



SURFACE VEHICLE RECOMMENDED PRACTICE

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Brake Dynamometer Squeal Noise Test Procedure for Commercial Vehicles with Air Brakes

RATIONALE

Commercial vehicle (CV) manufacturers and their suppliers need a standard laboratory method to assess the propensity of the foundation brakes to generate squeal noise. The early engineering assessment for noise provides a baseline during the vehicle or brake system development process. This document allows multiple parties to speak to the same parameters when reviewing squeal noise testing and before vehicle evaluations. A systematic squeal noise test procedure supports the entire supply chain for the lifetime of the braking system.

FOREWORD

This SAE Recommended Practice relies on prior knowledge of SAE J2521, with roots in the European test procedure, known as AK Noise, for passenger cars. The AK Noise procedure uses drag mode test modules (applying the brake when the vehicle speed is constant) and deceleration braking. The squeal noise investigation at the vehicle level commonly uses brake decelerations at light input forces to evaluate the whole system NVH. This document addresses the need for a global test procedure for CV using inertia dynamometer testing methods. Several brake systems and friction material manufacturers have adapted the SAE J2521 matrix to CV brakes in the last decade.

The different noise test modules, specific to typical air-braked CV, follow the structure of SAE J2521 for drag, conditioning, backward/forwards drags, and deceleration stops. The actual procedure comprises two schedules. Schedule A includes 1127 events in 17 modules with an initial burnish, noise block, and final burnishing, followed by two noise blocks. Schedule B (optional) consists of 250 events in six modules, including a series of brake heating snubs from the TP-121D procedure, followed by one noise block. The last block helps assess the brake squeal noise after a high-temperatures.

This document establishes the minimum standard specifications regarding test setup, inertia-dynamometer characteristics, test sequence, and test report items. Deviations from or changes to this document to accommodate a specific project are feasible if discussed and agreed upon among the interested parties before commencing the actual staging and testing.

This document owes much to the previous development of SAE J2521. This prior work is gratefully acknowledged.

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1. SCOPE

This SAE Recommended Practice applies to commercial vehicles above 4540 kg of gross vehicle weight rating equipped with air brakes used under normal operating conditions. The procedure incorporates high and low-temperature test matrices, but does not fully account for the effects of the environment on brake squeal. Much research is currently underway in this area. This document defines brake squeal as a peak noise level of at least 80 dB(A) between 500 Hz and 17 kHz for air disc and drum brakes on on-road vehicles.

1.1 Purpose

This document establishes a standard method to assess the propensity of a brake assembly to generate squeal noise under various test conditions. The modules use conditions considered more relevant during the development and evaluation of the braking system.

This document defines a test matrix for air disc or drum brakes using test conditions and steps to investigate the influence of pressure, temperature, and vehicle speed on squeal noise behavior. Each matrix replicates real-world vehicle conditions to evaluate brake corner systems or components, including burnishing effects on brake squeal.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2521 Inertia Dynamometer Brake Squeal Noise Test Procedure for Vehicles without Regenerative Systems

2.1.2 VDA Publications

Available from the German Association of the Automotive Industry VDA (Verband der Automobilindustrie e.V.), Behrenstr. 35, 10117 Berlin, http://www.vda.de/en/publikationen/publikationen_downloads/.

VDA 300 Development Guideline on Quality Control of Disc Brake Linings

VDA 303 Description of Noisy Brake Applications Concerning Brake Squeal

VDA 305 Data Exchange Format Description

VDA 306 Definition of charts for the evaluation of brake noise data/Dynamometer

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 61672-1 Electroacoustics - Sound Level Meters - Part 1: Specifications

IEC 61672-2 Electroacoustics - Sound Level Meters - Part 2: Pattern Evaluation Tests

IEC 61672-3 Electroacoustics - Sound Level Meters - Part 3: Periodic Tests

3. DEFINITIONS

To facilitate the application of this SAE Recommended Practice, the following definitions apply.

3.1 BRAKE RETARDATION FORCE

Retardation torque output from the brake during a brake event divided by the tire dynamic rolling radius. Measured in Newtons (N).

3.2 GROSS AXLE WEIGHT RATING (GAWR)

Maximum axle weight indicated by the manufacturer. Measured in kilograms (kg).

3.3 BRAKING SPEED

Linear speed at the onset of brake pressure when the speed reduces during the brake application due to retardation torque and test inertia.

3.4 DRAG SPEED

Linear speed that remains constant during the brake application.

3.5 INITIAL BRAKE TEMPERATURE (IBT)

Drum or disc temperature at the start of the brake application, unless otherwise specified. Measured in degrees Celcius (°C).

Lining temperature at the start of the brake application for burnish and performance check modules. Measured in degrees Celcius (°C)

3.6 RETARDATION FORCE RATIO

Brake retardation force divided by the gross axle weight rating (-).

3.7 BRAKE-SPECIFIC TORQUE

Instantaneous torque divided by the instantaneous brake actuating pressure. For dynamic brake applications, calculate the brake-specific torque value between t_1 and t_2 per 7.1. For brake drag applications, calculate it between t_2 and t_4 per 7.2.

NOTE: The brake-specific torque depends on the type of foundation brake (s-cam, wedge, or air-disc). Nevertheless, for assessment and comparison purposes, the values and ranges are specific to the kind of brake system. When assessing results from different tests, consider other influencing parameters. Some of them include axle loading, tire size; air actuator type and size; slack adjuster type and length; system hysteresis; caliper with fixed or increasing lever ratios; drum diameter, and effective disc radius.

3.8 TIRE DYNAMIC ROLLING RADIUS; ROLLING RADIUS (R_{dyn})

Equivalent tire radius generating for a specific tire size the same rotational speed as the tire theoretical rolling circumference published by the tire manufacturer. Use the tire dynamic rolling radius to calculate the test inertia and the dynamometer rotational speed. Unless the test requestor provides, determine the rolling radius using Equation 1.

$$R_{dyn} = 1000 / [2 \times \pi \times \left(\frac{revs}{km} \right)] \quad (\text{Eq. 1})$$

where:

R_{dyn} = tire dynamic rolling radius/m

$\frac{revs}{km}$ = revolutions per kilometer published by the tire manufacturer

4. TEST EQUIPMENT

4.1 Single-ended brake inertia-dynamometer capable of performing dynamic brake applications with deceleration- or pressure-controlled brake applications. Also, capable of conducting brake drag at constant pressure and brake drag with brake pressure profiles.

4.2 Reversible motor and drive control capable of performing the brake drag applications at no less than 90% of the nominal drag speed.

NOTE: Calculate motor torque based on the highest of the two following values: (1) brake drag at base speed and 1.75 bar of brake pressure and, when available, (2) motor torque used for electric inertia simulation during dynamic brake applications.

4.3 Control system capable of performing brake applications at constant pressure, pressure profiles, or constant deceleration (torque control)

4.3.1 Pressure ramp rate of at least 20 bar/s $\pm$ 3.5 bar/s (see 8.1) and a maximum pressure of at least 7 bar.

4.3.2 Overshoot of less than 0.35 bar during dynamic brake applications.

4.3.3 During pressure profiles, average pressure control is within 0.07 bar of the target value (setpoint).

4.3.4 Deceleration control and overshoot within ± 0.06 m/s² of the target value (set point).

EXAMPLE: For a 10433 kg (23000 lbf) GAWR, 0.527 m (20.7 inches) tire radius, the deceleration control, and overshoot limit equal to 165 N·m (1460 lbf·in).

4.4 Cooling air system directed at the brake.

4.4.1 Control the airspeed so it does not blow away wear debris or create noise above the background limit of 70 dB(A) above 900 Hz. The cooling air remains on during the brake events.

NOTE 1: The 70 dB(A) limit provides sufficient separation to detect noisy brake events above 80 dB(A). Use a noise-insulating layer to mitigate noise propagation or noise intrusion from the laboratory area.

NOTE 2: Other threshold levels could be more appropriate for specific projects or test facilities. Confirm the background levels with the test requestor before commencing the test. A higher threshold is acceptable during the burnish section, which uses a higher airspeed setting.

4.4.2 Set up the inlet duct for cooling air at a reasonable distance away from the outside diameter of the disc. The proper length ensures cooling times while meeting the background noise level from 3.4.1.

4.4.3 Adjust cooling air to 11 m/s (40 km/h) measured at the duct outlet during burnish and performance verification modules and 2.8 m/s (10 km/h) for all other modules; if needed, adjust to meet the background noise level per 3.4.1. Alternatively, adjust cooling airflow to 6600 m³/h during burnish modules and 1330 m³/h for all other modules while ensuring background noise level per 3.4.1.

NOTE 1: If the above conditions cannot be achieved, define them with the test requestor and document them on the final test report.

NOTE 2: Since the cooling air setup is a critical subsystem of the inertia dynamometer, which affects test variability and duration, establish proper definitions and test conditions for the test project. Measure airflow, assess cooling rates at specific temperatures and test speeds, review cycle times, and observe overall temperature regimes during the tests to better understand the conditions and effects on squeal noise and friction behavior.

4.5 Automatic data collection system capable of recording the following channels digitally at 250 Hz minimum:

4.5.1 Brake equivalent linear speed. Measured in kilometers per hour (km/h).

4.5.2 Brake input pressure. Measured in bars.

4.5.3 Brake output torque. Measured in Newton-meters (N·m).

4.5.4 Brake-specific torque.

4.6 Automatic data collection system capable of recording the following channels at 10 Hz minimum:

4.6.1 Brake disc or drum temperature. Measured in degrees Celsius (°C).

4.6.2 Brake pad or brake shoe temperature. Measured in degrees Celsius (°C).

4.6.3 Cooling air temperature, relative or absolute humidity (when available), and airspeed (or airflow).

5. TEST FIXTURE

5.1 The default fixture uses a stub (axle-end) from the vehicle. It uses vehicle-level components (hub, hub adaptors, bearings, seals, mounting or torque plates, brake spider, air actuators, slack adjusters, s-cam shafts, bushings, and other hardware) to reproduce the wheel-end assembly.

5.2 The test fixture significantly influences the test complexity and logistics associated with the test preparation and setup and can ultimately affect the dominant frequencies observed during the test. The fixture level specified for a given project results from many factors and shall remain the same for the same project or noise investigation.

5.3 Specify for the project the method required to drive the brake and the details regarding the driver material and design:

- a. Direct connection to the dynamometer.
- b. Spool-driver in combination with a constant velocity driveshaft.
- c. Wheel center driver with a constant velocity driveshaft.

NOTE 1: The drive system and connection to the main dynamometer can significantly influence a brake's noise propensity and the dominant frequencies during the test. Document and use the same design and material for the project as a best practice to reduce test-to-test and dyno-to-dyno variability.

NOTE 2: The spool-driver design should mimic the interface and force distribution of a reference wheel design when feasible or defined by the test requestor.

5.4 Report the brake fixture level and the drive method used for a test project.

6. TEST INERTIA

Unless the test requestor provides, determine the test inertia at half the GAWR and the tire dynamic rolling radius using Equation 2.

$$I = (\text{GAWR}/2) \times R_{\text{dyn}}^2 \quad (\text{Eq. 2})$$

where:

I = test inertia (kg·m²)

7. PARTS PREPARATION AND TEST SETUP

7.1 Temperature Measurement

- 7.1.1 Unless otherwise specified by the test requestor, use new drum and brake shoe linings or new disc and brake pads for each test.
- 7.1.2 For brake discs, install a thermocouple at a depth of 1.0 mm, on the inboard face, near the centerline of the braking surface.
- 7.1.3 For brake pads, install one thermocouple at a depth of 1.0 to 1.5 mm near the center of the pad's friction surface. When testing brake pads with grooves, install the thermocouple at least 4.0 mm from the groove edge on the leading side of the pad. For inboard pads on single-piston calipers, install the thermocouple on the leading side, between 3 mm and 4 mm from the piston outside diameter near the center of the friction.
- 7.1.4 For brake drums, install a thermocouple at a depth of 1.0 mm and near the centerline of the braking surface.
- 7.1.5 For brake shoes, install a thermocouple at a depth of 1.0 mm at the center of the most heavily loaded shoe. The thermocouple shall be 38 mm from any edge or center groove of a segmented lining. Install a second thermocouple within 12 mm of the first at a depth of 1.5 mm. use it only if the first malfunctions to prevent accidental overheating due to thermocouples or wiring failures.
- 7.1.6 Use the same temperature measurement(s) and location(s) for the same project.
- 7.1.7 Document and report on the final test report when using a different control thermocouple for the test.

7.2 Microphone Location

- 7.2.1 Position the microphone in the vertical plane and perpendicular to the brake axis and pointing downwards. Locate the center of the microphone:
 - a. 100 mm outboard from the midpoint between the braking surfaces of the disc or the width of the brake shoe lining.
 - b. 800 mm above the rotating brake axis.
 - c. On the vertical plane of the disc or drum axis.
 - d. With a minimum distance to the wall enclosure (or noise-insulating layer) of at least 180 mm. See Figure 1.

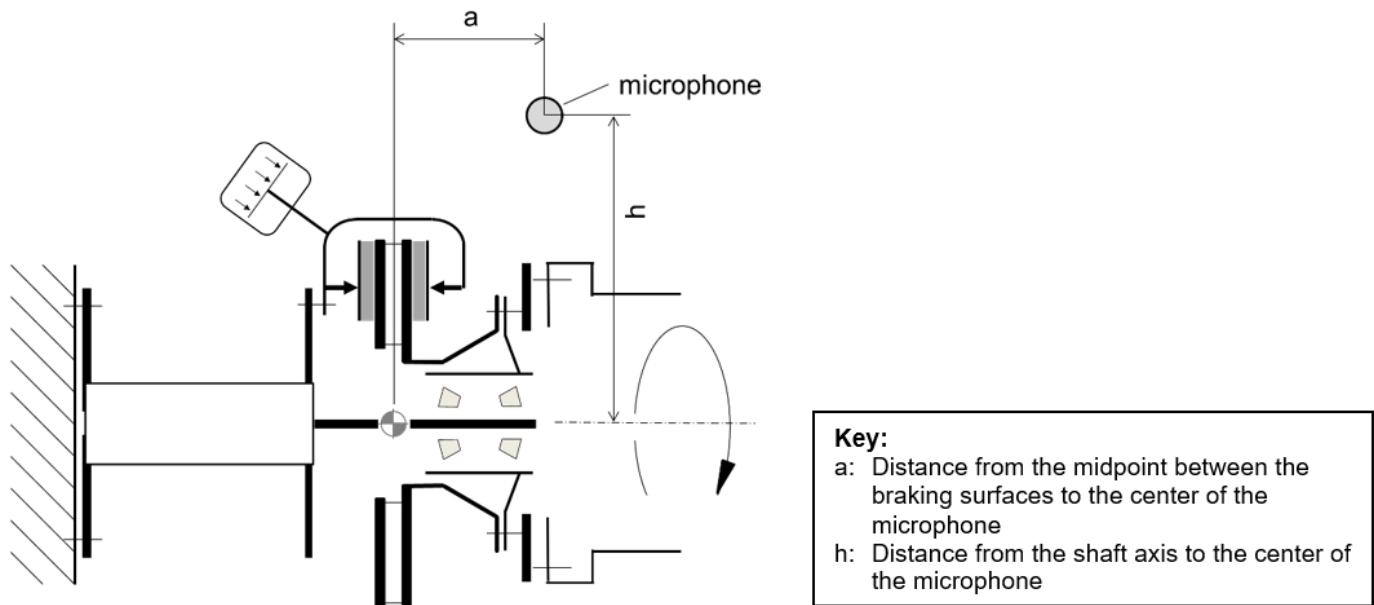


Figure 1A - Air disc brakes

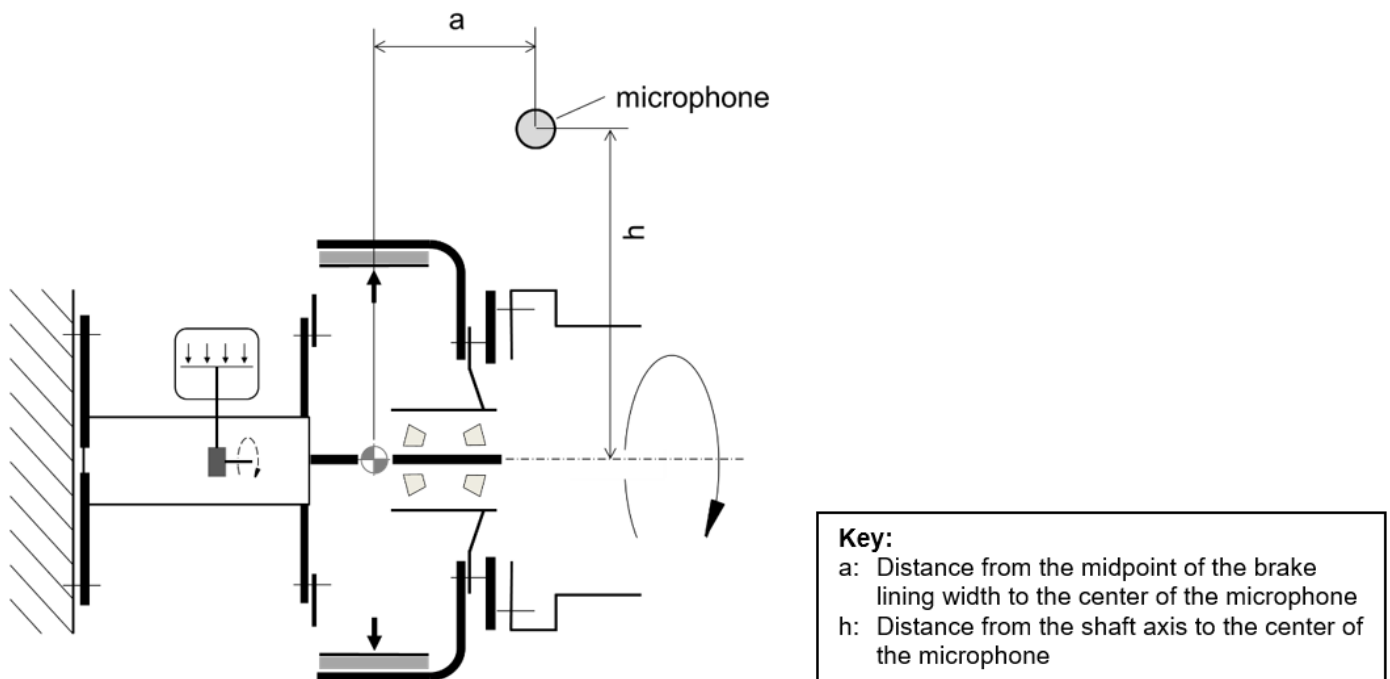


Figure 1B - Air drum brakes

Figure 1 - Microphone orientation and position relative to the brake assembly

7.3 Noise Measurements Settings

- 7.3.1 Unless otherwise specified by the test requestor, use a microphone conforming to IEC 61672-1 Class 2 or better with a corresponding windscreen.
- 7.3.2 Use a calibrator per IEC 60942 of the same microphone class at 1 kHz before and after the test.
- 7.3.3 Use a frequency analyzer or digital data acquisition system to record the sound spectrum in the time domain. The system must compute and record narrowband sound pressure spectra using the following parameters and capabilities:
 - 7.3.3.1 500 to 20000 Hz frequency bandwidth, with a frequency resolution of 25 Hz.
 - 7.3.3.2 Use peak-hold averaging with 66.7% overlap processing.
 - 7.3.3.3 Apply Hanning windowing to the time-based records.
 - 7.3.3.4 Anti-aliasing filtering.
 - 7.3.3.5 A-type signal weighting.

NOTE: Before testing, ensure the noise analyzer has the proper configuration using the A-weighting method. If not, any plausible post-test correction algorithm is beyond the scope of this document

- 7.3.4 Measure the sound pressure level (SPL) in dB(A) throughout each brake application for all sections.
- 7.3.5 Ensure the background noise level inside the test chamber with the cooling air system operating does not have peaks above 80 dB(A) above 900 Hz.
- 7.3.6 Noise measurement duration (recording) is the same as the brake application duration for all sections.
 - 7.3.6.1 From t_0 to t_4 for dynamic brake applications per 7.1.
 - 7.3.6.2 From t_0 to t_6 for brake drag applications per 7.2.
- 7.3.7 Use a noise measurement period for analysis.
 - 7.3.7.1 From t_1 to t_3 for dynamic applications per 7.1.
 - 7.3.7.2 From t_2 to t_4 for brake drag applications per 7.2.
- 7.3.8 Save microphone information as peak hold spectra, time recordings, peak-hold history at fixed intervals, or peak dB(A), and the corresponding frequency at a specified interval.
- 7.3.9 Optional—Use accelerometers to validate noisy brake events. Define the quantity, location, and data validation technique with the test requestor before commencing testing.

7.4 Fixture Setup and Inspection

- 7.4.1 Verify all interface components (hubs, torque plates, brake spiders, air actuators, slack adjusters, clevis pins, s-cams, caliper assemblies, bushings, and mounting hardware) for:
 - a. Compliance to manufacturer's specifications.
 - b. Material specifications (which may influence the frequency response of the fixture).
 - c. Wear and tear.
 - d. Surface or structural cracks.

- e. Tightening torques.
 - f. Lubrication.
 - g. Running clearance.
 - h. Surface conditions (free from corrosion, burs, or other surface defects).
- 7.5 Ensure the brake disc or drum setup meets the allowable assembled run-out and disc thickness variation determined by the manufacturer.
- 7.6 Set the diametric cage clearance to the value indicated by the test requestor, the vehicle service manual, or the brake assembly print for drum brakes. If no other information is available, set the diametric cage clearance to 0.6 to 0.8 mm, measured at the center of the brake shoe. Rotate to detect excessive residual drag and adjust if necessary.
- 7.7 Optional—Measure the natural frequency response of the brake disc.
- 7.8 Optional—Wear measurements for disc brake pads
- 7.8.1 Use an instrument with an accuracy of ± 0.01 mm for thickness measurements.
- 7.8.2 Use a weighing scale with an accuracy of ± 1 g for all mass measurements.
- 7.8.3 Measure wear on the components of the friction material. Even though this SAE Recommended Practice is not a wear test, measuring the thickness and weight of the brake pads is an important criterion to assess the test results.
- 7.8.4 Measure each brake pad for initial compressibility at an ambient temperature according to ISO 6310. If available, verify the value is within the compressibility range or specification indicated by the test requestor.
- 7.8.5 Measure the thickness of each pad before and at the end of the test. Measure the thickness at eight equally spaced positions, label 1, 2, 3, and 4 along the outer pad diameter, and label 5, 6, 7, and 8 along the inner pad diameter. Use positions 1 and 8 for the leading edge and 4 and 5 for the trailing edge. Keep a distance of 12 mm from the measurement position to any outer edge of the friction material. For measurement positions adjacent to chamfers or slots, reduce the length to 6 mm. See Figure 2.

NOTE: Using eight measuring positions allows the test technician to assess better the brake pad's propensity to develop taper wear. The latter can reduce the useful friction material thickness during a test. In addition, these eight measuring positions allow for keeping the same positions for brake pads with center slots.

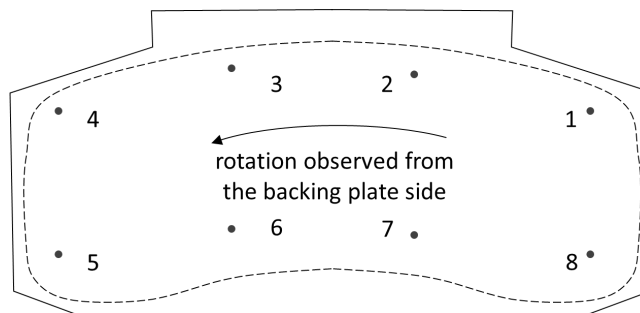


Figure 2 - Positions for brake pad thickness measurements

- 7.8.6 Measure the initial mass of each pad at the test's start and end. Vacuum and clean the parts before taking the measurement. Ensure any thermocouple wires or connectors are included (or not) during the mass measurements.
- 7.8.7 Label clearly and uniquely each pad with the corresponding test number, series number, and orientation (inboard and outboard).