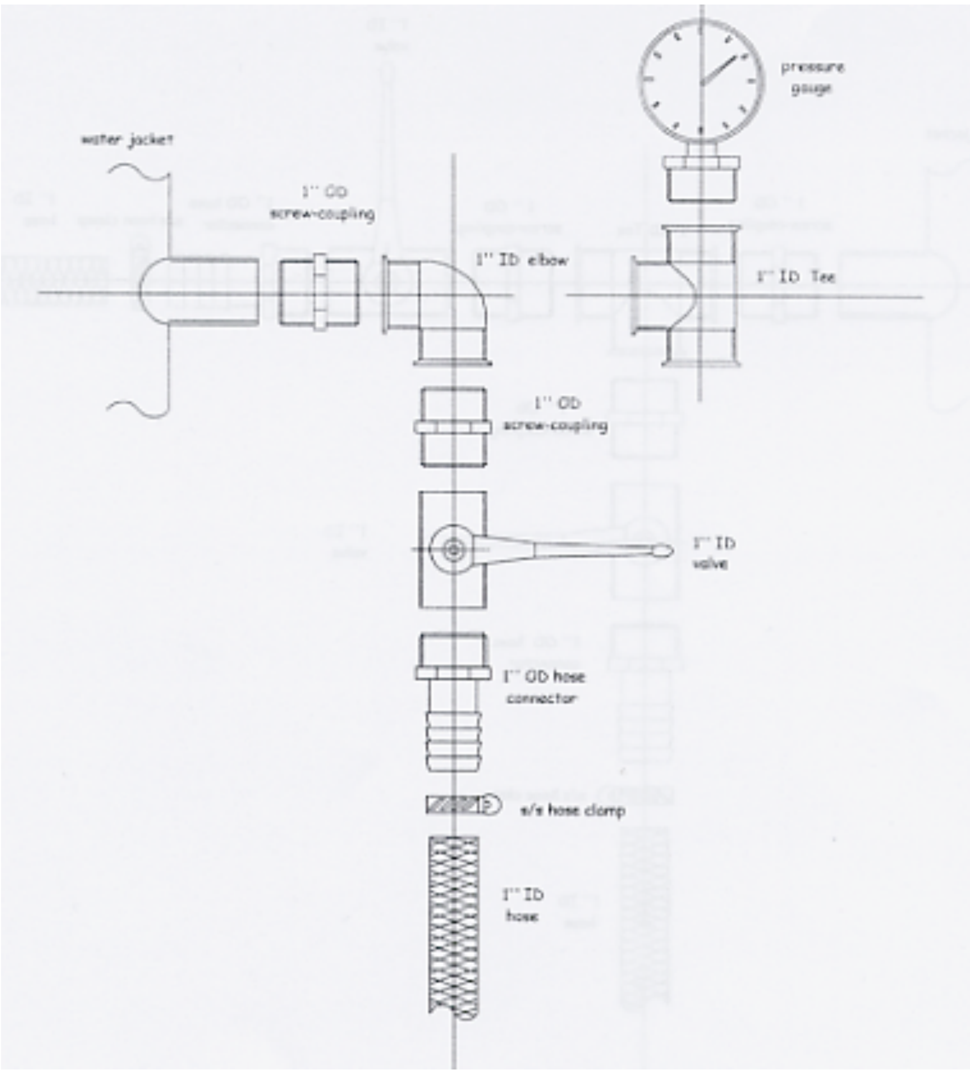
- "*water jacket outlet*" connection which includes :
  LP outlet (case TSG only)
  bubbles outflow, **trap inlet**, **trap outlet** (case TSG and trap)

- "*joining-the-ship circuit*" connection which includes :
  water inflow, **water outflow** (both cases)

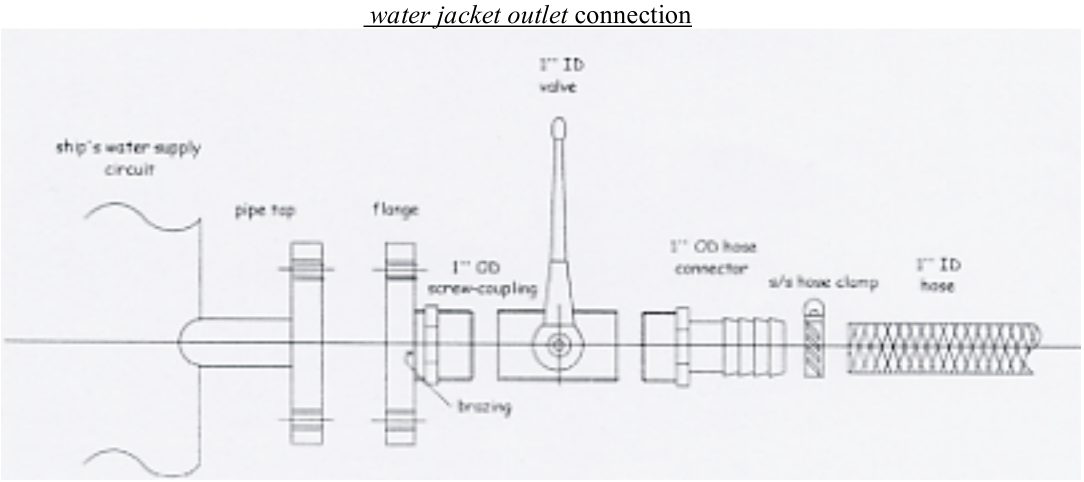
Each of these three connections are assembled in the following way :



Water jacket outlet and associated drain connection



water jacket outlet connection



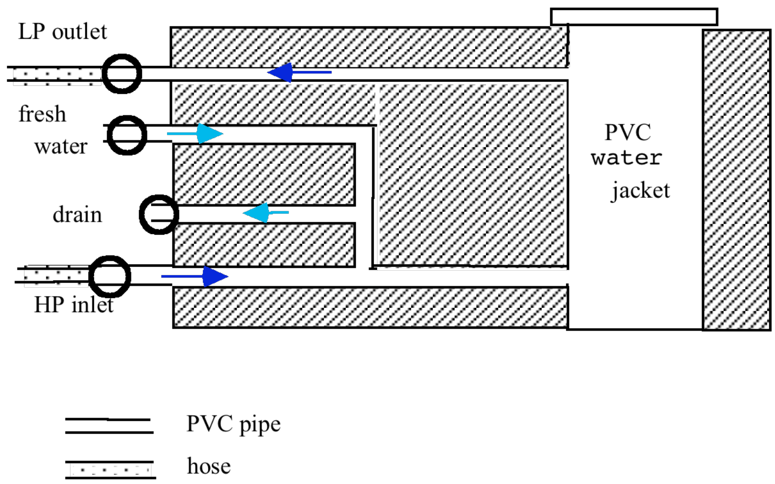
joining-the-ship circuit connection

We saw that the connection called "*joining-the-ship circuit*" could be achieved by tapping into the pipe (as shown on the associated diagram) using an existing blind tap or creating a new one. Creating a new tap consists of (*i*) making an opening in the ship's circuit, (*ii*) then welding a steel pipe on it, and weldinging a flange on the steel pipe or (*iii*) brazing a 1"OD screw-coupling on it.

Some of the components are drawn as examples; they can be omitted or replaced. Elbows can be inserted according to the path the circuit will follow. Tees can be inserted as well in order to use auxiliary instruments such as pressure gauge or flowmeter.

Water-tightness of each connection is obtained by wrapping the threads with teflon tape.

Note : use of Seabird housing



main connections - TSG only - PVC jacket and Seabird original structure

The Seabird structure is wholly consistent with the above-mentionned connecting techniques. Indeed, Seabird PVC tubes are also 1" ID, so screw-couplings are adaptable to them. Each of the four PVC outlets can be connected directly to hoses via "*water jacket inlet*"-like connections.

However, considering that fresh water access is scarce aboard, we usually close up the fresh water inlet with a 1" OD screw plug.

4.1.3. *Problems encountered and suggested solutions*

Many valves have been operated untimely during the voyages. We thus decided to post small notices asking the crew not to use them and to keep them opened.

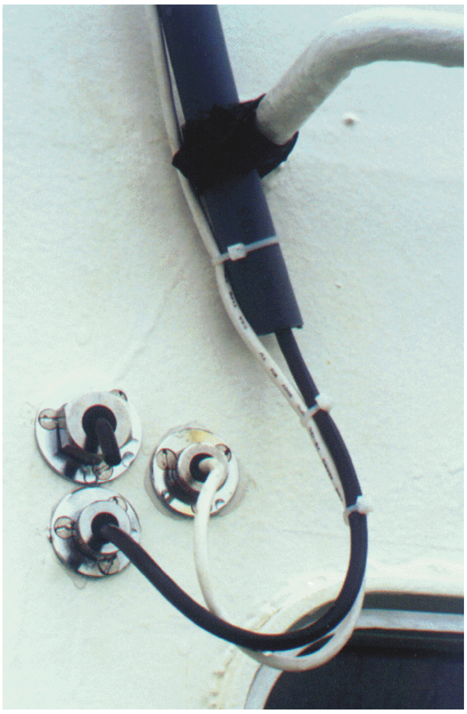
Connections between stainless steel water jackets and metallic pipes have sometimes brought about galvanic reactions which deeply corroded the jacket.

We imperatively recommend to use steel connectors instead of brass connectors to avoid any corrosion problems.

Too flexible and too small diameter hoses (3/4" ID) have been known to pinch. Hence, every hose should be of 1" ID and should withstand 15 bars pressure. Fibre-reinforced hoses seem to be the most suitable. Moreover, they do not undergo oxidation. Yet, it is advisable to replace them once a year.

4.2. Link between engine room and bridge

If there is suitable spare wiring, the TSG will have to be linked to the computer via a four shielded conductor cable which can withstand 80°C. Otherwise you will have to pull a new wire while acting upon the chief electrician's instructions.



Cable glands

Considering that each case is unique, we cannot lay down any general method for leading the cable towards the bridge. Nevertheless, we can mention a few tricks and items of advice we have already put into practice. For example, we were allowed to draw our wire through an air duct. It is also possible, and sometimes even necessary, to run it upward on the outside. In that case, you need to use a cable gland when going through the wall, and to protect the cable with an insulating sheath.

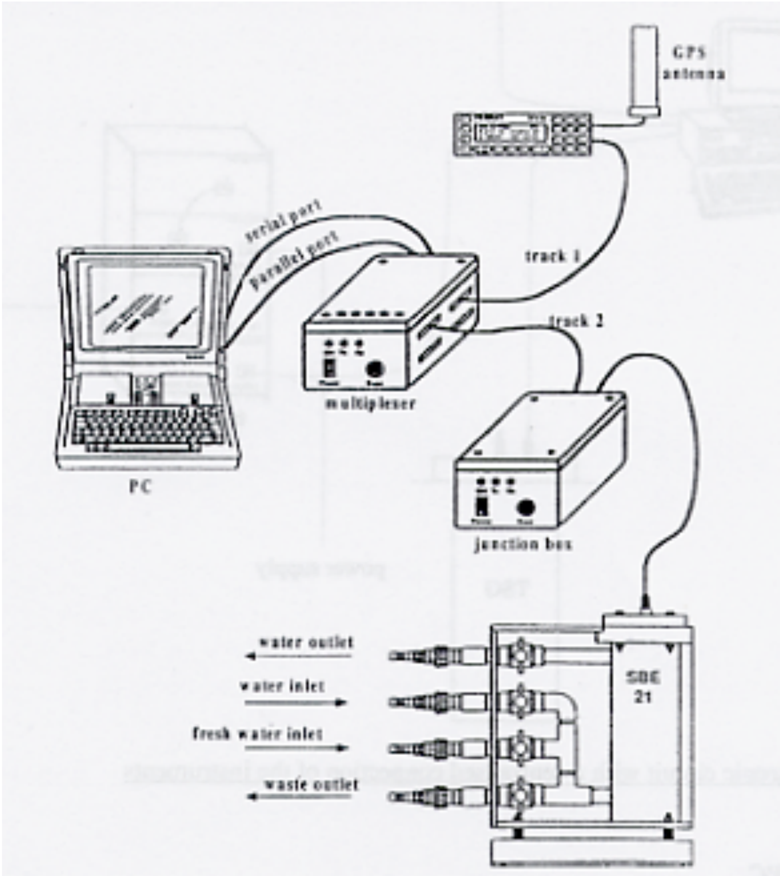
4.3. Bridge

Typically, the electronic system must allow real time data acquisition, ship position recording (GPS), and data transmission (transmitter).

An optically-isolated junction box is usually provided with the SBE-21 thermosalinograph. This box is designed to connect the TSG to the user's computer and to provide power to the TSG. However, in order to connect every instrument to the PC and to use them simultaneously, several serial interfaces are needed. Two different techniques have thus been employed in the recent years.

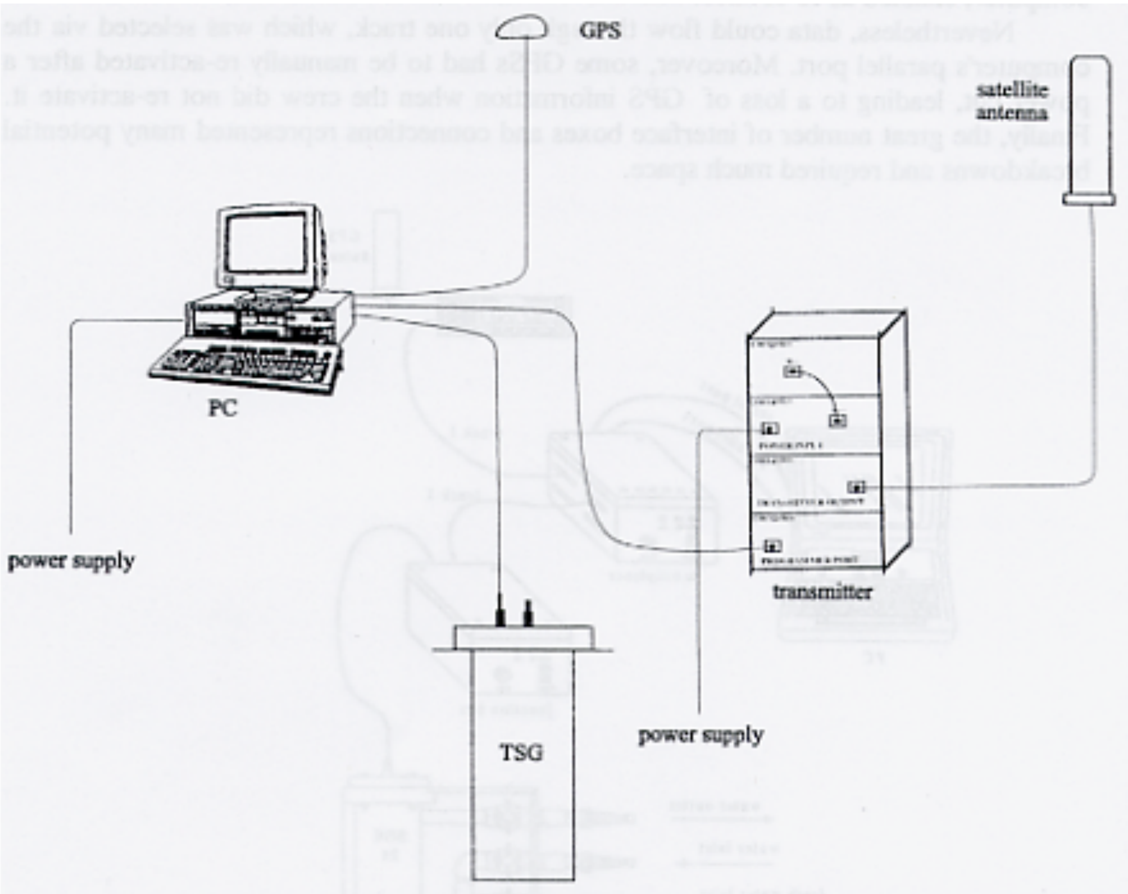
Initially, a serial tracks multiplexer, inserted between the junction box and the computer, enabled us to connect both the TSG and the GPS to the PC.

Nevertheless, data could flow through only one track, which was selected via the computer's parallel port. Moreover, some GPSs had to be manually re-activated after a power cut, leading to a loss of GPS information when the crew did not re-activate it. Finally, the great number of interface boxes and connections represented many potential breakdowns and required much space.



Electronic circuit with multiplexer

In order to avoid these drawbacks, we found another connecting method which substantially reduced the bulkiness of the system and decreased the risk of breakdown. All devices are now connected directly to the PC without any interface through duplication of the serial ports inside the computer itself. In case of a power cut, every instrument should now start again automatically. The PC provides power simultaneously to both the TSG and the GPS.



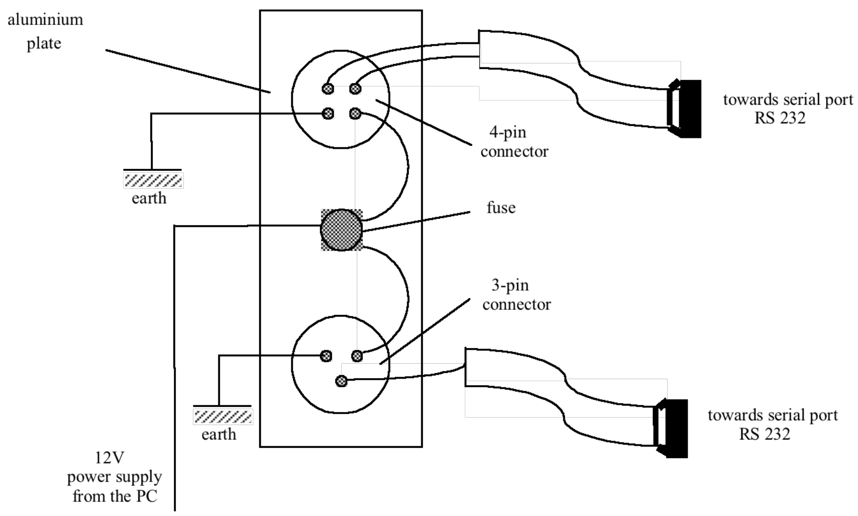
Electronic circuit with a centralised connection of the instruments

4.3.1. ***PC***

Any usual desktop without any special features is suitable. However, only two serial ports are generally available on computers for connecting optional appliances. Hence, the PC requires special modifications (i) to connect three devices (GPS, TSG and transmitter) and (ii) to supply the TSG and the GPS with power provided by the computer.

(i) An additional computer serial card provides two serial ports and one of which is dedicated to the transmitter's connection. The TSG and the GPS are then connected to the two originally available ports.

(ii) Power supply and data flow through two female connectors fixed on a small aluminium plate screwed on the back face of the desktop. Each of these connectors is linked to both a 12 V feeder pulled from the computer's power supply, and the desktop's serial port. These are 4-pin connector for the TSG (+12V, earth, interrogation, data transfer) and 3-pin connector at least for the GPS (+12V, earth, data transfer) respectively.



Connection of the TSG and GPS to the PC

There are many types of operating software. We usually use "*Thermo*" software (Grelet *et al.*, 1992, upgraded in 1998 for real-time data processing) for data sampling and converting. Data are saved in a binary data file on the hard disk ; a specific programme handles conversion into ascii mode.

4.3.2. *GPS*

We usually use the *Garmin 31* or *Garmin 36* GPS. The antenna and the receiver are wholly enclosed in a small box fixed on deck and directly connected to the PC.


GPS

Power (12V) and data are transmitted through a cable provided by the manufacturer, at the end of which a special male plug has to be fitted and adapted to the 3-pin connector.

The GPS should be fixed in a clear area where no structure may perturb signal reception (people, rigging, glass, ...). It is advisable to mount it on a short post.

4.3.3. *Transmitter*

We normally use a *Synergetics* transmitter which makes use of the GOES satellite transmission system. Its power supply is derived from the ship's mains through a cable provided by the manufacturer. The manufacturer also provides a serial cable with an appropriate plug for the PC connection and a cable for linking the satellite antenna. Thus, the installation is simple, although some cables may need extending.

5. TESTS AND INSTRUCTIONS

Prior to the ship's departure, you might test the installation and also advise the crew with concise instructions ; normally everything should run automatically. Few break-downs have occured in the past, and they were all consequences of human error.

Instructions should be delivered to the captain, but also explained to the deck and engine-room officers. As a precaution, you may post written warnings on the bridge or in the engine-room, and especially on the valves.

5.1. Engine-room

While the ship is alongside the quay, it is advisable to test water circulation and the reliability of the valves.

Ask the crew not to handle the valves (except in case of absolute necessity) ; feeding and draining circuits have to remain opened even when the ship is on port.

5.2. Bridge

The specific software "*Terminal*" has provisions for testing the electrical network.

In case of breakdown of the electrical circuit or power cut, the system is designed to start again by itself. Hence, watch-keepers do not need to intervene.

Nevertheless, ask the crew to switch on the screen from time to time, to make sure that the position is right and that temperature and salinity are realistic.

6. MONITORING DURING THE VOYAGE

First, note that analysis of the data recovered in real time by satellite will always point out a possible malfunction in the system.

Captains themselves may provide information by telex, or even e-mail.

If the ships are equipped with a sattelite transmitter, the data are available through internet and thus the operators can detect any malfunction. In that case, the operators can react quickly and even get the crew to operate. Therefore, do not forget to exchange adresses or telex numbers, before the ship's departure.

Possible partners/collaborators of the group may also undertake supervision when ships call at ports where these colleagues work. Breakdowns are usually rather minor and easy repairs can often save a whole voyage. The ideal would be to have a network of technicians belonging to various scientific institutitutions and who could operate on request.

7. MAINTENANCE DURING STOPOVERS

When the ship puts in, the operators have to proceed first to the bridge and then to the engine room. They have to bring various spares in order to solve diverse possible problems.

7.1. Bridge

7.1.1. *Operations*

We advise to run the "*Terminal*" software, included in the "*Thermo*" program, even when the system seems to be in good working order. This software allows communication with the different serial tracks and thus to test their working order.

Then it is a matter of collecting the data that have been sampled during the voyage. Although these data can be recorded in binary or ascii format (after running the conversion software) it is recommended to recover them systematically in both formats. The data files are generally recordable on floppy disks, it is however advisable to bring a compression software to perform the transfer of the larger files.

Once the data are collected, one has to configure the PC again. If the TSG is not replaced, the operation only consists of entering the name of the data file for the next voyage. Otherwise, remember to enter the calibration coefficients of the new TSG sensors.

Finally, once having checked the hard disk (with Scandisk, Norton Disk Doctor, or any other maintainance software), the operator may switch off the system and proceed to the engine room.

If any malfunction is detected, we recommend to replace the whole PC in order to examine and repair it later in the lab. Thus, it is advisable to have a spare computer at one's disposal.

7.1.2. *Tools and equipment required*

Here is a brief list of the equipment required during the calls for the maintenance of the bridge installation :

- Floppy disks
- Compression software
- Desktop PC and "*thermo*" software

7.2. Engine-room

7.2.1. *Operations*

Regular cleaning of the TSG and the bubble trap is imperative. Deposits inside the jackets and aroud the cells must be removed, otherwise water may not flow correctly and sensors may provide wrong values.Valves must remain closed while cleaning.

Water jackets and the exterior of the TSG can be easily washed with household products and utensils: detergent, sponge, pan-scraper,...

The conductivity cell requires more precautions. It is imperative to rinse it with a 1% solution of *Triton* (available from the manufacturer) through the tygon tubing supplied with the TSG, which usually contains distilled or deionized water when it is not in use. After a few minutes soak, drain it with fresh water and then fill the tube with distilled water again until the next use. Remember as well to change anti-foul cylinders.

For further details, refer to the Seacat thermosalinograph SBE 21 operating manual.

If there is any doubt or when the instrument is out of order (multiple leaks, erroneous measurements not due to fouling,...), replace the TSG by another which has been checked in the laboratory or which has been recalibrated by the manufacturer. Notice that it is advisable to have a spare TSG.

After reinstalling the system, it is advisable to spray some anti-corrosion product on the jackets and connections.

Finally, reconnect the water circuit, go to the bridge and test the network again.

Each of these operations should be repeated frequently, at least every time the vessel calls.

7.2.2. *Tools and equipment required*

Here is a list of the necessary equipment for the maintenance of the engine-room equipment during the calls :

- A tool-box
- Household ustensils and products
- A 1% solution of *Triton*
- Tygon tubing
- Anti-foul cylinders
- Anti-corrosion spray
- Spare sensor

We do not mention here the necessary plumbing fittings in case of serious damage (deeply corroded or broken parts, etc, …). Such damage is generally notified by the crew prior to the call. In such cases, one has to anticipate extra materials according to the crew indications.

7.3. Laboratory

If the call is long enough, take time to go back to the laboratory and process stored data in order to detect possible breakdown due to some misuse of the valves or to some deterioration of the conductivity cell or the temperature sensor. If necessary, or if the device has been used for more than two years, send it back to the manufacturer and have it repaired or recalibrated : successive calibrations have shown that after a period of two years, the sensor drift is most of the time negligeable and re-ajustments of the calibration coefficients do not change significantly the signal.

7.4. Aboard

Eventually, before the ship leaves, take time to go on board again in order to give oral or written instructions one more time.

Use the occasion to motivate the crew again and to make them more aware by showing the latest records or by bringing scientific articles and documents written for the general public.

8. CONCLUSION

Sea surface salinity and temperature measurements have much improved throughout the last decade. Thermosalinographs have definitely replaced the old meteorological buckets for *in situ* observations. TSGs, which are far more user-friendly, have greatly improved the quality of the measurements. Salinity and temperature data are now at least one order of magnitude more accurate than those obtained by manual sampling (0.02 instead of 0.2 in salinity; 0.002°C instead of 0.2°C in temperature). Space resolution of the measurements along shipping routes has increased more than sixtyfold and enabled us to define small scale phenomena such as salinity fronts. Automation, appended bubble traps, improved techniques and locations for TSG implantation have also enhanced the reliability of the apparatus. Moreover, TSG network has become very efficient since the beginning of satellite transmission in 1998. Data are now transmitted in real time, whereas samples were often analysed a few weeks or even a few months after being taken with buckets.

Unfortunately, the multiplicity of measurements largely depends upon the number of ships. Although our network has substantially spread out, insufficient financial support still limits the number of thermosalinograph installations.

Some technical limitations also still exist. Geometry of the sensors and their time responses prevent high density sampling. Today, the maximum sampling frequency which can be reached without data distortion is around 15 seconds for both salinity and temperature. Also, the time response of the conductivity sensor is longer than the temperature sensor's, so simultaneous data of the two parameters often match two different water masses. As a result, the salinity value, which is calculated from both temperature and conductivity measurements, can be erratic. This feature is distinguished by artificial peaks corresponding to temperature gradients. The technological limitations and the processes we study led us to opt for a 5 min time interval to record data. We have chosen to store the median values instead of the mean or the instantaneous values to reduce the effect of outliers caused by artificial peaks, which are generally less than 2.5 min long. Consequently, finding other methods that identify and remove data outliers would bring a new advance in the development of the system.

Finally, we may hope that in the near future cooperative correspondents will assist in our project and guarantee the system's upkeep, which is fundamental for the smooth operation of the equipment and thus for any future scientific advances which may derive from SSS and SST measurements.

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APPENDIX 1 : Ships equipped by the Nouméa based IRD Center

(Updated : August 1999)

Code	Company	First sail	Latest sail	In operation
Western Pacific				
Coral Islander	Kyowa	08/04/95		yes
Kyowa Cattleya	Kyowa	10/22/97		yes
Kyowa Hibiscus	Kyowa	01/04/99		yes
Pacific Islander	Kyowa	05/11/92		yes
TAS Explorer	TAS	06/27/93	07/11/95	no
TAS Mariner	TAS	11/02/90	09/25/91	no
TAS Voyager	TAS	12/11/91	12/26/92	no
Central Pacific				
Argentina Star	Blue Star Line	03/11/99		yes
Around the world				
Contship London	Contship	09/22/98		yes
Contship Rome	Contship	02/22/99		yes
Contship Washington	Contship	05/12/98		yes
CGM Rimbaud	CGM	08/21/96	01/04/98	no
CGM Ronsard	CGM	07/22/93	01/17/97	no
Providence	Marfret	10/12/97	02/08/98	no
Local				
Ferry President Yewene	SODIL	05/16/95	11/04/95	no
Lady Geraldine	CMI	11/14/95		yes
Oceanographic ships				
L'Alis	IRD	05/05/92		yes
L'Atalante	IFREMER	06/26/93		yes
Le Noroit	IFREMER	02/08/91	03/01/93	no
Le Suroit	IFREMER	12/03/89	12/27/89	no
Revictualling Terre Adélie				
L'Astrolabe	TAAF	12/05/93		yes

APPENDIX 2 : Check-list for TSG installation

Denomination	Model/Make
System	
Thermosalinograph	SBE-21
Anti-foul cylinders	SeaBird - ref. PN 24012
TSG water jacket	
Bubble trap	
GPS + cable	Garmin 31 or Garmin 36
Transmitter + antenna + cable	Synergetics
PC	Desktop
4-pin connector	SeaBird - ref. PN 17416
3 to 5-pin connector	SeaBird - ref. PN 17670
4-pin male plug	SeaBird - ref. PN 17412
3 to 5-pin male plug	SeaBird - ref. PN 17671
"*Thermo*" software	
Hardware	
1" ID valve	
1" OD screw-coupling	
1" ID Tee	
1" ID elbow	
Hose clamp	
1" OD hose connector	
Teflon tape	
1" ID hose 15 bars rated	Fiber-reinforced hose
Satellite antenna cable	
4 shielded wires cable (GPS extension cord)	
Data cable (TSG extension cord)	SeaBird - ref. PN 80438
Tools	
Complete electronics tools box	
Complete tool box	
Soldering iron	
Drill and accessories	
Hot air gun and accessories	

APPENDIX 3 : Thermosalinograph SBE-21 main specifications

Mechanical

Water jacket dimensions :	425 mm-height, 150 mm OD
Water jacket weight :	~ 10 kg
Water jacket volume :	~ 5 l
Maximal flow rate :	1 l/s
Maximal pressure inlet :	3 bars
Maximal pressure outlet :	0.5 bar

Power

Voltage :	12 V
Consumption :	80 mA , 10-15 VDC

Performance

Sample interval :	5 seconds to 18 hours
Measurement range :	-5 to + 35°C (temperature) 0 to 0,7 S/m (conductivity)
Accuracy :	0,01°C (temperature) 0,001 S/m (conductivity)
Resolution :	0,001°C (temperature) 0,0001 S/m (conductivity)
Memory :	128 Kbyte CMOS static RAM with a 2 year battery

APPENDIX 4 : Effects of the bubble trap on the salinity measurements

The bubble trap gets rid of possible micro-bubbles which distord measurements when entering the conductivity cell. By comparison, we present data derived from 2 Kyowa Cattleya's voyages recorded prior to and after the bubble trap installation, respectively. The TSG onboard since 1997 provides T and S data between New Caledonia and Japan. Figure 1 displays the route of the Kyowa Cattleya during these two courses.

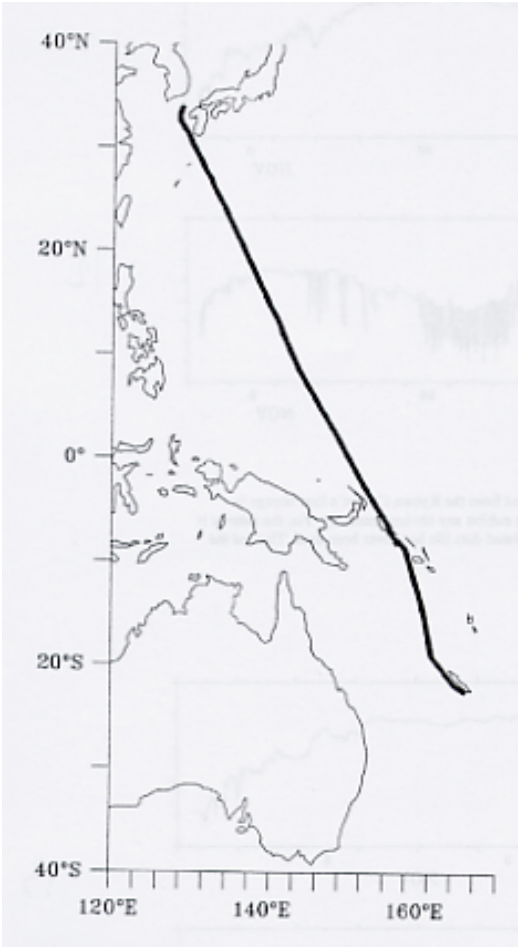

Figure 1. Main route of the Kyowa Cattleya

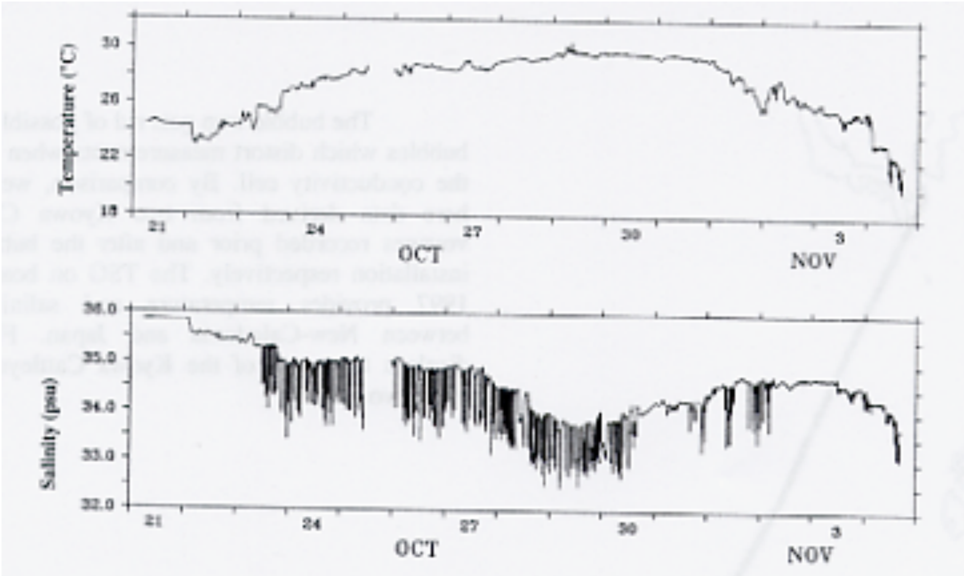

Figure 2. Temperature and salinity data derived from the Kyowa Cattleya's first voyage in October 1997. The temperature plot looks realistic ; it does not exhibit any obvious anomaly. Yet, the salinity is largely distorded by numerous atificial peaks. Thus, the associated data file has never been used. This led the Noumea group to install a bubble trap upstream of the TSG.

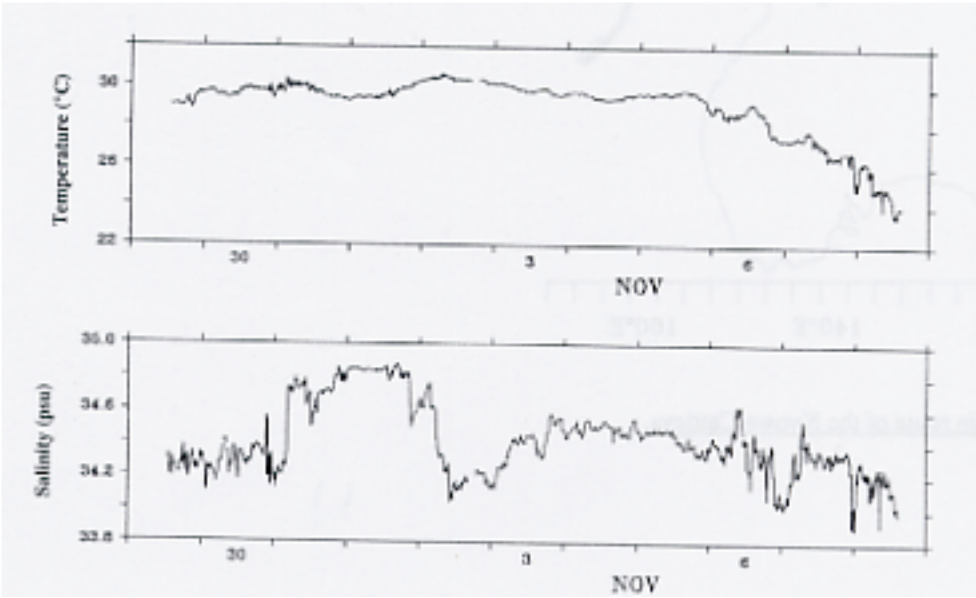

Figure 3. Temperature and salinity data derived from the Kyowa Cattleya's voyage in October 1998. The salinity has been obviously improved. The data are now plausible and useable.

APPENDIX 5 : IRD participants to TSG installations

Name	IRD Centre	e-mail
BUISSON Bruno	Bondy	buisson@bondy.ird.fr
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GALLOIS Francis	Nouméa	gallois@noumea.ird.nc
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HENIN Christian	Nouméa	henin@noumea.ird.nc
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PEIGNON Christophe	Dakar	peignon@ird.sn
VARILLON David	Nouméa	varillon@noumea.ird.nc

Addresses of the IRD centres

Centre IRD d'Abidjan
15 BP 917 - Abidjan 15
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tel. : (225) 24 37 79
fax. : (225) 24 65 04

Centre IRD de Dakar
BP 1386 - Dakar
SENEGAL
tel. : (221) 832 34 80 / 832 58 64
fax. : (221) 832 43 07

Centre IRD de Bondy - Ile de France
32, avenue Henri Varagnat
93 143 Bondy Cédex - FRANCE
tel. : (33 1) 48 02 55 00
fax. : (33 1) 48 47 30 88

Centre IRD de Nouméa
BP A5 - 98 848 Nouméa Cédex
New-Caledonia
tel. : (687) 26 10 00
fax. : (687) 26 07 92
http://noumea.ird.nc/ECOP

APPENDIX 6 : Conversions of French vs. English units

lengths

1 millimètre (mm) = 0,03937 in.	1 in. = 0,0254 mètre
1 centimètre (cm) = 0,3937 in.	1 ft. = 0,3047 mètre
1 mètre (m) = 3,280 ft.	1 yd. = 0,9143 mètre
1 kilomètre (km) = 0,6213 m.	1 m. = 1609 mètres

weights

1 gramme (g) = 0,035 oz.	1 oz. = 28,35 grammes
1 kilogramme (kg) = 2,205 lb.	1 lb. = 435,59 grammes
1 quintal (q) = 220,5 lb.	1 cwt. = 50,8 kilogrammes
1 tonne (t) = 0,984 t.	1 t. = 1016 kilogrammes

volumes

1 litre (l) = 1,76 pt.	1 gal. = 4,54 litres
1 hectolitre (hl) = 22 gal.	1 pt. = 0,567 litre
	1 qt. = 1,136 litres

temperatures

° Celsius (°C) = 5/9 (°F - 32)	°F = 9/5 (° Celsius) + 32

pressure

1 bar ≡ 10^5 N-m^{-2}

1 N-m^{-2} = 14.49 X 10^{-5} psi	1 psi = 6.9 X 10^3 N-m^{-2}