

THE PRACTICAL DIFFICULTIES OF ASSESSING THE STABILITY OF CRUISE SHIPS

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SUMMARY

There has been significant growth in the number and size of cruise ships, due to the popularity of cruising holidays, with a resulting increase in passenger numbers. This growth in passenger numbers has occurred at the same time as regulatory changes to ensure adequate margins of stability in intact and damaged conditions are provided.

However, the statutory requirements for confirming the accuracy and reliability of the lightship properties remain largely unchanged and do not reflect the increased risk presented by ever larger passenger ships.

Cruise ship operators regularly seek to improve both the appearance of and the amenities on their vessels, resulting in potential weight changes. This then results in the requirement to verify the lightship properties. It is becoming increasingly popular to perform lightship surveys when the vessel is in service, ensuring that if an inclining experiment is required, this can take place at the end of a refit. However, it is also becoming more common to undertake inclining experiments with the ship in service.

1. INTRODUCTION

It is a requirement of the International Convention for the Safety of Life at Sea, Part B, Reg. 20, that: "On completion of loading of the ship and prior to its departure, the master shall determine the ship's trim and stability and also ascertain and record that the ship is in compliance with stability criteria in relevant regulations."

To assist the ships staff in providing reliable results, the lightship data of the ship must first be determined.

In accordance with SOLAS Chapter II-1 Regulation 5 all passenger ships are to undergo lightweight surveys at 5 yearly intervals. The maximum permissible deviation from the previously approved lightship data requires an inclining experiment if the lightship weight or longitudinal centre of gravity deviated from the previously approved values by more than 2% and 1% respectively.

Burness Corlett Three Quays Ltd has been involved in inclining experiments and lightweight surveys on many different ship types. BCTQ personnel have been involved in overseeing shipyards conducting these experiments and surveys. We also regularly organise this work on vessels in service, particularly cruise ships. This results in our personnel travelling throughout the world, surveying and inclining vessels in the most unexpected locations.

Should these surveys not be performed, the authorities may rescind the passenger ship safety certificate, resulting in the vessel being unable to operate.

It is important to note that although these surveys and experiments are conducted in accordance with statutory requirements, and are regularly witnessed by appropriate class or flag surveyors, BCTQ can only request assistance from the ships staff/shipyards to enable a successful outcome to be achieved. Procedures are

submitted to the authorities for approval prior to the start of the survey and even though specific requirements are identified and agreed, these may not always be fulfilled.

2. STATUTORY REQUIREMENTS

In Annex 1 of the Intact Stability (IS) Code, clear guidance is given on how to prepare for and conduct an inclining experiment. This guidance includes a comment on the number of slack tanks that are acceptable and at what level slack tanks should be. However this is very difficult to achieve, particularly when the ship is in service. Very often, most fuel and fresh water tanks are slack, if only to achieve an acceptable trim and fluid KG. Also, on older vessels, the ships engineers are generally reluctant to press tanks full in case of potential damage to the tank structure.

3. DEFINITIONS

A few definitions applicable to all ships are required to explain the technical terms.

Deadweight is the difference between the lightship weight and the displacement of a ship at the load line corresponding to the assigned freeboard and is the weight of all consumables, stores, cargo, crew and/or passengers and effects and all other liquids on board.

Deepest subdivision load line is the waterline that corresponds to the greatest draught permitted by the subdivision requirements which are applicable.

Displacement is the overall weight of the ship i.e. the sum of the lightship weight and deadweight at the assigned freeboard.

Gross Tonnage (GT) is a measure of the total enclosed volume of a ship.

KG fluid is the vertical centre of gravity above the baseline, corrected for the effects of free surface moments.

LBP is the Length between Perpendiculars.

Lightship weight is defined as the weight of a ship complete in all respects, but without consumables, stores, cargo, crew or passengers and effects, and without any liquids on board except that machinery and piping fluids, such as lubricants and hydraulics are at operating levels.

Lightship weight survey is a detailed survey of the vessel which is undertaken to identify and record all deadweight items, thereby allowing the weight of the lightship and the position of its' longitudinal and transverse centres of gravity to be derived.

Inclining experiment is a test which is used to derive the vertical centre of gravity of the lightship.

Passenger ship is a ship that carries more than 12 passengers.

4. DATABASE

With a database of more than 30 cruise ships that includes over 120 lightweight surveys and in excess of 25 inclining experiments, BCTQ has significant experience with this type of ship. The range of sizes of these ships is also significant with the smallest having an LBP of approx. 67m, GT of approx. 2100 and the largest having an LBP of approx. 300m and GT of approx. 150,000 (see Fig. 1).

Similarly the age profile also varies significantly with the oldest vessels having being built in the 1970's. This age profile is significant in various ways. For example, the older ships, in general, tend to be smaller but have relatively large open deck spaces with superstructures constructed from steel, thereby allowing inclining weights to be used. However, suitable locations for pendulums can be difficult to arrange, resulting in pendulums and troughs having to be arranged in awkward locations such as engine casings, storerooms or even in swimming pools.

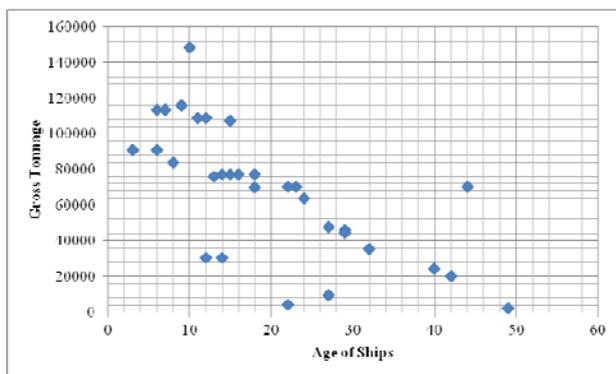


Fig. 1 Cruise Ship database

The larger, newer vessels offer different problems. The drive for larger cruise ships has resulted in most of these vessels being built with aluminium superstructures and although they have significant open deck space, the strength of these decks is, in general, not sufficient to take the load imposed by the inclining weights that are required to heel the ship sufficiently without adequate reinforcement. This reinforcement is often not practical and therefore an alternative method to heel the ship during an inclining experiment is very often required. One alternative method involves the transfer of fluids.

5. HYDROSTATIC DATA

The accuracy of any lightweight survey and inclining experiment will depend upon the available data e.g. tank calibrations and the vessels' hydrostatic properties. More modern ships are generally defined electronically, using one of a number of naval architecture software packages.

However for the older vessels, it is not unusual for the available information to be limited to tank capacity tables and even keel hydrostatic data. Worse still, hydrostatic curves on paper that is over 40 years old and which has been reprinted on numerous occasions, resulting in very suspect data.

6. LIGHTSHIP WEIGHT SURVEYS

As previously stated, lightship weight surveys are conducted at 5 yearly intervals in accordance with statutory requirements. However it is becoming quite common to conduct these surveys at more regular intervals. The reasons for this are varied and may be due to discrepancies between the calculated and observed draughts onboard caused by erroneous results from preceding surveys, unrecorded weight changes, preparatory work in advance of planned changes to the ship at forthcoming refits or the ship being sold or internally transferred.

In our experience, practically all such surveys are performed with the ship in service.

A lightweight survey can be conveniently subdivided into three categories. These are dry survey, tank survey and draught survey.

6.1 DRY SURVEY

The dry survey consists of visiting all dry compartments onboard the ship including provision and cold stores, machinery spaces, machinery workshops and stores, all deck stores, lockers, pantries and miscellaneous spaces such as AC rooms, engine casings and funnels etc. The survey is laborious and time consuming and the final outcome usually comprises only a small percentage of the total deadweight of the ship. Also during this survey any water in the ships bilges is noted and the weight

estimated. The numbers of all personnel and their effects is also recorded.

6.2 TANK SURVEY

The tank survey consists of taking tank soundings and/or gauge readings for all tanks, void spaces and cofferdams. Ideally, all voids and cofferdams should be opened and entered to ensure that any fluids in the spaces are taken into account.

6.3 DRAUGHT SURVEY

During the draught survey, the draughts are read at a minimum of six locations around the ship i.e. aft, amidships and forward, both port and starboard. Sea water density readings are also taken at a depth of half the ships draught, both forward and aft.

7. INCLINING EXPERIMENTS

Ideally, inclining experiments are performed following the completion of a refit, the survey taking place during the refit and the actual inclining experiment being performed once the ship is floated in the dry dock but prior to the ship leaving the dock. However, in the recent past, BCTQ has had to conduct these experiments during a cruise with a scheduled overnight port stay. The reasons for this are primarily financial due to dry dock work overrunning and therefore insufficient time to allow an experiment to take place without incurring significant costs, or the need to perform an experiment outside the operators refit schedule.

Inclining experiments therefore tend to take place overnight with all passengers and crew in their cabins, except for essential personnel. Therefore, the permissible time to perform the experiment is usually between 3 to 5 hours.

The inclining experiment can similarly be subdivided into a) weight transfer and b) pendulum readings.

7.1 WEIGHT TRANSFER

Weight transfer is usually either by transferring solid blocks of known weights across a measurable distance. However as discussed previously, for many modern cruise ships, this is impracticable, resulting in the need to transfer fluids from one tank to another.

7.2 PENDULUM READINGS

Generally a minimum of two pendulums are required. The pendulum lengths should be sufficient to give an average deflection of at least 15cm for each weight transfer. Although inclinometers can be used for recording the angle of heel during an inclining experiment, the difficulties in transporting this equipment anywhere in the world makes the use of this equipment

impracticable. Also ensuring the equipment is properly calibrated is extremely difficult in these circumstances.

As stated previously, pendulums can be difficult to arrange. The older vessels tend to be much smaller in size and therefore the length of pendulum is usually quite short i.e. approx. 3 to 6m. Pendulums of this length can usually be arranged in way of stairs or hatches and occasionally in machinery compartments. On more modern vessels, the positioning of pendulums is more problematic and usually results in lift shafts being used as the required length of pendulums is often between 8 and 10m (see Fig. 2 and 3). Measuring the length of the pendulums when lift shafts are used is achieved by entering the shaft when wearing appropriate safety gear.



Fig. 2 Pendulum in lift shaft, view looking upwards



Fig. 3 Pendulum in lift shaft, view looking downwards

8. TIMING OF SURVEYS AND EXPERIMENTS

The most favourable time to conduct this work is at the end of a refit period. This is when there is the smallest potential for error as in general, the quantity of fluids in tanks and food etc in provision stores is minimised, provided of course that re-storing has not yet commenced, and the least number of personnel are onboard. In some instances, the numbers of personnel can literally be kept to a minimum for the duration of the

experiment with only sufficient numbers to conduct the experiment and to ensure the safety of the ship.

Also greater accuracy can be guaranteed when reading the ships draughts and when taking water samples when the ship is in a controlled environment such as a dry dock as the effects of weather and passing river traffic will be negligible.

Similarly, the effects of these external influences on pendulum movements will also be reduced.

However, BCTQ regularly undertake lightweight surveys on cruise ships with the ship in service i.e. during a cruise. Although not ideal, reasonable results can be obtained during these periods. Although, if performing an inclining experiment with the ship in service, good results are more difficult to achieve.

The reasons for this are numerous and are identified in the following paragraphs.

9. HEELING TANK ARRANGEMENTS

In theory, water transfer should be very easy to control and monitor. If installed, sounding pipes are used to confirm the quantity of fluid in the tanks following each transfer. However, if no sounding pipes are available, sight tubes are arranged. Typically, if available, heeling tanks are used for fluid transfer as these tanks are normally a closed system with either no connection to any other system or with a connection that can be easily closed or disconnected, thereby ensuring that no fluids are added to or lost from the system during the experiment. In general, these tanks are also located on the ships side, thereby maximising the transfer lever. Sight tubes can be attached to the water sampling cock located near the bottom of the tank. The sight tubes are lengths of transparent tubing through which the water level can be seen. Secured close by are measuring tapes, thereby allowing for the depth of water to be measured following each water transfer.

As a precursor to an inclining test, BCTQ prepare and issue for comment/approval a procedure to be followed by all concerned. This procedure includes a request to the ship staff or shipyard personnel, to inspect and confirm that the heeling tanks system does not leak. In the past, we have experienced a new isolating valve being installed in the cross over pipe between the tanks to ensure that leaking did not occur.

Unfortunately all ships are different as are the arrangements of the heeling tanks. The following diagrams indicate the different arrangements we have found.

For the arrangements in Figs. 4 and 5 it is relatively easy to arrange sight tube and tape measures adjacent to the heeling tanks. Fig. 5 does present some problems

however as the sight tubes and measuring tapes must be run through a hole in the deck and in many cases crew accommodation is located adjacent to the heeling tanks and bulkhead linings etc may have to be removed. Therefore during the actual experiment, reading the depth of water in the tanks may prove to be difficult but not impossible.

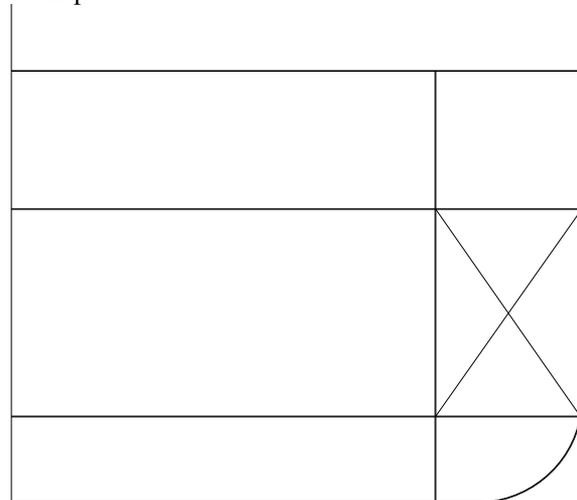


Fig. 4 Heeling tank one 'tween deck high

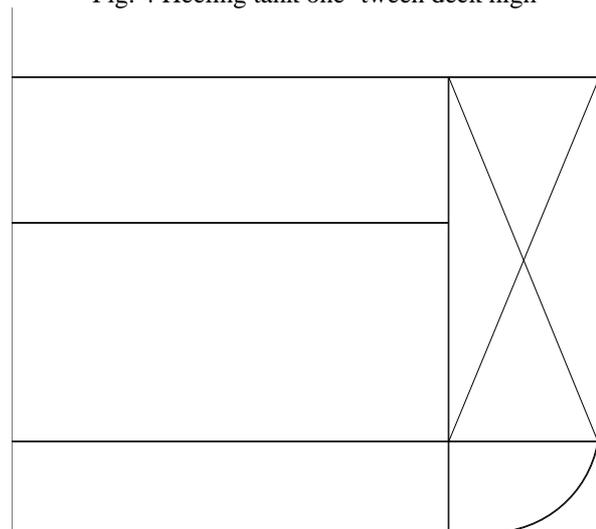


Fig. 5 Heeling tank two 'tween decks high

The arrangement in Fig. 6 is more problematic as the sight tube and measuring tape could only be fitted to the side of the tank that is above the tank top. Opening up the tank top to gain access to the part of the tank below the tank top is not acceptable to ships' staff, particularly if the experiment is taking place whilst the ship is in service.

Therefore once the water level is below the tank top, readings can only be taken from one side. However if the heeling system is a closed system, this will not give any significant problems.

The heeling tanks as shown in Fig. 7 could not be used as the fitting of sight tubes etc and access into the double bottom was not possible.

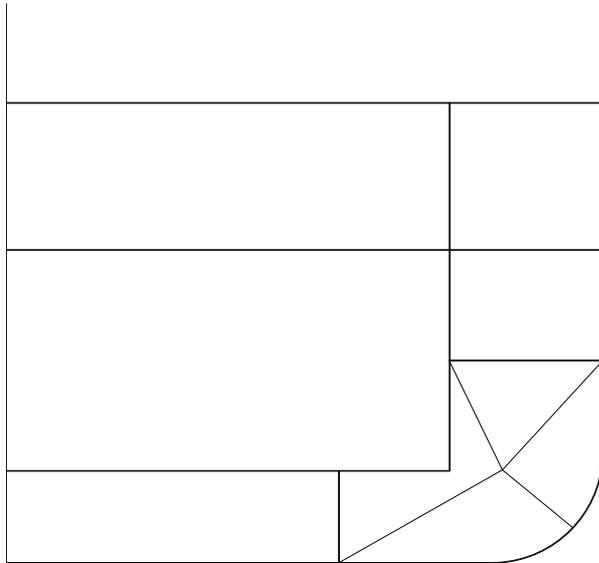


Fig. 6 "L" shaped heeling tank

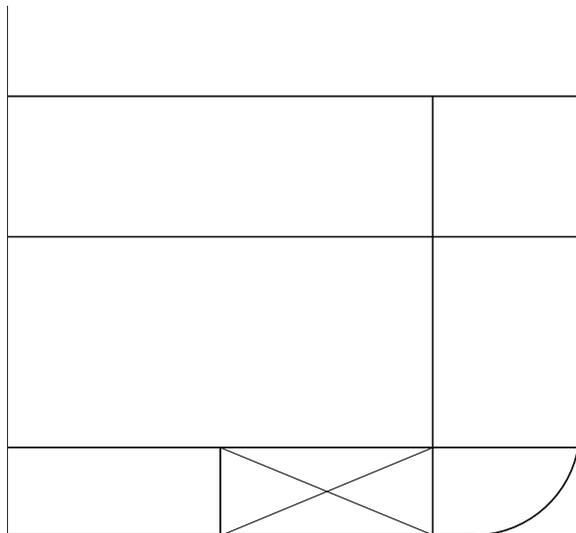


Fig. 7 Heeling tank in double bottom

10. WHAT CAN GO WRONG?

If something can go wrong, then inevitably it will. We can only try to ensure that every possible precaution is taken to mitigate all eventualities. However, the following are just a few of the problems encountered:

10.1 DRY SURVEY

Although this event should be the easiest part of the survey process, there are several potential areas of concern. During this survey, master keys are normally made available by the ships staff so that all compartments can be entered and surveyed for extraneous weights. If a ship is in service, inevitably the dry provisions and cold stores will be well stocked. The greater the quantity of provisions onboard the greater the risk in accurately estimating the weight of such provisions.

Engineering stores are more difficult to assess. The ships engineers generally have detailed lists of the stores onboard; however, these lists can be misleading as stores which have been onboard for a significant period of time will probably not be recorded. Neither will the location of the stores. Therefore great care and attention is needed to establish precisely what items are considered to be stores particularly when it is very common to find spare motors, pumps, crank shafts etc secured to flats and bulkheads in machinery spaces and not in dedicated store rooms.

Also, it is not unusual for non-standard locks e.g. padlocks, to be fitted to stores and lockers. If the owner of the keys cannot be established and contacted, any extraneous weight inside these compartments becomes part of the lightship weight. Similarly the locks of deck stores, if not properly maintained, may have to be forced in order to gain access to these stores. For whatever reason, ship's crew tend to store equipment in the most inaccessible spaces that can be found onboard. It is not always possible to find or gain access to these places. Once again, any unfound extraneous weight is added to the lightship weight.

The weight of all personnel (passengers and crew) and their effects is calculated using average weight allowances. However, if there are 2000+ passengers and 1200+ crew, the margin for error is significantly increased.

Irrespective of the above, it should be noted that even for a fully stored ship, the results from the dry survey normally only equate to between 10 and 15% of the total deadweight and therefore the effects of any errors will be relatively small.

10.2 TANK SURVEY

In the past, practically all tanks, void spaces and cofferdams (with the general exception of potable water tanks) had sounding pipes. More recently, these sounding pipes have been replaced by gauges. However unless these gauges are maintained regularly, in my opinion, this must be seen as a retrograde step.

Sounding pipes can fail inasmuch as they can be damaged, be fouled by the end of a sounding tape or they may even corrode to the extent that they are disconnected to prevent the tank contents from leaking. Therefore readings from sounding pipes can be misleading. However it is usual practice for the shipbuilder to provide sounding tables, to be held onboard. The total sounding of the pipe can be verified prior to sounding the tank contents. Therefore when a tank is sounded, the accuracy of the sounding is immediately known and appropriate adjustments to the sounding can then be made.

Gauges on the other hand, tend to be reliably unreliable. It is not unusual to have one, two or even three gauging systems on some passenger ships; one in the ECR, one on the bridge (linked to stability software) and a local gauge. It is also not unusual to have three different gauge readings for some tanks. Which gauge readings are used? Inevitably the gauge reading that has the greatest impact on the ship i.e. that which gives the lowest capacity and therefore, potentially, the lightship weight increases.

On a recent survey, BCTQ were assured that although the two gauge readings for a water ballast tank gave different results, the tank was full. The tank in question had a capacity of over 300 tonnes and although one gauge reading suggested the tank was empty, there was no way of verifying the quantity of water in the tank, other than taking off the tank lid or pressing the tank to overflow. As the survey was conducted during a cruise, the tank could not be opened and the advice of the crew had to be taken.

Empty tanks, void spaces and cofferdams, should be opened and inspected, in accordance with Annex 1 of the Intact Stability Code, 2008. However if the vessel is in service, this is not practical due to the length of time required to open the compartment, gas free, check the air quality and then close up and make watertight after the compartment has been inspected. Tanks can only be opened when the ship is in port but as the time for port visits is relatively short, between 6 and 8 hours, only one tank can be opened at any one time. Also, the crew have other duties to perform, therefore making this activity very undesirable.

As the tank survey accounts for between 85 and 90% of the total deadweight, a more accurate method of assessing the quantity of fluids in tanks must, in the opinion of the author, be established.

10.3 DRAUGHT SURVEY

The draught survey is usually carried out from a low freeboard boat, preferably not belonging to the ship. However a ship's boat is more often used with the weight of the boat and crew added to the lightship weight after the draught survey has been completed.

Draughts are read from as many locations as is possible but at least six, these being at the aft, amidships and forward draught marks, both port and starboard. If the ship is in dry dock, the accuracy of the draught readings will be much better than if the ship is in a river, alongside in a port or even at sea, as the number of outside influences, such as wind, sea state and passing river traffic, will be minimised.

Provided the sea water is flat and calm, the water level is measured from the nearest draught mark. However, the likelihood of the sea conditions being perfect is not good

and therefore the actual draughts tend to be an estimate of the mean wave height.

Sea water samples are taken at mid draught. This is to ensure that layering of sea water is discounted. Sea water can lie in layers, with different densities in each layer. This is particularly evident in rivers and estuaries, especially after heavy rainfall.

On one occasion, following the completion of the inclining experiment, the results obtained were not as anticipated. After a lengthy investigation, it was established that the aft draught marks, located on the rudder, were not in the correct vertical position due to the rudder having been raised, some years previously, to install a new steering gear. The jumping collar located between the top of the rudder and the rudder head box, had also been reduced in size but the consequences of these changes were not realised at the time.

On another occasion, we read the draughts during a slight swell. The following day the sea conditions were greatly improved and so the draught readings were repeated. The difference in displacement between the two readings was significant.



Fig. 8 Algae on draught marks.

If in service, the draught marks may not be clear or clean. It is not unusual to have to clean algae from the draught marks in order to record the draught measurements (see Fig. 8).

Due to the shape of the after hull on many cruise ships, reading the aft draught can be difficult with the boat used for the draught survey not being able to approach the marks (see Fig. 9). Perhaps an additional set of draught marks should be arranged on the stern.

In general, the boat used to read the draughts tends to be a rescue boat from the ship. However, it is not unusual to have to use a boat with much larger freeboard i.e. a ships tender or even a tugboat. This can make reading the draughts even more difficult (see Fig. 10).



Fig. 9 Aft Draught Marks



Fig. 10 High freeboard boat

10.4 WEIGHT TRANSFER

As mentioned previously the weight transfer is generally either using solid weights or fluids. If in dry dock and provided the ship structure is suitable and sufficient open deck area is available, transferring solid weights is relatively easy and accurate, the weights having previously been verified using a calibrated weighing machine. The location of the weights is also accurately measured as is the actual transfer distance.

However, if the ship is in service or if there is no suitable deck area available, then fluid transfer must be used. This may not be as accurate as transferring solid weights.

The premise for water transfer is that the quantity of fluid in the tanks can be accurately assessed. This relies upon the accuracy of the computer model being used and therefore the calculated value of the fluids in the tanks. Also, even though in general the heeling system is a closed system that is totally independent from other ships systems, any valves in the pipe connecting the two tanks must be capable of being made watertight.

Transferring fluid from one heeling tank to another is easily achieved and although it is very difficult to

achieve the same weight transfer on each occasion, fortunately it is not necessary to do so.

Water transfer is required on more modern ships, but these vessels tend to have suitable electronic models available to assist with the calculations.

10.5 PENDULUM READINGS

Once the pendulums have been arranged and the length of pendulums measured, the deflections are recorded on a strip of paper attached to a batten. When in dry dock with outside influences reduced to a minimum, good pendulum deflections are relatively easy to achieve, with the wind being the only significant factor affecting the results. However, if in a river, estuary or open seaway, the sea state, passing traffic and wind are all factors that need to be considered. Depending upon the size and sensitivity of the vessel, the number of persons onboard may also affect the results.

During an inclining experiment, the ships moorings need to be continuously observed to ensure the wind has not blown the ship against the quayside or fenders or away from the quayside, resulting in external forces on the ship caused by moorings. Therefore regular checks on wind speed, direction and status of the mooring lines are required.

10.6 GENERAL

There are other external factors that can disrupt inclining experiments, resulting in the experiment being cancelled. Most of the following have occurred at one time or other and include:

- bad weather (high winds and seas),
- lack of water due to dry weather resulting in the ship touching the river bottom,
- mechanical failures onboard the vessel with fluid transfer occurring,
- medical evacuation,
- time constraints, particularly when the ship is in service, as the experiment must be completed before the ship staff commence work.

11. CONCLUSIONS

There are several factors that can and do affect the results from inclining experiments and lightweight surveys that, in the opinion of the author, should be addressed by Owners as well as approval authorities. These include the following:

- Location of draught marks, particularly in way of the stern. Consideration should be given to draught marks on the stern of the vessel.
- All cofferdams, tanks and void spaces should have, in addition to tank gauging systems, sounding pipes or, in the case of potable water, sight tubes.
- Official inclining experiments should only be undertaken with the ship in a flooded dry dock

thereby ensuring all voids, cofferdams or tanks, where gauge readings or soundings are suspect, can be opened up and inspected.

- The number of personnel onboard the vessel should be kept to an absolute minimum.

And finally, is it time for Annex 1 of the IS Code to be reviewed and updated to also reflect ships in service?

12. AUTHORS BIOGRAPHY

David Ridden is a Principal Consultant at Burness Corlett Three Quays Ltd. He is responsible for the day-to-day running of the technical department in the London office including the supervision of all technical staff on a wide variety of projects. With over 46 years in the marine industry including 26 years employed in a U.K. shipyard and 16 years with a U.K. based maritime consultancy, he has attended and performed numerous lightweight surveys and inclining experiments on a significant number of ship types. These include cruise ships, ferries, large luxury yachts, cargo ships of many descriptions, tankers and warships.