Trial by Water

Sea trails can reveal everything from mild flaws and weaknesses to imminent catastrophic failures aboard any powerboat, new or used. The challenge is getting the trials done right.

Text and photographs by Steve D'Antonio

Above—*A good sea trial starts long before the lines are cast off. First, the goals must be clear. Is this run for data collection, evaluating a symptom reported by an owner or operator, or simply determining performance and reliability? Second, those involved must know and understand their respective roles, ranging from helmsman to mechanic to data recorder.*

"Negative. We don't run vessels at full throttle around here," declared the dealership's captain and lead mechanic shortly after I handed him my requested sea-trial guideline.

"Why not?" I asked, "The engine has over 200 hours on it, and it's rated by the manufacturer to operate at full throttle."

"Do you know *anything* about the melting temperatures of metals?" he retorted, his dismissive response a red herring that would prevent me from performing a thorough sea trial.

In my 25-year career in the marine industry I've performed hundreds of sea trials and learned something new with each one. I've also learned that most sea trials lack rigor and thoroughness to the point of negligence in some of the worst cases. As a result, boat owners often don't receive the benefit of the careful and knowledgeable scrutiny they pay for and need. In practical terms, a casual approach to sea trials results in a failure to identify, detail, and correct faults and flaws in the vessel's propulsion system or handling characteristics—a failure that leads to boat-owner frustration, added expense, and loss of confidence in those who

While the purpose of a sea trial is not to try to break things, neither is it to avoid breaking something. For problems to manifest themselves, vessels must be run hard, usually harder than their owners or daily operators run them.

built or serviced the boat, as well as whoever performed the sea trials.

Those who direct the trials—industry professionals, captains, mechanics, and/or surveyors often overseen by brokers or builders in the case of new and used boat sales—may not understand the goals, or are misinformed, improperly trained for the task, in too much of a hurry, or simply unwilling to test the vessel to ensure that all systems are operating under load and in as close to real-world conditions as possible.

So, whether you are testing a repair or a new installation, troubleshooting a reported problem, evaluating a vessel for purchase, or simply making certain all systems are working properly aboard a vessel you believe to be sound, the onus falls on you, the industry professional, to ensure that a rigorous and complete sea trial is performed.

Goals

Sea trials are carried out under a variety of circumstances. Perhaps the most common and critical is as part of a pre-purchase survey and inspection for a new or used vessel. In other cases, sea trials can help diagnose the cause of a problem such as: an unusual vibration or noise, inability to reach rated maximum rpm (or exceeding it), or excessive fuel consumption, smoke, or overheating. Also sea trials are employed: to trace a leak that occurs while under way; to test a new installation such as a depthfinder, sonar, or autopilot; after major engine or running gear repairs; and after a repower.

Pre-purchase sea trials and those carried out after a major refit or repair are likely a boat buyer's or service facility's final opportunity to determine if the vessel handles acceptably in a seaway, and to uncover any obvious or latent flaws or defects in the systems, engines, or gear when the boat is under way.

While breaking things is not the ultimate goal of a sea trial, neither is avoiding failures that might occur while testing a boat's capacities and performance within expected operating conditions. I notice a tendency in many sellers, professional captains, and mechanics to avoid running the vessel hard during trials. It's an understandable instinct among owners who treat their vessels well and among hired professionals who don't want to be responsible for a failure. However, if something fails or breaks during a sea trial whose parameters are reasonable and within the bounds of engine and vessel manufacturers' operating requirements (more on what that entails below), and providing the vessel's systems appear to be in good working order, chances are it was going to break soon anyway. When a failure occurs shortly after the buyers take possession, they will naturally feel as if they've been let down by all the professionals involved in the purchase.

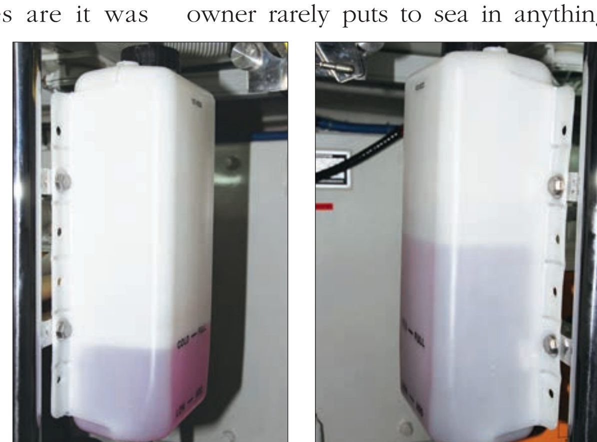
One of the primary goals of the sea trail is to determine whether all systems function normally even when run hard under challenging conditions. Among other things, mechanics should assess engines and generators for *full compliance with the manufacturer's original installation guidelines*, in new and used vessels. You should be able to assure the customer that the installations meet these important standards—compliance with which often defines the difference between a valid and invalid warranty—as well as offer a reasonable expectation of reliability.

Mechanics should also check crankcase and exhaust back-pressure, measure rpm with a stroboscopic tachometer in mechanically controlled engines, and check exhaust plumbing and gas temperature. For electronically controlled engines, mechanics should use a laptop to retrieve error codes and monitor and record operating characteristics. I've worked with many mechanics, and can't overstate the value of those who are savvy, experienced, and curious.

Preparation

Prepare for a sea trial before the vessel ever slips its lines. In addition to the required tool kit, take notepads, a laptop or tablet, etc. to record any observations you may have. A camera is also helpful, preferably one that can take still and video images.

Begin by ensuring the vessel is ready to go to sea, especially if it has been dockside for some time or if the owner rarely puts to sea in anything



Observe details as seemingly mundane as coolant recovery bottles. If the coolant fails to rise and fall from cold start-up ***(right)*** *to the engine's full operating temperature* ***(far right),*** *something is probably wrong. A level that falls below the starting mark likely indicates an internal or external leak.*

but benign conditions. Check that vases and glassware, as well as furniture, TVs, and other gear that might fall or shift, are securely stowed.

The tanks—fuel, water, and waste—should be at least half full; ideally, fuel and water should be full. Filling tanks will not only increase engine load (particularly for semi-planing vessels) but also will more likely reveal leaks. I've seen fuel tanks whose tops were so badly rusted that I could put several fingers through the hole, yet because they were not full, they didn't leak during the sea trial.

A Sea-Trial Checklist

Closely monitor and periodically photograph engine instruments throughout the sea trial, and observe the Rules of the Road.

- Start one engine, let it run for five minutes, then shut it down. Start the other engine (if there is one), let it run for five minutes, then restart the first engine.
- When it is safe to do so and in compliance with the Rules of the Road and good seamanship practices, operate the main engines while under way at 800 rpm, advancing to 1,400 rpm in 200-rpm increments, dwelling at each step for three minutes.
- Advance to 80% load in 200-rpm increments, and remain there for 60 minutes.
- Operate the main engine at 100% load for five to 10 minutes.
- At 1,200 rpm, perform four full lock-to-lock steering turns.
- Perform reverse test: While moving ahead at approximately 1,000 rpm, shift to neutral, and then with no more than a three-second delay shift to reverse *without* providing any throttle. Wait five seconds and then advance the throttle to 50%–75% for five seconds.
- Operate the get-home system (if so equipped) at 75% load for 15 minutes with the main engine turned off.

—Steve D'Antonio

At dockside, visually inspect the vessel's key systems, particularly running gear, including the engine and transmission fluids, stuffing box, gearshift, and throttle components, shaft coupling, exhaust system, and steering gear. For post-sea-trial comparison, mark the level of coolant in the recovery bottle for engine and generator. Be sure to look under engines and generators and note (photograph if possible) any accumulation of oil, coolant, or other fluids. You'll check these areas again for comparison after the trials are complete.

Ensure that engine alarms operate. Typically, this can be done by turning the keys or ignition switches to the "on" position without starting the engines. A low-oil-pressure alarm should chirp or sound continuously. If you hear nothing, the engines might be operating *without* low-oil-pressure or high-water-temperature alarms, and there will be no warning to impending overheating or catastrophic loss of oil pressure—either of which could cause rapid, irreparable damage to the engines. You may be aware of the failed alarms and think that as a professional you will be able to adequately scan instruments for telltale signs of trouble. Just a few seconds of lost oil pressure can cause potentially catastrophic engine damage. If it's on your watch, you may have to explain why you didn't first determine if the alarm was operational before getting under way.

For all sea trials, ensure that a qualified person is available to operate the boat. Mechanics and other systems specialists should not be expected to simultaneously operate the boat and carry out underway inspections of engines, running gear, steering gear, and other equipment.

Each and every system that might ever be engaged while under way should be checked. This includes main propulsion engines, as well as a wing engine. The latter should be operated to propel the boat for a minimum of 15 minutes at 75% load with the main engine and generators turned off, not just in idle. All engines should be cycled through gear positions several times to check proper operation of controls and transmissions. Additionally, perform a back-down test; more on that in a moment.

Generators should be run, while under way, to at least 50% load and preferably at or above 80%. This ensures they are capable of carrying and sustaining a heavy load and are not hindered in any way by vessel motion. In addition, they add heat to the engineroom for a more thorough, real-world test for all systems. Include in the "run list" the navigation electronics, radar, depthfinders, plotters, etc. If the sea trial is to test a specific installation or repair—a new or repaired turbocharger, heat exchanger, or running gear component—then this equipment should be singled out for close monitoring.

One important and often overlooked aspect of a sea trial is temperature monitoring, specifically the temperature of the air being drawn into the engines and generators. Don't confuse this with the temperature of the engineroom, which is important in its own right but not as easily quantifiable as the intake-air temperature. Note that the cooler an engineroom operates, the better for all the gear and equipment in it, particularly soft items such as motor mounts, hoses, insulation, and electrical components.

Most engine manufacturers specify a maximum temperature differential between the air an engine consumes and the air outside the vessel—often referred to as the delta T, or symbolized as ∇T. Typically, the maximum delta T is 30°F/17°C (and as little as 15°F/8°C in some cases); which means, on a 78°F (26°C) day, the temperature of the air entering the engine should not exceed 108°F (42°C), and less for some engines. Many engine manufacturers also specify a maximum absolute allowable temperature, often 125°F (52°C).

Ideally, and especially if you are not a dealer, you should obtain the installation and operating specification for the engine being sea-trialed. In as little as two pages, these can offer a variety of useful data, including the manufacturer's specified maximum delta T, the required area for engine combustion air-intake cross-section, the maximum rated and idle rpm, and fuel consumption curves. Such documents are available for most engines, even those no longer manufactured. Don't rely on other people to provide this information or recite it from memory; if you find fault with an installation, *you* must be able to back it up with the correct documentation.

Sea and weather conditions can

have a significant impact on how a vessel performs during a sea trial. Many boats, even those poorly found and ill maintained, will perform acceptably in glassy calm conditions. To the extent possible, a model designed for offshore passagemaking should be tested in offshore conditions, assuming it is in good repair. On many occasions I've encountered resistance from brokers upon notifying them that I expected sea trials to take place beyond protected waters. Simply put, failing to operate a vessel in conditions for which it was designed may conceal significant flaws, and could expose those who do the testing to legal and professional liability.

While displacement vessels can be run only at displacement speed, planing or semi-planing vessels can be operated at a wide range of throttle settings. Test a planing vessel at planing speeds even if the current or potential owner doesn't intend to run it at those speeds. Flaws or insipient problems often reveal themselves only when the vessel is operated under this sort of load, especially if the present owner rarely runs the boat this way.

To standardize the sea trial procedure in your firm or shop, particularly if trials are to be carried out by various staff members, prepare a written outline or checklist describing how the vessel is to be operated (see sidebar on the facing page). It's easy to be distracted or to overlook specific tasks during a sea trial; if anything is left out and a second trial is required, that work should not be considered billable time. Finally, the checklist from individual sea trials should be retained for future reference and as proof that specific parameters were met.

Sea Trial

This process cannot be rushed; it may be your only chance to thoroughly evaluate a boat and its systems or repairs. When I managed a boatyard I stressed that sea trials were an opportunity to identify problems *before* they were experienced by the boat owner, and trials were a primary means of avoiding warranty work. If a vessel left the yard and a component or system we had worked on failed, in addition to losing credibility with the customer, the resulting repairs were likely to become the yard's responsibility.

Some smoke at start-up is normal, especially for mechanically injected diesels, but persistent smoke long after the engine is warmed up can be a sign of problems in the injection or air-intake system, the turbo, or the valve guides.

A sea trial should begin with cold engines, not having been run for at least 12 hours. Begin by shutting off and disconnecting shore power. To evaluate engine start batteries there should be no charge source connected when engines are started. If the boat has twin screws, start just one engine and let it run for five or 10 minutes. Observe and note any unusual noises or abnormalities: Is the engine difficult to start? Did it require more than three seconds of cranking? Did it produce excessive smoke? Shut the engine down, and start the other engine, carrying out the same observations. Don't start other equipment such as generators, air-conditioning, or ventilation systems until you've completed engine-start-up observations.

Trials should be conducted with the boat in its typical cruising trim, which means the *engineroom hatches and doors should remain shut at all times*, except when personnel are passing through them. Given the choice, mechanics will understandably avoid working in hot, cramped spaces; setting up a laptop outside the engineroom is more comfortable than inside. However, leaving engineroom doors or hatches open invalidates a variety of testing parameters, not the least of which are air-intake temperature/ventilation, engineroom depression or vacuum, and proper operation of fixed fire-suppression systems.

The generator should not be providing power to the DC electrical system via a battery charger or inverter/charger. Doing so often masks an inoperative alternator. During the sea trial, house- and start-battery voltage should be monitored, and the output amperage of the alternator(s) should be checked as well. Because so many inverter/chargers automatically default to charge mode, when a generator is running for instance, it is imperative that all battery chargers and inverter/chargers be switched off, even if that means opening the DC disconnect switch. Aboard approximately 25% of the vessels I sea-trial, operators are so accustomed to running with the generator on all

Many enginerooms become too hot, which during a sea trial means anything hotter than the maximum induction-air temperature specified by the engine manufacturer. This symptom of inadequate ventilation is routinely ignored by boat owners and professionals.

High exhaust-system temperature often indicates that the installation fails to follow engine manufacturer recommendations for size and angle. Check this temperature throughout the rpm range; counterintuitively, many systems manifest their highest temperatures at low rpm, when less water is flowing.

Measuring engine crankcase pressure is relatively easy, and invaluable in finding internal engine faults, including worn piston rings.

the time that they aren't aware that their alternator isn't producing any charge current, and in some cases hasn't for years.

Prior to getting under way, the helmsman should monitor all engine instrumentation, especially coolant temperature and oil pressure, heed related alarms, and during the sea trail, scan instruments regularly.

Once under way, with the engines at normal operating temperature and with proper sea room, run the main engine(s) at 800 rpm for 10 minutes. At the end of this timed run, measure the temperature of all accessible exhaust-system components with an infrared pyrometer. No portion of the dry exhaust or the metallic riser for wet exhaust systems should exceed 200°F (93°C). The same holds true for

The temperature of an engineroom affects all the gear in the space. Of greatest concern is the temperature of the air as it enters the engine. To measure whether that air meets the engine manufacturer's standards, a conventional probe thermometer close to the air intake, as shown here, is most accurate. An infrared pyrometer tends to be inaccurate in this application.

the wet exhaust's rubber and fiberglass components. In their cases, anything over 150°F (65.5°C) is cause for alarm (most exhaust alarms are set to sound at approximately 165°F/74°C). Advance the rpm to 1,400 in 200-rpm increments, dwelling at each for three minutes, and repeat the exhaust-temperature test. It's worth noting that the wet portion of many exhaust systems often runs hotter (often too hot) while at lower rpm, when less water is being pumped into the system.

If all systems appear to be operating normally, go to the next phase of the sea trial by advancing the throttle in 200-rpm increments until reaching 80% load (or 80% of maximum rated rpm if the engine instrumentation does not provide load information) and holding that for 60 minutes, during which time temperature readings should be taken for the exhaust system, cooling system, and stuffing box.

On a sea trial I performed not long ago, one of the vessel's stuffing boxes overheated enough to raise a column of steam. While there's no hard-and-fast guideline for stuffing boxes, my rule of thumb is similar to that for engine air intake: a delta T of no more than 30°F (17°C) above ambient *seawater* temperature.

If the engine aboard your sea-trial vessel is capable of providing load, throttle position, and fuel-consumption information, make a note of these at

Fuel vacuum data are a window to the health of the fuel supply and filtration system. Record the vacuum at idle as well as at wide-open throttle. Even with clean filters, some systems generate measurable vacuum, which will reduce their tolerance of filter clogging.

each 200-rpm increment. During the 60-minute 80% run, periodically visit the engineroom to take pyrometer readings of the aforementioned components as well as:

• *Alternator casings.* These rarely exceed 200°F (93°C); anything over 250°F (121°C) is cause for concern. Ideally, the alternators should be supplying all the vessel's DC needs during the sea trial.

• *Coolant expansion tank* (not to be confused with the recovery bottle). The pyrometer reading should be roughly the same as the engine-temperature readout on the dash gauge, rarely above 195°F (91°C)

• *Transmission.* Most rarely exceed 160°F (71°C), but because some, such as Detroit Diesels, will run as hot as 180°F (82°C), it's best to get a spec from factory technical literature, a dealer, or the manufacturer. An overheating transmission can be a sign of worn clutch discs, a fouled cooler, or improperly adjusted controls.

• *Oil temperature.* This should be measured at the middle of the vertical side of the oil pan. Ideally at this load it will be roughly similar to coolant temperature, and as high as 220°F (104°C). Anything higher leads to increased oxidation and shorter lubricant life, while anything under about 160°F will cause varnish and sludge buildup, which in turn could eventually lead to oil starvation of bearings, rings, and valve trains.

• *Thrust bearing.* The acceptable temperature for thrust bearings depends on the manufacturer. However, for one of the more popular brands, the range for the thrust bearing itself (don't confuse this with the CV joint) is approximately 120°F to 160°F (49°C to 71°C). Anything above this often indicates poor alignment.

• *Primary-fuel-filter vacuum.*

During these tests, keep in mind that entering the engineroom of a boat under way in a seaway to take readings on hot rotating machinery is a challenge even for seasoned professionals. Wear ear and eye protection, and no loose clothing, drawstrings,

Left—*Electronic engines offer a wealth of information, provided those conducting the sea trials know how to access it. In some systems, menus are neither intuitive nor easily accessible, but familiarity with these displays is a prerequisite for recording the most relevant data. Here is the important readout showing rpm, load, and throttle position during a wide-open-throttle test.* ***Right***—*For non-electronically controlled engines, a stroboscopic tachometer should be employed to verify the accuracy of the vessel's own instrumentation.*

tassels, or ponytails, which can inadvertently be wound up in propeller shafts, belts, or pulleys; and always proceed with caution.

At the conclusion of the 60-minute 80% run, check and record the temperature at the engine air intake. If all systems are operating properly and no gear shows signs of overheating, move to the 100% throttle run. Advance the throttle to its maximum position while monitoring the tachometer. Ensure that the throttle lever on the engine, if it's mechanical, reaches its stop. The engine should reach the wide-open-throttle (WOT) rating established by the manufacturer and, ideally, slightly more. For instance, an engine rated at

2,500 rpm should attain 2,500–2,540 rpm. The slight overage allows for weight that almost certainly will be added to the boat, especially a new one, during normal operation.

An engine that fails to reach its full rated rpm fails to meet the manufacturer's installation specifications, and it's overloaded. Overloading an engine never bodes well, and in severe cases can lead to serious damage. On the other hand, mild underloading by slightly over-revving ensures the engine is operating in a safe rpm zone. But the engine should not exceed the rated rpm by too much before reaching the governed rpm. While it won't cause any damage per se, it means the engine is failing to provide the horsepower it was designed to produce. Once again, it should reach rated rpm and just slightly more.

On an *electronically* controlled engine, the instrument rpm reading is likely accurate. If the engine is *mechanically* controlled, then the rpm should be verified with a stroboscopic shop tachometer.

If, after three or four minutes the engine fails to achieve its rated rpm, it's either under (more than 100 rpm) or over (more than 50 rpm), and continuing this portion of the trial will serve no purpose. If the engine reaches the proper rpm, stay the course for five to 10 minutes while carefully monitoring instruments for signs of overheating or dropping oil pressure. At the end of this segment of the trial, return to the engineroom to take another round of temperature readings, and do so once again while the engine is idling, before returning to the dock.

If you are specifically interested in the vessel's performance and speed, be sure to conduct reciprocal runs and then average the results to eliminate the effect of tides, current, and wind.

Next, conduct a steering system test. At approximately 1,200–1,500 rpm, execute four full turns, rotating the wheel lock to lock. During this test, an experienced mechanic should be in the lazarette or "tiller flats" area monitoring rudderstocks, stops, tiller arms, tie-rod hardware, hydraulic rams, cables, and pulleys, etc. for any signs of galling, fretting, and excessive or otherwise inappropriate movement. Make certain that purpose-made clevis pins, rather than common fasteners, are installed where moving parts bear directly on them.

Counterintuitively, some manufacturers of hydraulic steering systems specify that the steering ram itself, rather than the rudder stops, limits the travel of the tiller arm. Therefore, be certain you are familiar with the system manufacturer's guidelines before carrying out this inspection and analysis.

Next, perform a back-down test. While motoring ahead at approximately 1,000 rpm, shift to neutral, wait three seconds, and then shift into reverse, but don't apply any throttle for at least 10 seconds. The engines should not stall. If they do, there may be a problem with propeller size, gear reduction, or idle adjustment. Whatever the cause, such stalling is not normal or safe.

If the engines do not stall in this test, increase throttle to approximately

50% and hold it there for three to five seconds. During this test, closely monitor motor mounts for signs of excessive movement or loose hardware.

Following the back-down test you can return to the dock, but the trial isn't over. While the engineroom may be uncomfortably warm, now is the time to inspect it again: How does it smell? Is there an odor of fuel, coolant, burning oil, exhaust, or the telltale acrid whiff of electrical or battery anomalies? Has any fluid accumulated under the engines or generators? Is there water, oil, or fuel in the bilge that wasn't there before?

Next, conduct an analysis of all vital fluids: engine and generator crankcase oil, coolant (after it has cooled), transmission fluid, and, if applicable, stabilizer hydraulic fluid. Note any leaks or consumption. When hot, the coolant-recovery-bottle level should be above the mark placed on it earlier; once cool, the level should return to its starting point.

The ultimate and perhaps the most important step in the sea trial is preparation of the written report. If a sea trial is carried out at a boat owner's or buyer's request, the report must contain appropriate details and explanation that can be easily understood by a nonprofessional. As a consultant, few things are more frustrating to me than seeing a sea-trial report provided to one of my clients that is seemingly just an unintelligible compilation of numbers. Many of these reports are of little value even to professionals.

Reports should provide vital information, including but not limited to temperature(s), rpm, load, throttle position and speed, as well as exhaust system back-pressure and crankcase pressure. Any reading considered out of the ordinary should be flagged, and the correct or preferred range or figure noted. As an expert, your opinion is essentially what a customer is paying for. Customers want to know what you are thinking and what you would do in their situation. Therefore, be sure to include an executive summary that provides a professional opinion regarding, and an interpretation of, the findings. Avoid using subjective terms like *good*, *bad*, and *fair*. What's good to you may be horrendous to a boat buyer or boat owner. Instead, explain deficiencies and problems along with a brief description of potential causes and corrective actions.

No sea trial will reveal all a boat's secrets, but a thorough one can be expected to tell what you need to know to complete an evaluation of a vessel a customer is considering buying, to troubleshoot a problem noted by a customer, or to assure the efficacy of significant repairs or refit work you've completed. PBB

About the Author: *For many years a full-service yard manager, Steve now works with boat builders and owners and others in the industry as "Steve D'Antonio Marine Consulting." He is the technical editor of* Professional BoatBuilder*, and is writing a book on marine systems, to be published by McGraw-Hill/International Marine.*