10. SHIP'S ACCEPTANCE TRIALS

10.1. Introduction to specification and organization of ship's acceptance trials

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A few weeks before delivery, after many months of planning, procuring tons of materials, and expending thousands of man-hours involving many trades, the shipbuilding contractor is faced with one of the most critical periods of construction. For it is during this relatively short span of time that the many diverse activities associated with final testing and delivery must be systematically scheduled so all contract requirements can be completed in a timely manner. A few loose ends at this juncture can result in costly delays in delivery.

For obvious reasons, in the design of a ship's structure and its machinery systems, reliability is a primary consideration. As illustrated in Figure 10.1, in keeping with this philosophy, the testing during all stages of construction should be extensive and thorough. In addition to the owner, there are several regulatory bodies which must also witness the testing procedures and be assured that their numerous requirements are being met.

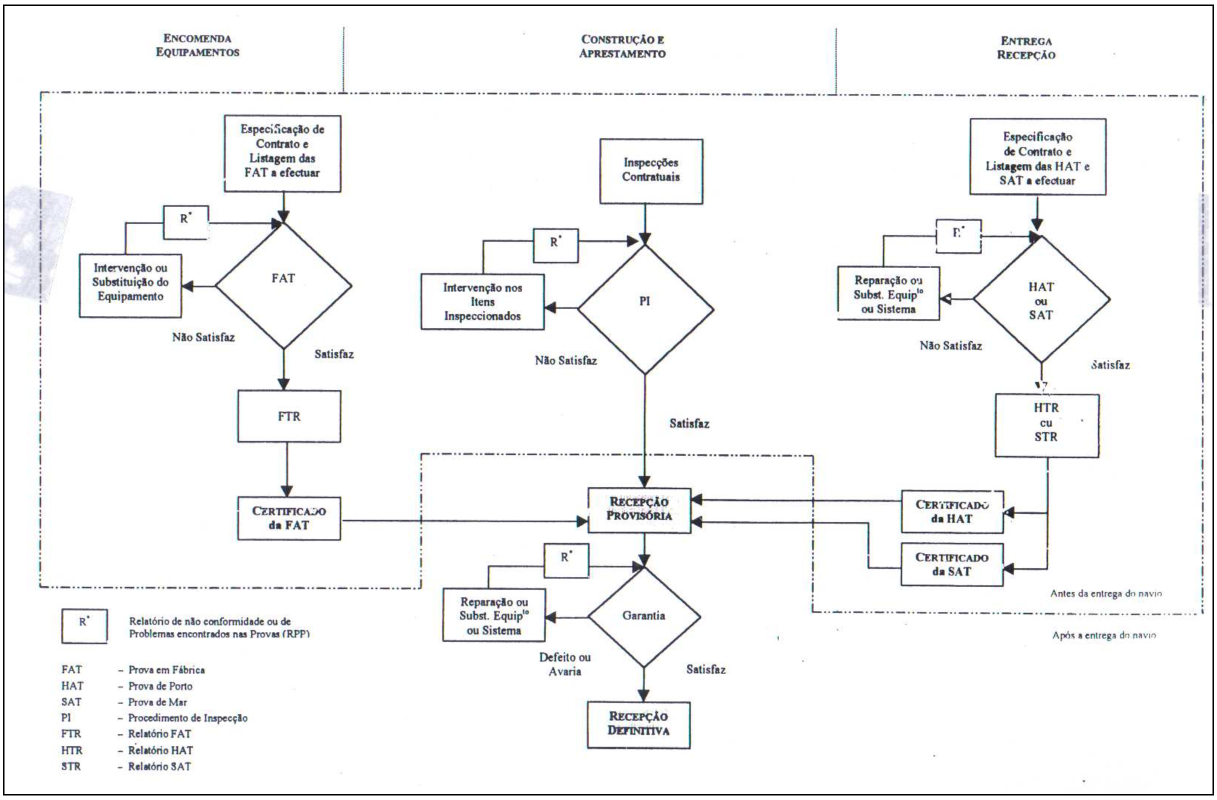

Fig. 10.1 – Flow diagram of the ship's acceptance procedure.

Dock/harbor trials, builder's trials, and sea trials are the normal media for conducting tests on major shipwide systems for merchant vessels. Dock/harbor trials are used to test major outfit systems prior to completion of the ship. Builder's trials are often conducted by the shipyard to locate and solve problems before the official sea trials are held. The sea trials involve testing of the vessel and its main systems underway. For naval ship construction, a similar series of trials is conducted. These are called builder's trials, acceptance trials, underway trials, and final contract trials. The specific items to be tested during sea trials are generally included in the shipbuilding contract.

It is intent of this chapter to discuss those activities that are associated with the delivery process and the fulfillment of guarantee obligations and to suggest procedures that have been found helpful by some shipbuilders and owners. These also contain a number of references to other material where more detailed information and instruction may be found.

10.1.2. Regulatory body requirements

All ship classification societies perform the primary service of certifying the soundness and seaworthiness of merchant ships and other marine structures. They establish standards known as Rules for the design, construction, and periodic survey of vessels. By applying these internationally accepted Rules, Classification Societies assure that ships are fitted for their intended service.

In Europe we have the following regulatory bodies:

1. International Maritime Organization (IMO) Conventions: SOLAS, MARPOL, Load Line, Standards of Training, Certification & Watchkeeping (STCW);

2. International Labor Organization (ILO) Convention: ILO147 Crew;

3. EU Directives: 94/57/EC for Classification Societies;

4. Regions of Port States MOU;

5. Flag State rectifies and transforms the statutory regimes, mentioned above into National Laws and Regulations.

Certification that the construction and tests meet the standards of each of the above regulatory bodies is a requirement for all ships built around the world. The lack of such certification is generally justification for the purchaser to refuse to accept delivery of the vessel.

10.2. Factory acceptance tests, harbor/dock trials and builder's trials

10.2.1 Factory acceptance tests (FAT)

The Society of Naval Architects and Marine Engineers (SNAME) published the "Code on Shop Installation Tests and Merchant Marine Propulsion and Auxiliary Equipment", Technical Research (T&R) Bulletin Nº 3-8, in 1960. The stated objective of this code for testing procedures is to provide the industry with a standard test procedure for machinery and thereby:

- Simplify the preparation of ship's specifications and provide a uniform basis for bids;

- Reduce the uncertainty of the manufacturer and the shipbuilder as to test obligations;

- Remove from current shop and ship test practices many items which can no longer be considered to add to the quality of the vessel.

These are essentially performance tests which are accomplished to verify individual system performance characteristics. For instance, tests are designed to determine whether a diesel or electric motor will provide the necessary output, whether the pipeline will withstand certain fluid pressures, and so on. Also, it is necessary to verify form, fit, interchangeability, product safety, and other comparable features such as environmental qualification: temperature cycling, shock and vibration, humidity, wind, salt spray, dust and sand, fungus, acoustic noise, pollution emission, explosion proofing, and electromagnetic interference.

10.2.2. Dock/harbor and builder's trials (HAT)

As the piping installations are completed, the systems are cleaned and flushed and then hydraulic tested prior to the application of lagging. The test pressures are generally 150 percent of the working pressure or 297 [kPa] for suction piping. Working pressure is the pressure at which the relief valve is set, or the highest obtainable in service, the shutoff pressure of a centrifugal pump. All equipment in the system such as heaters, coolers, strainers, etc. which are subjected to the system pressure should be tested with the system. A detailed description of the recommended pressures for testing piping systems can be found in literature.

Similarly, all electrical cable must be tested after installation for continuity of circuits and resistance of insulation.

As installations of the various machinery and electrical systems are completed, testing is carried out in accordance with test memoranda described below. A typical memorandum would include the following steps:

- Pre-test inspection of installation for proper foundation, accessibility for maintenance, and damage;

- Record cold insulation resistance of motor and controller;

- Determine actual setting values of all safety and control devices.

- Demonstrate system in all modes of control.

- Operate system at design capacity, if possible, for extended period, recording all pertinent data. Check unit for deficiencies such as vibration, overheating of bearings, and capacity.

- At conclusion run, record hot insulation resistance of motor and controller.

- Post-test inspection, including disassembly if operation suggests damage or defective parts. After all pertinent components and system tests have been completed, the main propulsion system is subjected to a low power test while the ship is restrained at the dock.

Test schedule and test memoranda are developed early in the construction stage. A test schedule is developed listing all the components and systems subjected to test. Most yards divide these tests into three groups of numerical sequences, the 100 series for mechanical and piping systems, 200 series for electric and electronic equipment, and 300 for hull tests. Table 10.1 is an abbreviated example of a test schedule which illustrates the manner used in breaking down the extensive testing program into finite and manageable increments.

Estimated dates are established for each item to provide a logical sequence of testing and to ensure that the dates for trials are and delivery can be met. This schedule is a very useful instrument for management, serving as a production gage with multiple bench marks for the determination of construction progress.

Tab. 10.1 - Example of test schedule.

Test Nº	Title	Date Scheduled / Completed
100	Piping Systems Pressure Test	
101 to 115	Engine Room Pumps & Systems	
116	Main Shafting & Gear Alignment	
117	Steam Generating Plant	
118	Forced Draft Blowers	
119	Distilling Plant & Pumps	
120	Sewage Treatment Plant	
121	A/C Refrigeration Plant	
122	Calibration of Gages & Thermometers	
123	Air Compressors & System	
124	Combustion Controls	
125 to 200	Centralized Throttle Control, etc.	
201	Ship’s Service Generator	
202	Emergency Diesel Generator	
203	Mater Calibration	
204	Circuit Breakers	
205	Transformers	
206	Insulation Resistance	
207	Lighting System	
208	Commissary Equipment	
209	Echo Depth Sounder	
210	Radio Equipment	
211 to 299	Interior Communications, etc.	
300	Hull, Tank & Compartment Testing	
301	Cargo Hatch Covers	

302	Ventilation & A/C	
303	Accommodation Ladder & Winch	
304	Life Boats & Davits	
305	Cargo Gear	
306	Hydraulic Doors	
307	Anchor Windlass	
308 to 323	Mooring Winches, etc.	

A test memorandum or procedure is prepared for the test of each component or system based on the requirements of the specifications and those of the regulatory bodies, as well incorporating the recommendations of the manufacturer and the desires of the owner. These memoranda include such information as:

- List of applicable drawings and documents;
- Basic design data of equipment or system;
- Pre-test inspection procedure;
- Detailed step-by-step procedure for conducting the test;
- Tabulation of data to be recorded together with blank data sheets;
- Post-test inspection procedure;

After approval by all concerned, these agenda should become the undisputable authority for the manner of conducting the tests.

The dock/harbor trials provide an excellent opportunity to demonstrate under safe but realistic operating conditions the performance of various mechanized control and safety devices for the auxiliary and main engine.

10.3. Sea acceptance trials (SAT): specification, planning and execution management

10.3.1. Trial objectives

A sea trial may have one or more of the following objectives depending on the position of the ship in its class, the innovative content of the design, and the need or desire of its owners.

a) Demonstration of operability

The ship propulsion and control systems can be shown to operate in their design modes only at sea, and the shipbuilder and his customer both benefit from a demonstration of proper operation which verifies the correctness of construction, manufacture, and installation.

b) Demonstration of performance

The attainment of maximum contract levels of power or speed is particularly important for the first ship of a class to verify the adequacy of the propulsion plant and its supporting auxiliaries.

c) Demonstration of endurance

Demonstration of the ability to maintain maximum power and speed for sufficient time to develop equilibrium conditions and to so operate for the prescribed period without failure of system components is important for every ship. It is assumed that ability to operate thus indefinitely or for the design life will thereby have been demonstrated, as any functional inadequacies will have been made evident by this and other trial operations.

d) Demonstration of economy

Demonstration of the contract specified fuel consumption is mandatory when there is a penalty involved or when required by the ship's specifications. Attainment of the best possible fuel consumption is important when there is a bonus involved. When neither are involved it is still required to determine fuel rate for the first of a class to verify design and for subsequent ships to verify proper operability of the energy conversion system.

e) Demonstration of controllability

Demonstration that a vessel has maneuvering qualities permitting course keeping, turning, operating at acceptably slow speeds, and stopping in a satisfactory manner is important for every ship.

f) Provision of operating data

It is desirable to establish a data baseline for a new class of ships and to a lesser degree for individual ships so that ship operators will have a standard with which to compare current operating data, enabling them to monitor plant performance.

Ship pilots as well as operators also need to know the controllability characteristics of the vessel. IMO Resolution A.601 provides comprehensive guide to providing such data in a standard format.

g) Provision of forensic data

It is increasingly important for ship operators to have available certificate data on the ship's maneuvering capabilities in the event the ship is involved in legal action for collision damage. Data from other ship systems may be pertinent to litigation involving habitability, safety or pollution responsibilities.

h) Provision of design data

All trial data augments the bank of design data on which naval architects and marine engineers draw, but special data to verify the success of an innovative feature or to advance the state of the shipbuilding art may be called for. In such cases it is important that the design authorities who will use the data specify requirements in detail, including instrumentation, operating conditions, and procedures. The IMO, for instance, is gathering data on ship maneuverability in its developing and refining of standards and has detailed specific maneuvers that are include herein.

i) Classification and safety requirements

Classification societies and safety authorities often require demonstration of equipment and systems which affect safety of the ship, its cargo or its crew.

10.3.2. Ship and environmental conditions

Proper ship environmental conditions during trials are often critical for achieving useful results.

a) Ship and environmental conditions

Trials will generally be carried out in the loaded condition where it is possible.

Contractor's Sea Trials, however, will usually be performed at other drafts. Separate trials in the ballast condition may be required. In selecting ballast drafts for oil tankers, for uniformity, consideration should be given to those specified by IMCO 1973 MARPOL for designed ballast draft capability for tankers.

In all cases, the fore and aft drafts at the time of the trial must be recorded. For ships not provided with full draft ballast capability, trial drafts will not approximate maximum design draft, and demonstration of capabilities that are draft dependent, such as ship's speed and maneuverability, are of limited value. In such cases it is advisable to specify model tests at anticipated trial drafts as well as maximum design draft, as without such tests, extrapolation of trial results depends on uncertain estimates. Trials should be conducted at drafts as close as practicable to the model tests condition. In the absence of model test data, standardization at other maximum design drafts is not recommended.

b) Water depth

The most demanding requirements for many ships are met in shallow water during coastal and port navigation. Unfortunately, this conflicts with the usual practice of performing ship trials in deep water for standardization and comparative purposes. The adequacy of a ship's capabilities in shallow water, particularly maneuvering, must be usually be inferred from its success in deep water, and from its deep water characteristics relative to other vessels.

Ships interact with the bottom, with banks, and with other vessels with an effect on ship movement. Trials should therefore always be made in deep unconfined waters where possible.

To minimize the possibility of such effect on the underway performance trial results of the ship, water depth, other than for a special trials to investigate shallow water capabilities, should always excess five times the mean draft of the ship. During speed trials additional depth is needed based on speed and vessel fullness. From DnV Nautical Safety-Additional Classes NAUT-A, NAUT-B, and NAUT-C, July 1986, the following guideline is recommended: $H = 5.0\sqrt{A_m}$ and $H \rangle 0.4V^2$, where:

$H =$ water depth [m];

$A_m =$ midship section area [m^2];

$V =$ ship's speed [m/s].

c) Wind, waves, and currents

The uncontrollable environmental conditions of wind, waves, and currents can significantly influence the results of all underway trials. The effects are also difficult to account for. Trials should thus be held in the calmest weather conditions available. Wind direction and speed should be noted at the start of each test, so that the effect can be studied and corrections applied. Local currents, wave and swell conditions and their change should also be noted.

10.3.3. List of trials and selection

Listed below are the names of tests covered in the "Guide for Sea Trials", Technical Research (T&R) Bulletin Nº 3-47, 1989, from SNAME. The recommendations associated with the names are provided to assist in developing a trials program. In addition, Portuguese preliminary standard prNP4367: "Guide for planning and carrying out sea trials" (1997) should also be addressed.

Tab. 10.2 – Recommended list of tests and trials by SNAME.

Name	Recommendation
Economy Trials	First of a class only
Endurance Trials	All ships
Astern Trial	All ships
Main Turbine Steam Rate	If elected
Boiler Overload	If elected
Centralized Propulsion Control System	All ships
Ahead Steering	All ships
Astern Steering	All ships
Auxiliary Means of Steering	All ships
Turning Circles	First of a class only
Z Maneuver	First of a class only
Initial Turning	First of a class only
Pullout	First of a class only
Direct Spiral	First of a class only
Reverse Spiral	If elected
Thruster	First of a class only
Quick Reversal from Ahead to Astern	All ships
Quick Reversal from Astern to Ahead	All ships
Low Speed Controllability Maneuvers	If elected

Slow Steaming Ability	All ships
Anchor Windlass	All ships
Distilling Plant	All ships
Miscellaneous Auxiliary Systems	If elected
Emergency Propulsion Systems	If elected
Navigation Equipment	All ships
Dynamic Positioning System	All ships
Standardization Trials	First of a class only

The following is a typical list of 20 sea trial activities for typical merchant vessels:

1. Depart shipyard
2. Ballast to trial draft
3. Adjust magnetic compass
4. Adjust radio direction finder
5. Standardization runs
6. Four-hour economy runs at normal power ahead
7. One-hour water rate test
8. One-hour boiler overload test
9. Two-hour endurance run at maximum power ahead
10. Perform turning circles
11. Perform Z maneuver
12. Perform ahead steering test, rudder hard over to hard over
13. Crash stop to full power astern, measure reach
14. One-hour endurance run at full power astern
15. Perform astern steering test, rudder hard over to hard over
16. Crash stop to full power ahead, measure reach
17. Two-hour run at a desired lower power ahead
18. Anchor test
19. Deballast

20. Return to shipyard

10.3.4. Recognition of uncertainty

Although ship designers, builders, and trial personnel may exercise the greatest diligence in pursuing their arts at their most advanced state, there is inherent in the mensuration of ship performance an unavoidable uncertainty. No measurement is perfect and shipboard conditions preclude the use of the most precise techniques. Since the major ship performance parameters involve measurement of many fluctuating quantities, each with an element of uncertainty, the cumulative effect might be considerable. By applying probability techniques to the degree of fluctuation and the inherent prevision of the instruments involved, it is possible to identify the degree of certainty with which a ship's performance can be determined. It is important that all parties to a ship construction program recognize the uncertainty of trial results and take it into consideration when establishing performance targets/bonus/penalty levels.

Knowledge of how and how much the prevision of the individual measurements affects the performance determination and the range of precision available for the instruments involved enables the trial planner to make an intelligent and economic decision on instrumentation.

10.3.5. Planning

From award of a contract until delivery of the official trial report, sea trials require planning. Trial instrumentation requirements should be incorporated into design; prearrangements may be required for obtaining and calibrating trial instruments; trial readiness checks should be included in production planning; trial data acquisition, processing, and reporting systems should be developed, installed and checked; instructions and procedures should be developed for trial operating and data crew; and these crews should be trained.

These actions have an optimum time of accomplishment beyond which there is added expense and disruption.

A prerequisite to all planning is a clear understanding as to the tests and trials to be conducted, the depth of instrumentation and the data to be reported.