

CASE STUDY

Using PULSE™ for Analysing and Improving the Sound Quality and Sound Level of Boats at Mercury Marine
by Phil May, Brüel & Kjær



For environmental and health reasons we are demanding less noise in our surroundings. Strict legislation is a major contributor in protecting us from noise pollution, and dictates what is acceptable and unacceptable, legal and illegal in terms of noise levels. But we are not only concerned with the level of sound. The quality of sound is of ever increasing importance to customers and manufacturers alike.

Mercury Marine, experienced and innovative manufacturers of Mercury outboard boat engines and MerCruiser inboard and sterndrive boat engines, realise that the quality of their products' noise is part of what attracts the customer. They, like many other manufacturers who lead their respective fields, are aware that the right sound can lead to increased sales and, in extreme cases, make or break a product.

PULSE Sound Quality

How Important is Sound?

Sound is important to both customer and manufacturer alike. For large international companies such as Mercury Marine based in Fond du Lac, Wisconsin, USA, the sound level is important, first and foremost, in terms of being able to sell worldwide according to national and international standards and according to national and international legislation. But sound quality is also important, especially for the customer. Ian House, Ph.D., Manager of NVH at Mercury Marine explains, “Just imagine for a moment the average person going into a dealer to buy a boat. The first thing he notices is how it looks. Second thing – does it start? And the third thing how does it sound?” It can therefore be of significant competitive advantage to create a product with a pleasant sound quality.

Boats and Sound Levels

“Brüel & Kjær’s PULSE Sound Quality system helps us make the boating experience more pleasant. Many people don’t want to hear the motor at all, whereas others equate a particular sound quality with a feeling of having a powerful engine, so you’re adding to the enjoyment of a day out in the boat. Customer satisfaction is what it’s all about.”

Generally speaking the sound level of a boat increases with the horsepower of the boat, this being particularly true for outboards. For stern-drives and inboards the installation in the boat is very significant, as is the exhaust treatment. If an engine is poorly installed, or if the exhaust treatment is insufficient, then the sound level is dramatically higher than that of a comparable engine correctly installed and with good exhaust treatments. There is also the question of exposure. A large engine may indeed be louder than a small engine, but usually the noise fades away quicker. On the other hand, a small boat that doesn’t plane might be quieter but the sound might linger for up to four times as long. However, it’s not just a question of sound level – sound quality comes in. A lot of complaints involve personal watercraft. Personal watercraft are not significantly louder than the average outboard but the sound level is more likely to fluctuate, and they are more likely to be in one area for a longer period of time. That can annoy people on the shoreline.

Shoreline residents and the personal watercraft issue have been a major factor in increasing the interest in boat noise. Shoreline residents often form Lake Committees and demand or initiate boating restrictions such as banning all boating, banning a particular type of boating (for example, personal watercraft or jet skis), limiting the noise levels allowed on the lake, getting rid of high performance boats, or banning all powered boats on certain days. In some places Sunday is a sailing only day.

Boats and Sound Quality

Sound quality isn’t always related to the quietest engine. Mike Freund, Engineer at Mercury Marine says, “We’ve been approached by people who prefer the sound of one engine compared to another, even though that particular engine has a higher sound level. It has much to do with the feeling of power and we, as manufacturers, have to balance that with trying to produce a sound that does not annoy shoreline residents.”

Customers are also very heedful of unusual ticking, whining or whistling sounds that may signify a faulty engine. The sounds might not be significant as far as the mechanics of the engine are concerned, but if something sounds wrong or strange to the customer's ear, then the product will undoubtedly be returned for investigation, fault or no fault. For Mercury Marine and other manufacturers this could have an impact on warranty costs, as every complaint has to be investigated thoroughly.

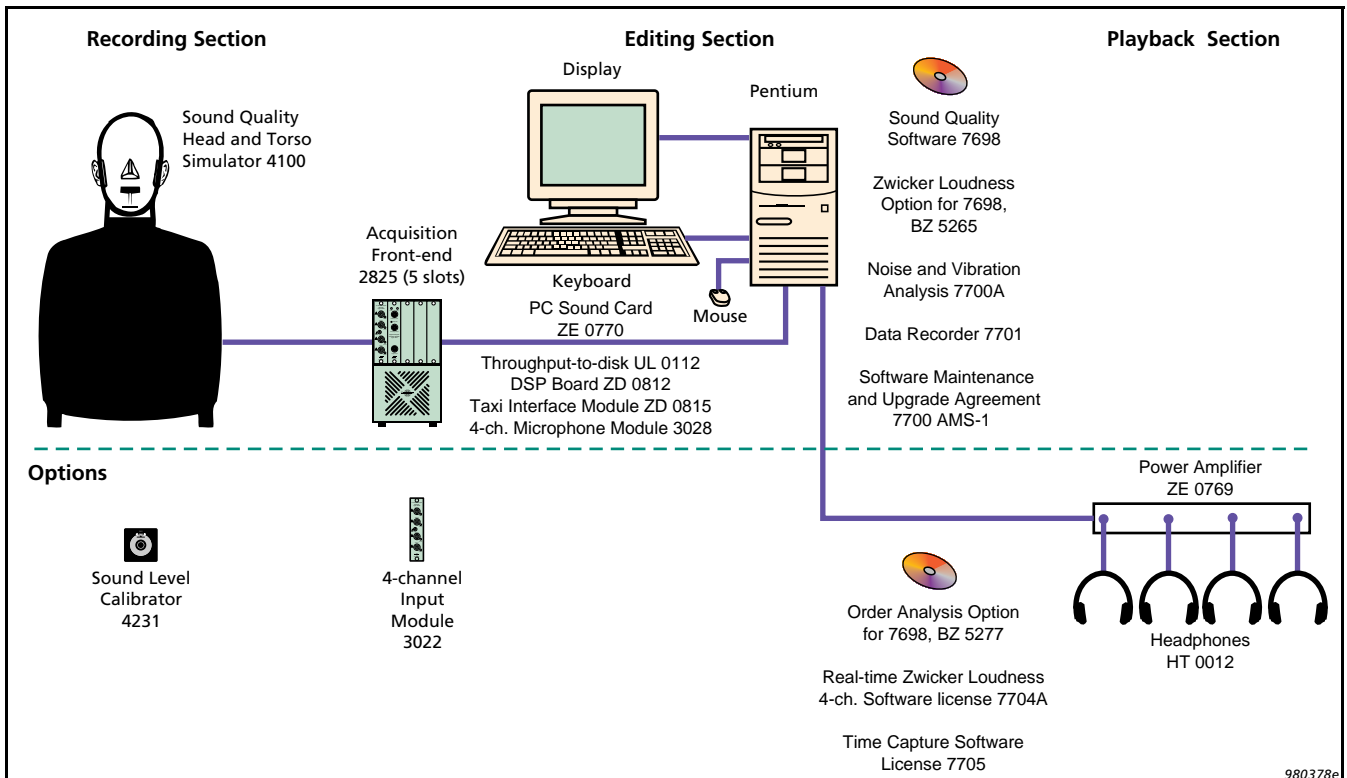
Dealing with Sound

To try and keep the customer complaints to a minimum, Mercury Marine implements stringent production line testing prior to boxing the engines. Each and every engine is run in a test cell and can be rejected on the basis of sound. The testers' trained ears and years of experience usually ensure that any strange sound is detected before the product leaves the factory. Rejected engines are returned to production, the noises investigated and an effort made to improve or rectify the sound quality.

In light of the above, Mercury Marine had two main reasons for investing in the PULSE Sound Quality system. The first involves the task of improving the sound quality of all Mercury Marine products. In this way customer satisfaction can be enhanced. Mercury Marine is committed to total customer satisfaction, and noise control and sound quality have been identified as two of the key parameters that enhance the boating experience. The second reason concerns the elimination of annoying sounds, even if they do not correlate with actual mechanical problems, since they too can have a dramatic impact on customer satisfaction.

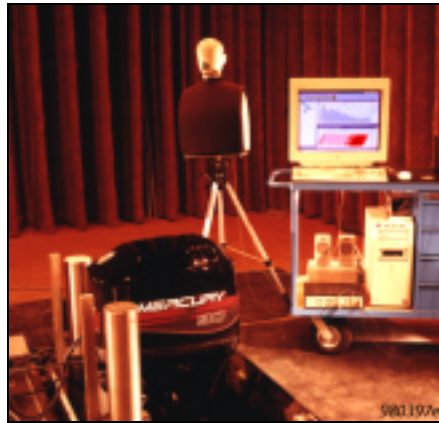
As well as these two activities, the system is used for other smaller outboard related projects such as dealing with feedback from customers, management, engineers and testers regarding unusual, unpleasant or loud boat engine noises.

Fig. 1 Brüel & Kjær's Sound Quality System for PULSE. DAT recorders are also available



Test Setups

Fig. 2 A typical indoors setup for sound quality testing



A typical sound quality test involves Sound Quality Program Type 7698 and the Sound Quality Head and Torso Simulator Type 4100. When testing takes place in the laboratory, the head and torso simulator is placed on a tripod in a hemi-anechoic chamber next to a tank of water (containing the running engine being tested) in a position representative of where one would stand on a dock next to a boat, e.g., a couple of metres away at a 45° angle. Out in the

field, the head and torso simulator is typically placed in the boat's passenger seat. Using such setups to make recordings and using informal jury tests, Mercury Marine is able to analyse sound much closer to the way the human ear experiences it.

The results are correlated with the parameters of sound, or metrics, and then it's determined whether certain aspects of the sounds fall within an acceptable range and also, which metrics are appropriate for a particular problem. Offending noises can be analysed in order to determine their frequency content and, once that's done, an intensity probe can be used to discover the source of the particular frequencies. By using this combination of techniques, Mercury Marine is able to ascertain which components are problematic and need to be worked on.

Features

The benefits of playback

According to Mercury Marine, the most cherished feature of the Brüel & Kjær hardware and software package is the ability to play back binaural recordings to engineers. Ian House explains, "In the past we've had to rely on water testing and it's not always easy to get all the relevant people together at the same time. The alternative is to show them the results on a graph, which is not always convincing! But if you can present the investigating team with a tape, a set of headphones and play them the "before and after" noises back to back, then they can react immediately to whether they feel you've made an improvement to the sound quality or not. It really improves the visibility of the acoustics group by just being able to say here's what we measured; we've worked on it, we feel this is better, what do you think? This gives everyone involved a better understanding of what we're doing and sets focus on whether the improvement we're working on is significant and worthwhile."

Using PULSE on a Daily Basis

Fig. 3 At Mercury Marine PULSE is used daily. On the right, PULSE shown being used for modal testing, and below for sound intensity measurements



At Mercury Marine, using PULSE is part of the daily routine (see Fig. 3) – in the laboratory for all standard noise and vibration tests (using 5 or 6 channels and a tachometer) and for analysing noise and vibration DAT recordings made in boats (typically using 12 or 14 channels including 2 or 3 triaxial accelerometers, a tacho signal, a sound level meter and two signals from a head and torso simulator).

For a recent project Mercury Marine needed to measure a boat's engine mount transmissibility as well as the sound quality using a head and torso simulator as well as sound levels using a sound level meter. All the information gathered from these recordings were simply fed into a DAT recorder and analysed by PULSE. Mercury Marine has also successfully used the system for modal analysis, correlating it with finite element predictions.

For pass-by measurements, Mercury Marine relies a lot on $1/12$ th-octave CPB (Constant Percentage Bandwidth) analysis. The pass-by measurements are made with a setup that includes a microphone and a head and torso simulator on the shoreline. The boat being tested passes at a distance of 25 m at full throttle and perpendicular to the line of the microphone. Because boat length, weight, width and hull configuration specifications have been laid down by a new ISO standard, the results of the pass-by tests are very repeatable.

Fig. 4 Making a pass-by measurement with the Head and Torso Simulator on the shoreline and a boat passing by at full throttle



Mercury Marine is currently involved in creating the new standard, as some of the old ones don't take everything into account. For example, the trim angle of the motor can have a dramatic effect on the speed and the sound level of the boat as can water conditions, especially with the smaller, faster boats. These things are not accounted for in the old ISO standards. In fact, Mercury Marine engineers have managed to get the sound levels so low for some craft that the splash noise resulting from minor ripples adds a dB to the sound level!

Mercury Marine has also used PULSE to identify the main resonant frequencies of the drive shaft housing and has modelled this component using ANSYS®* (Finite Element program) in the main office. Simple modifications were made in an attempt to reduce one of the resonances. The main aim of the project is to predict how to modify the drive shaft housing in advance in order to stop it resonating and from there, hopefully, to be able to design for "low noise" from scratch.

Fig. 5 The Mercury Marine NVH Engineering team. From left to right: Ian House, Ph.D., Mike Freund and Mike Docter



The last word...

"PULSE's multichannel capability has certainly made us more productive. The multi-analyzer capability is quite unique – being able to look at three different views of the same data simultaneously and not having to keep playing the same data over and over again. Multichannel and multianalysis cut down testing. When you're testing on a boat, it's difficult to repeat the same conditions twice and the amount of time you have good conditions is limited. You never know when the wind's going to pick up or it's going to rain, so anything you can do to speed up the data analysis and make the different measurements simultaneously – "you never meet the same wave twice" – is really helpful. The fact that PULSE is a PC platform is also very important to us. It's so handy to be able to transfer data to Excel and Word for report writing."

*ANSYS® is a registered trademark of SAS IP, Inc.

For Further Information

PULSE Literature:

For more information on PULSE Sound Quality see the Sound Quality brochure (BG 1319), or the Sound Quality System Summary (BU 3073)

PULSE Demo:

The PULSE demo will whisk you through PULSE's concept, functionality and options interactively with easy to use controls. For your free copy contact your local representative or see it live on our homepage www.bk.dk

The Internet:

A comprehensive selection of Brüel & Kjær literature as well as software demos are available on our website www.bk.dk

All photos courtesy of Mercury Marine