J. & A. Enterprises, Inc.
Noise and Vibration Engineering

17 Lime St.
Marblehead, MA 01945
phone (781) 631-9551
fax (781) 631-9231

Noise and Vibration Specifications for Large Yachts

JOE SMULLIN - SOUNDOWN

The contract specification for a yacht, or other project, defines the result which the customer agrees to purchase and which the manufacturer agrees to deliver. Its purpose is to clearly state performance and physical characteristics of the critical items in the delivered product. A yacht is different from a commercial ship in the subjectivity of the product. i.e. It is easier to determine the money making potential of a commercial vessel than it is to measure the pleasuring potential a yacht. Furthermore, a shipyard is not likely to sign a contract based on measured pleasure that the owner receives from his yacht. One purpose of the specification is to quantify the items of pleasure, security, and fit for service of the project.

The specification, when properly written, allows the owner to know what he will be getting and allows the shipyard to quantify the cost to deliver the product, and therefore its price. The correct writing of the specification is an important step in the equation of commerce — the correct goods at the correct price. If the specification calls for features or an extent of a specific feature beyond the appreciation of the buyer, it results in a needless increase of the product price.

Over the last Decade there has come a growing awareness of reduced noise and vibration being a major component of luxury and pleasure in yachts and other vehicles, devices. Building quiet and low vibration into a yacht has significant effect on costs including; price, weight, volume, and complexity of machinery and constructions. In any application, one or the other of these may be the major balance against reduction of noise and vibration. The specification, when well written, should make the correct balance, ultimately reflecting a balance between the owner s wallet and his desire for noise and vibration comfort.

Many yacht owner s are not sufficiently aware of noise and vibration parameters to know what are the quantitative levels which they wish to achieve in a new build yacht project. Statements such as, wanting to build the quietest yacht, spare no cost or weight . wear thin quickly in the Mega Yacht business, where the spare no cost barrier can always be penetrated and where weight is always an issue, even in submarines. Guidance for appropriate specification limits may be obtained from classification rules for noise and vibration comfort, and hopefully, further understanding obtained from this presentation.

What to Specify

Requirements related to noise and vibration comfort on large yachts generally fall into three basic categories:

Noise limits when the vessel is underway and when at anchor or dockside;
Vibration limits when the vessel is underway and when at anchor or dockside;
Acoustic privacy between different living spaces.

The organization of the paper deals with these three basic categories. Other measures of noise and vibration quality exist, but are not discussed in this presentation, as they are generally less important and not so commonly dealt with or seen as a problem. Footfall noise from deck-to-cabin, is the one topic in that list of other measures which next requires attention.

Noise Limits

Noise in yachts is most often measured in decibels A-weighted, dB(A). The dB(A) scale is intended to give an accurate single number loudness scale for noises, by accounting for the combined various pitches of noise in a given environment and relating each pitch to the sensitivity of hearing of a typical human subject. The dB(A) scale is universally known and it does a reasonable job of rating noises. Many devices are available at economical prices for measuring noise in dB(A) units. dB(A) is the unit of loudness used by the various marine classification societies, and it is the favored unit of this author.

In recent years, the various marine classification societies have started publishing Comfort Class rules for application to vessels including large yachts, which include limits related to sound and vibration. Specific rules are:

DNV — Rules for Ships, Part 5 Chapter 12 — Comfort Class (July 1995)
RINA — Rules for the Evaluation of Noise and vibration Comfort on Board Pleasure Vessels
Lloyd s - Provisional Rules, Passenger and Crew Comfort, Feb. 1999
ABS — Guide for Passenger Comfort on Ships December 2001.

These rules set a range of limits applicable to large yachts and ships for acceptable and for excellent performance. Except for ABS, they recognize a fast craft category, distinct from displacement yachts. RINA has a specific fast yacht category while DNV and Lloyd s recognize fast craft general. Fast craft have potential to be noisier than displacement types, because more power is typically installed in lighter weight structures for the fast craft, and they also have less margin for weight of installed abatement treatments. It is also generally true that the fast craft are likely to use their speed potential to avoid reduce the number of overnight passages, relaxing the requirements for quiet sleeping cabins during underway operations, but that fast yachts require comparable comfort to the displacement craft for the harbor conditions.

It is noted that DNV was the first classification society to offer comfort class noise and vibration limits, when they published them in July 1995. RINA, Lloyd s, and then ABS followed with their own rules. The rules are new, and representatives from the majority of these societies have stated that their requirements are currently in review with revisions expected shortly. (None have shared their thoughts regarding the direction such revisions might take.)

Some brief decibel factoids are appropriate before discussing actual decibel limits, though there is growing understanding of the scale amongst members of the marine community.

- An increase of 10 dB(A) is heard by the human ear as a doubling of loudness, though it actually represent a factor of ten increase in sound power (i.e. increasing stereo system power from 25 Watts to 250 Watts gives a 10 dB(A) increase, which is heard as a twice as loud.).
- A one decibel change of noise is audible, when it happens, but is difficult to discern from day to day.
- A three decibel change of noise is distinct and clearly discernable, from day to day.
- Improving insulation of a single panel wall by 10 dB(A) generally requires an increase of the panel mass by a factor greater than three. (Luckily, there are more effective ways than simply increasing the panel mass.)

For noise, the considerations for limitation have a hierarchical organization:

Avoidance of hearing damage
IMO A.468 requires personnel to wear hearing protection when entering a space louder than 85 dB(A), and further limits 110 dB(A) for spaces occupied by persons wearing ear muffs.

Ability communicate by speech, at close distances
Typical water noise at the aft deck of 80 dB(A) limits speech, with full comprehension, in very loud voice level, to persons standing no further than 0.5 m apart.

Avoidance of noise induced fatigue
IMO A.468 limits noise in lounging areas to 65 dB(A), while ABS sets a limit of 60 dB(A) — these are limits for crew spaces.

Ability to sleep
IMO A.468 limits noise in sleeping cabins to 60 dB(A)

Luxury-to-comfort quiet (not aware of noise- examples, leaving the ship world).
38 to 48 dB(A) in Living and Drawing Rooms
38 to 48 dB(A) in sleeping and relaxation areas

Super-Quiet
18 to 23 dB(A) for Concert and Recital halls (classical music listening).

This hierarchy of considerations and attached noise levels is useful to keep in mind when setting noise limits, based on the desired function of a space. As has been noted, the desired levels will not be able to be practically achieved in all cases in yachts, due to constraints of weight, space, and cost.

Harbor Conditions- Except for the rare salty large yacht owner, who spends many days at sea making passages, the harbor conditions are the most critical noise and vibration condition. Table I. shows the classification noise limits for harbor conditions from the various societies having Comfort Class rules. ABS comfort class rules do not include a harbor condition set of limits, so we have carried over their underway limits. For the fast boat category, DNV has communicated that use of the displacement yacht dB limits is appropriate, as noted. There is modest consistency between the classes, with a general drift from the quietest lower bound in the DNV limits from Lloyd s higher by as much as 15 dB. For the displacement vessels, the limits fall into the range of luxury quiet. RINA and Lloyd s offer a 5 to 10 dB margin for the fast boats, in comparison to displacement.

Table I.

Upper and Lower Acceptance Bounds for Noise, dB(A), for Yachts in Harbor Conditions
Various Classification Societies
Lower Bound is Highest Quality - Upper Bound is Acceptable

Harbor Conditions

		Salon		Cabins		Open Decks		
Displacement	DNV	40	55	35	45	50	60	
	RINA	40	50	40	50	40	50	
	Lloyds	50	55	45	50	55	60	
	ABS -passenger vessels	45		45		65		taken from underway limits

Harbor Conditions

		Salon		Cabins		Open Decks		
Semi Displacement - Planning	DNV < 50 m DNV > 50 m	40	55	35	45	50	60	DNV taken from yacht
	RINA	45	55	45	55	55	65	
	Lloyds	55	65					taken from underway
	ABS -passenger vessels	45		45		65		

It is the experience of the author s consulting practice that the range of noise levels used for the lower limits (35 to 45 dB(A)) are practically achievable in yachts of 30 m and larger, whether displacement or fast yachts, with resulting high satisfaction of their owners. In smaller yachts, upward adjustments may be required due to limitations of space and weight for quieting generators and air conditioning ducts.

The classification rules generally state what equipment is to be operating during the Harbor Condition acceptance noise measurements. A more concise statement concerning the machinery operating set-up during noise acceptance checks is appropriate for the contract specification. In particular, if HVAC

systems are oversized to the extent that they will operate at reduced fan speeds for 95% of the time, particularly at night time, then it may be appropriate to set the reduced fan speed condition as the operating condition in the noise limit specification. The benefit of designing the noise control for a rarely used full power condition may come at a severe price, related to increased oversized ducting needed to adequately quiet the high flow condition. The benefit of the further quieting the air conditioning may be negligible or worse, due to the presence of more annoying machinery noises unrelated to the air conditioning.

One step beyond the classification rules which is used in specifications written by my company, for the most noise sensitive yachts, is to specify a limit for machinery noise in-harbor limits exclusive of the air conditioning. Because machinery clatter is generally more annoying than the pink noise of the air flow, we set the limit for the machinery lower than that with the air conditioning operating, so that the air conditioning noise partially masks the mechanical noises.

Underway Conditions- Table II. shows the classification noise limits for underway conditions from the various societies having Comfort Class rules. For purpose of comparison, I have plotted, in Figs. 1 — 6, these noise limits against measured noise levels on a number of yachts for the three different types of spaces. The plotted data covers the most critical (loudest) space in each category on the various yachts. For the cabins, the loudest guest cabin is plotted -usually closest to the engine room. For the open decks, the aft main deck or cockpit deck is plotted, except as noted on Fig. 3.

Limits for underway noise may prove to be more difficult to write in terms of the noise critical operating condition. Commercial vessels are likely to have designed operating speeds which are well defined. For yachts this is often not the case. In commercial displacement vessels, it is common to assume normal operation at 80% of the maximum continuous rating (MCR) of the propulsion engine. For a displacement boat with normal power, 80% MCR is likely to be reached at approximately 93% of the maximum rated engine speed (based on the cubic curve law for power vs speed). Our experience is that displacement boats are more likely to be operated at 80% of the maximum speed, which is closer to 50% of the MCR. The noise level difference between these two speeds may range from 2 and 4 dB. The worst case of bad noise limits which we see is typified by a large sail yacht which is overpowered by an engine having a high speed rating (limitation to operate for only one hour in a 12 hour period at the high power, or some similar limitation) which power it will only use in some emergency situation, when noise will not be an issue) and with a specification calling for the noise limits to apply with the engine operating at its full power. The full power scenario is not likely to be really a noise critical point, and to design quieting against high propeller cavitation, extreme exhaust rumble and other characteristics of the overpower operation will not necessarily reduce the noise during the normal cruising speed operation. The noise limits should be set for the conditions at which the yacht will operate, when reduced noise will be important.

Review of the comfort class limits for underway operation is best done separately for displacement and for fast boats, after first making the observation that the limits for the fast yachts are equal or higher than those for displacement yachts. This is not surprising.

Displacement boats The underway noise limits for the displacement yachts are, not surprisingly, higher than the limits for harbor conditions. They are generally higher than the desired comfort levels referred to in the list for comfort in sleeping and lounging spaces. This is partly a concession to the fact that, because of the machinery and power generated and dissipated in very close proximity to the passenger spaces, there are limitations on how quiet the yacht came be made to be within reasonable quieting efforts. It is also in recognition of the fact that the motion of the boat in the seaway and even the sensation of the moving seascape create sensations which reduce the passengers sensitivity to relatively quiet sounds.

The variation, between different classification societies, of noise limits (Table II.) for the displacement yachts is fairly close, with a spread of 5 dB, except that there is a range extending to 20 dB for the noise on open decks. Examining the plots (figs 1-3), it is seen that the quietest yachts of 50 m or larger fall well into the acceptance range and may be meet the highest quality limits. For the yachts in the 30 m

range, the quiet ones fall in the acceptance ranges, generally, but do not achieve the highest rating. For the 15 m yachts, they are all outside of the acceptance range. Size has a clear influence on the noise level, with smaller being louder. When addressing noise requirements in specifications for yachts under 30 m, an allowance of 5 dB or more appears to be appropriate.

Reasons for the higher noise in the smaller boats appears to relate to the lack of volume available for the highest quality insulation systems, and the tendency to generally overpower them, as compared to the larger displacement yachts. It is also clear that in the majority of cases the smaller yachts have greater financial limitations affecting the level of noise and vibration mitigation.

The noise at the Aft Main Deck (Fig. 3) is worthy of some further discussion. There is wide disparity of requirements for this location. The entire span of the DNV limits lies outside the limits for the others. Regarding the lower limit for noise at the aft main deck, we have observed that the aft deck noise has a lower limit defined by the stern wash noise. Figure 3 shows an asymptotic lower limit for that noise as observed on blunt transom displacement yachts, having the deck within approximately 3 m of the waterline. An example of the benefits of greater elevation above the wash is shown at the lower portion of the plot. Here, the boat deck of a 60 m yacht, 3m above the main deck and 4 m forward of the aft main deck area has a noise level reduced by 7 to 10 dB compared to the main deck. Special fishtail sterns, having smooth attached flow, have lower noise at the aft deck.

The yachts at the upper range of aft deck noise can be defined as noisy and the sources of the excess noise include: propeller cavitation, diesel exhaust, and engine room ventilation. All of these are readily quieted, if addressed in the design phase.

Numerous yacht contract noise specifications omit setting limits for the open decks. The aft main deck usually has the most pleasant sea motions during rough conditions, and is one of the best lounging locations, minus noise and vibration. Specification limits for the noise at this deck are needed to assure treatment of local noise sources so that the greatest level of comfort is achieved.

Fast Yachts I refer to semi-displacement and planning hulled yachts as fast yachts . The classification noise limits for underway operation of these craft, shown in Table II, vary from one society to the next. DNV and Lloyd have no fast yacht designation, but offer a Fast Craft category, applicable to passenger boats. We have used the Fast Craft limits, where there are no limits specific to fast yachts. Excluding, ABS, there is agreement from the other three societies that 55 dB(A) in public spaces (Salons) deserves the best comfort rating.

RINA and Lloyds yacht rules correctly account for the option of preset operating condition at reduced power settings to be attached to the noise limits. The absence of noise limits for sleeping cabins and open decks, as the case of the class rules, is not acceptable for typical yacht projects. In some fast yachts, certain cabins might not be intended for use at the higher speed ranges, due to ship motions in a typical sea state. In these cabins it is reasonable to avoid a noise and vibration limits for the high speeds. However, if it is intended that those cabins be used at a lower speed range, then it is appropriate to set limits for that range. Often fast boats will have a displacement speed cruising mode and a fast cruise mode, each of which is commonly used. For these boats two sets of limits are appropriate. A single limit for one speed condition does not necessarily guarantee good results to follow at the other speeds. This is because different sources may dominate for the different conditions. At low speeds exhaust, engine room ventilation noise, and propeller singing may dominate at the open aft main deck, but at high speed propeller cavitation, machinery structureborne noise, and stern wash noise might dominate. Treatments to quiet one of these groups will not significantly reduce the noise at the speed dominated by noises of the other groups.

Figs 4-6 show the class limits along with noise levels experienced in a range of fast yacht projects, with hulls up to 43 m long. None of the data relates to horror story cases of extreme noise, though the upper boundary is the range where complaints of excess noise are anticipated from purchasers of a custom yacht. The lower range is achieved only by the most extreme measures. The cabin and salon data show a broad grouping in the upper mid region, consisting of less custom yachts 35 to 50 m, having modest attention paid to noise reduction. A group of noisy boats, of length 13 to 20 m dominates the loud upper left corner of the figures. There is a group of four boats that are significantly quieter than group in the upper mid range and come within 1 to 4 dB of 55 dB(A) high comfort range recognized by

the societies for the salons. Looking at the difference between the quietest group and the mid group, a spread of approximately 10 dB is recognized, while the difference between the mid group and the noisy boats is in the range of 5 dB.

Table II.

Upper and Lower Acceptance Bounds for Noise, dB(A), for Yachts Underway
Various Classification Societies
Lower Bound is Highest Quality - Upper Bound is Acceptable

			Underway							
			Salon		Cabins		Open Decks		Wheel House	
Displacement	"contract normal speed or at least	DNV	53	62	44	55	75	85	60	65
		RINA underay at "normal cruising speed"	55	65	50	60	65	75	60	65
		Lloyds underway at 85% power unless prior agreed lower poer normal operation	55	60	50	55	60	65	60	65
		ABS -passenger vessels	55		45		65		55	

			Underway							
			Salon		Cabins		Open Decks		Wheel House	
Semi Displacement - Planning	DNV "Fast Craft" limit	DNV < 50 m	65	75					60	65
	"contract normal speed or at least 85% MCR	DNV > 50 m	60	68					60	65
		RINA underay at "normal cruising speed"	60	70	-	-	-	-	65	70
	Lloyd's "Fast Craft" limit	Lloyds underway at 85% power unless prior agreed lower poer normal operation	60	70						
		ABS -passenger vessels	55		45		65		55	

At the open aft main deck, fig. 6, the data is more compacted. The figure includes a shaded line showing the J&A general experience for the background noise due to the stern wash for fast boats, similar to that described for Fig. 3. The stern wash noise is the cause of the compacting. At high speed the loudest group tends to diverge, due to propeller noise issues. At reduced speeds, the quieter boats diverge downward as stern wash noise becomes quieter and vessels with higher mechanical noises show their relative deficiencies.

All three plots show the slope related to speed and the separation due to length of the yacht. Guidance in setting spec limits might be taken from these plots, understanding that the upper boundary is where noise compliant are expected and where what are the general limits of noise reduction excellence, depending on speed and length. They should be considered as a tool to be used in evaluating a set of contract noise limits for fast yachts, having more relevance than the limits set by classification.

Vibration Limits

Vibration limits in yachts and ships have been set in the past using units of velocity (mm/se or in/sec —semi amplitude) as a measure over the critical frequency range 5 to 100 Hz. This frequency range is that prevalent in yachts of 70 m and less. (For larger yachts the frequency range of interest may

extend lower, due to their slower shaft rotation speeds. Those craft have slightly different requirements applied below 5 Hz, and are not discussed in this section.) Limits on vibration have a hierarchy of goals, including the following, listed in order of reduced limits:

Vibration Limitation Goal	Underway Flat seas	Harbor
Avoiding motion sickness, and extreme discomfort	7 mm/sec	
Avoidance of vibration induced fatigue (24 hrs)	5 mm/sec	
Ability to sleep comfortably	3 mm/sec	1 mm/sec
Luxury smooth (not aware of vibration).	1 mm/sec	0.25 mm/sec

The limits related to discomfort and fatigue are fixed values, independent of the seaway induced motions. The comfort and luxury zones are related to the total sensory environment, including the seaway induced motions, noise, and even to the visual perception of motion. This is the reason for different limits for underway and harbor. Class requirements for vibration are given in Table III. Figure 7. compares the class limits for displacement yachts. There is agreement by the three classes, excluding ABS, that 1 mm/sec is the required for the highest rating, underway for the displacement yachts, and a general relaxing of the limit for the fast yachts, where class has limits. The rules of these societies all refer to a common methodology for measurement of vibration, ISO-6954, so there is good commonality of the values being compared.

Figure 7 shows a graphic representation of the acceptance levels, including the ABS acceleration values converted to the velocity semi-amplitude, by the mathematical process of integration. It is noted that the ABS limit in the frequency range below 10 Hz is highly relaxed compared to the other limits. This frequency range is the domain of shaft rate vibrations which constitute the majority of vibration complaints in the industry. For this reason the ABS vibration limits appear to be unacceptable for use on yachts.

The lower limits (highest rating) applied to harbor conditions by the societies do not meet the standards that J&A has found required by owners and to be practically achievable in yachts. Our experience shows that quiet displacement yachts demand vibration levels in the range of 1 mm or less, and the very quiet fast ones require a limit of 2 mm/sec at fast cruise. Slightly relaxed limits may be appropriate for these vessels at full power operation. This author agrees with the general classification guidance for vibration the lower vibration limits when applied to yachts of 30 m and larger. But we find that the upper limits for underway conditions shown in Table III. are above the range where we receive strong complaints.

Up to this date, many builders of fine yachts are not comfortable with appropriate vibration limits, and we often see specifications limiting the vibration to a value of 7 mm/sec, and similar. Such limits are unacceptable for a yacht, as no honest and knowledgeable builder of fine yachts would defend a boat experiencing such levels as acceptable. One of the issues influencing the disparity between specification limits for vibration and actual comfort limits is the fear of consequences if the limits are exceeded. The reasons for excess vibration usually lie in machinery installation errors, machinery design errors, or structural design errors. Corrections, after the fact, for installation errors is common, understood, and usually can be done at modest cost. When there is a problem related to the design of the machinery installation, or of the ship structure, corrections can be very costly. With this reality, yards may make full efforts to deliver a yacht meeting levels in the range of the class tables, but wish to cut themselves some slack in case higher vibrations are discovered during the sea trials. This points to an issue of insufficient confidence in the vibration control design process. Greater use and experience with numerical calculation tools for structure and vibration should build greater confidence, allowing more builders to accurately state acceptable vibration limits in their yacht specifications.

Speech Privacy

Speech privacy in yachts is a major quality issue. People on yachts (crew as well as owner s party) live in confined space, and the ability to occasionally feel remote from the rest of the gang is important. Speech privacy between crew spaces can be a major factor in crew comfort and satisfaction with working conditions. I first know of decibel privacy standards applied to a yacht in 1970. In recent years use of such standards has become usual practice for the best yachts, and privacy limits are included in the comfort class requirements of all.

Table III.

Vibration Limits mm/sec-pk (except ABS units - acceleration)
Various Classification Societies
Lower Bound is Highest Quality - Upper Bound is Acceptable

			Underway								Harbor Conditions					
			Salon		Cabins		Open Decks		Wheel House		Salon		Cabins		Open Decks	
Displacement	"contract normal speed or at least 85% MCR	DNV time averaged peak velocity	1	3	1	3	2	4	1.5	4	0.5	2	0.5	2	0.5	2
		RINA underay at "normal cruising speed" 0 TO 100 Hz	1	4	1	4	2	5	1	4	0.5	2	0.5	2	1	3
		Lloyds underway at 85% power unless prior agreed lower poer normal operation 5 to 100 Hz max rept pk	1	2	1	2	2	3.5	1.5	3						
		ABS-passenger ship acceleration m/sec,sq rms (.5 to 80 Hz)	0.2	0.32	0.2	0.32	0.2	0.32	0.2	0.32						

			Underway								Harbor Conditions					
			Salon		Cabins		Open Decks		Wheel House		Salon		Cabins		Open Decks	
Semi Displacement - Planning	"contract normal speed or at least 85% MCR based on High Speed Craft"	DNV time averaged peak velocity	2	5	2	5	2	5	2	5						
		RINA underway at "normal cruising speed" 0 TO 100 Hz	2	5	-	-	-	-	2	5	1	3	1	3	2	4
	High Speed Craft	Lloyds underway at 85% power unless prior agreed lower poer normal operation 5 to 100 Hz max rept pk	2.5	4												
		ABS-passenger ship acceleration m/sec,sq rms (.5 to 80 Hz)	0.2	0.32	0.2	0.32	0.2	0.32	0.2	0.32						

Measures of speech privacy are based on the noise reduction between spaces, and ultimately also include consideration of the background noise in the receiving space. The background noise may be disregarded as a variable, if it is assumed that we are speaking of the quiet conditions on yachts, when all considered spaces might be similarly quiet. (This simplification does occasionally cause errors, but it is a good starting point.) The single rating numbers used to rate privacy between spaces is STC (Sound Transmission Coefficient) in the U.S.A. and under ISO it is R_w (weighted apparent sound reduction index) but sometimes referred to as I_a, based on early norms. Ratings R_w and STC for a given wall are usually equal, as the rating methods are quite similar.

Speech privacy ratings, by functional definition and the associated STC/R_w, as used by J&A Enterprises for yachts is presented below:

Privacy Required	STC/R_w
Barrier against other parties being forced to hear remote conversation	35
Barrier against other parties listening and understanding a remote conversation	40
Barrier against other parties being aware of a remote conversation	45
Barrier against other parties being aware of a remote conversation at elevated level.	50.

Table IV.

Acoustic Privacy Rw ISO 717/1
Various Classification Societies
Lower Bound is Highest Quality - Upper Bound is Acceptable

			Cabin-Cabin		Cabin-Public		Cabin-Passage	
Displacement	"contract normal speed or at least	DNV	55	45	65	55	52	42
		RINA	RINA privacy for L> 24m	30		30		
		Lloyds	45	40	55	50		
		ABS -passenger vessels						
			Cabin-Cabin		Cabin-Public		Cabin-Passage	
Semi Displacement - Planning	"contract normal speed or at least 85% MCR	DNV < 50 m	55	45	65	55	52	42
		DNV > 50 m						
		RINA	RINA privacy for L> 24m	30		30		
		Lloyds	45	40	55	50		
		ABS -passenger vessels						

Table IV. shows the classification society requirements for R_w privacy ratings, with some interpretation applied to make them comparable. There is significant disparity between them. For the highest rating between a sleeping cabin and a public salon, a rating of 65 is required by DNV, but under a RINA full merit is recognized at a rating of only 30. The Lloyd s requirements fall between RINA and DNV, and fall in the range of my list, above. In a full noise specification, the privacy ratings should be presented in a grid format relating the particular cabin groupings, including separate headings for owner s party and for crew.

Acoustic privacy is an important aspect of living comfort aboard yachts over 20 m, having distinct partitioning, and where an expectation of overall privacy exists. Realistically, privacy partitions must be double skin types. Class privacy limits vary wildly. The description of functional meaning of STC/R_w, given in this paper should be used in assessing desired privacy. These are most closely addressed by the Lloyd s limits. Elements of weight and partition thickness must be reviewed to determine if the desired limits can be practically achieved in a given project.

Setting the Noise and Vibration Limits

Establishing sound and vibration requirements appropriate to a particular yacht project might be done by relating the limits for the noise and vibration levels with which the owner is familiar. Comparison with another boat which has the desired noise and vibration comfort required, can give a clear indication

of what is required in the new project. Comparison with an existing boat, upon which improved noise and vibration levels are required is helpful, but possibly not as clear, as it may be difficult to convey to the owner the difference in comfort related to a certain percentage reduction vibration amplitude or decibel reduction of the noise level.

Current classification society comfort class rules for noise and vibration do not form an adequate basis to be simply plugged into the specification. We make the following suggestions for the setting of noise and vibration limits on yachts.

Harbor condition noise for yachts of 30 m length and greater — displacement and fast - can practically be limited to the 38 to 48 dB(A) range suggested for land based sleeping and lounging areas, and open deck noise can be held to 55dB(A) and less. The inclusion of a more restrictive set of noise limits with machinery operating but excluding operation of interior ventilation, is useful for creating a more comfortable environment by greater exclusion of mechanical noises.

Classification rules for underway noise are quite diverse, and particularly sparse in requirements for fast boats. Underway limits must take into account speed and size, and location on vessel (particularly deck level for open aft decks). Practical underway noise limits for yachts must generally be compromised, in comparison to land based noise limits, to account for the reality of a large machine having noise emissions from major rotating and reciprocating machinery, as well as hydrodynamic and aerodynamic sources on noise and vibration. The experience data in figures 1-6 provide some guidance relating; normal, quiet and quietest, in regard to speed and size of yacht. Particular attention should be paid to the operation mode of the yacht to which the noise limits are attached. More than one speed condition might be specified, if there are to be multiple modes of operation.

Vibration Limits from the classification societies (excluding ABS) are more uniform and more closely related to our experience of what yacht owners might demand, than is the case for noise. These limits are appropriate for use in contract specifications. The classification limits for excellence are, however, below what some yacht builders are willing to offer in contract specifications.

Specifying Techniques and Practices

The best specification for noise and vibration, for owner and for shipyard, is a performance specification, leaving the shipyard significant latitude to determine the means of complying which are most suited to the practices and materials used at the shipyard. Still there are certain practices which an owner may wish to include in the specification, in the same way that he might specify a particular engine type, and not just a performance speed and range. The techniques and practices list might state the general type of insulation products, the arrangement of the engine/shaft vibration isolation, the arrangement of the exhaust system, provision for elastic mounting of machinery and pipes. Normally, the specification should stop short of detailed requirements which might over-ride and prevent complying with the performance requirements of the specification. In some cases, items from the list of practices may allow performance better than the performance limits. The specification should clearly state whether, in such a case, the technique or practice is to be kept, giving further noise and vibration improvement, or whether that practice may be discarded to allow saving cost, weight, or space.

Professional Noise And Vibration Help

The specification, combined with the general arrangement, is the DNA of a new yacht design. To the extent that noise and vibration issues are an important part of most large yacht projects, the noise and vibration sections are crucial to a good project. In cases of repetition of a similar and satisfactory project or in cases where the owner is not at all sensitive to noise and vibration, outside expertise of a noise and vibration engineer may not be required at the time of specification writing. Most large yacht are not repeats, and noise and vibration are high on most owners quality list. For this reason, participation of a

specialist to identify noise and vibration requirements and to be able to list the anticipated means (implies cost and weight) to achieve them is a useful practice during the specification preparation period.

Conclusion

None of the current comfort class rules of the various classification societies are satisfactory for use as a contract spec callout for noise and vibration in a yacht project. They do form a useful metric against which to relate measured levels in an existing yacht. The data shown in figures 1-6 is useful for describing noise levels attainable with high, medium, or low effort in boats of various length and speed. These should be used to set limits at appropriate underway conditions.

For harbor conditions, large yachts need not have more noise or vibration than tolerated in land applications.

The various class rules for underway vibration limits are in reasonably agreement, except for that of ABS. The rules are in reasonable agreement with J&A experience of appropriate comfort limits, but they are below limits to which most shipyards are willing to contract.

When there is an noise and vibration performance specification, the list of means of treatment should be secondary to the limits. Still a list of properly selected methods helps reassure the owner that the limits will be complied with, and in some cases may allow further improved performance.

All of the classification societies are in the process of revising the first generation of comfort class. We hope to see improvements. Hopefully the yachts will be given adequate attention in this revision. Fast yacht noise and vibration rules should be explicitly written, adding sleeping cabins and open decks to the category public spaces currently used by DNV, RINA, and Lloyd s.

Fig. 1 Noise Levels in Salon Displacement Yachts

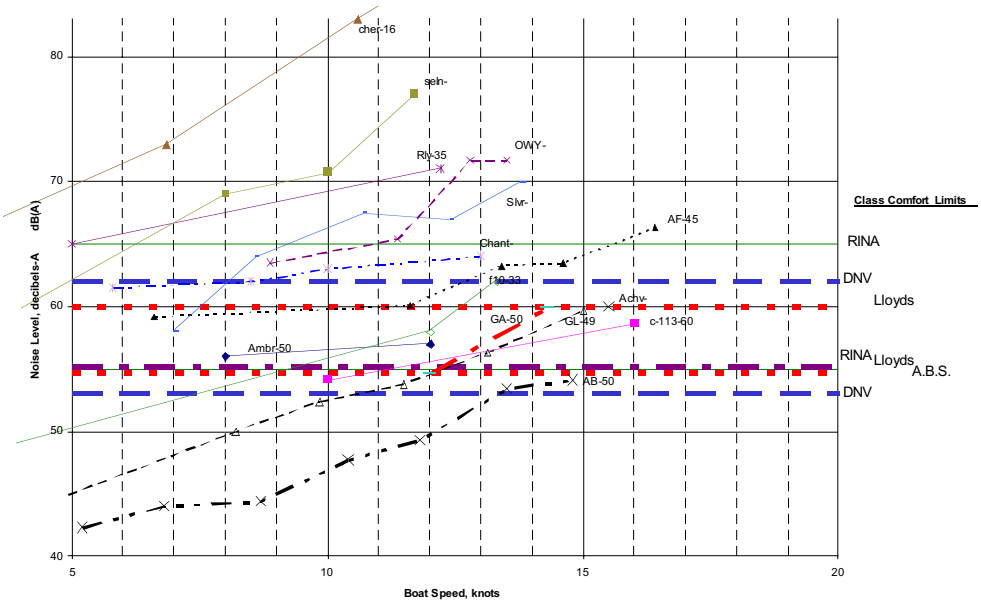


Fig. 2 Noise Levels in Sleeping Cabins Displacement Yachts
(-XX is length in meters)

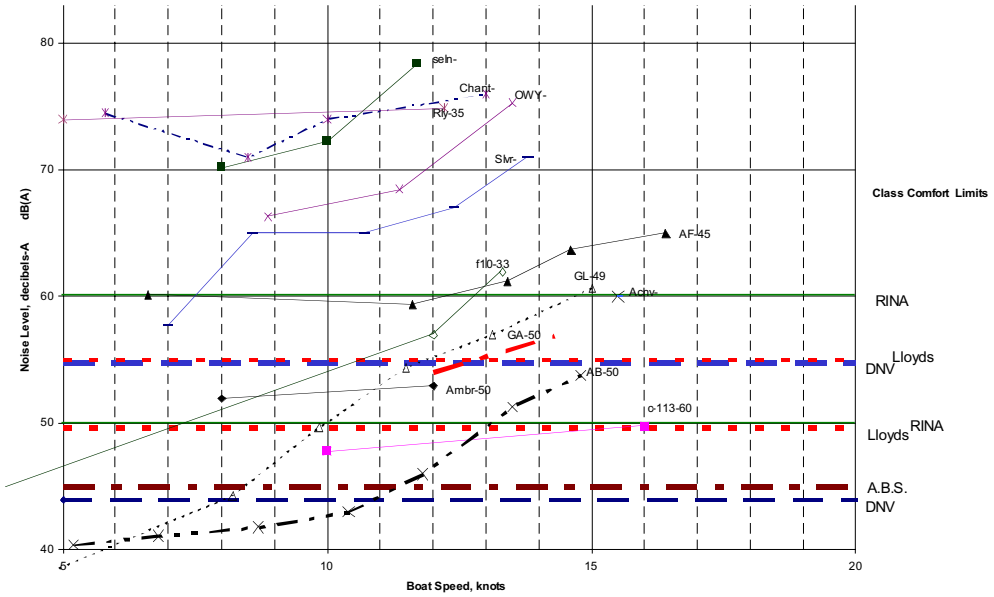


Fig. 3 Noise Levels in Aft Main Deck & Cockpits (open) Displacement Yachts
(-XX is length in meters)

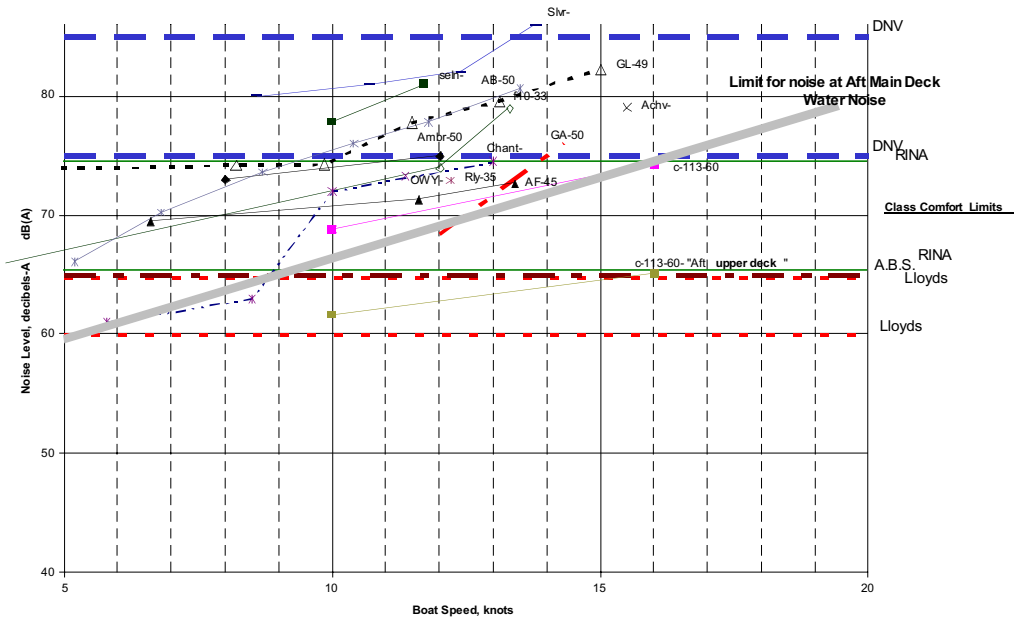
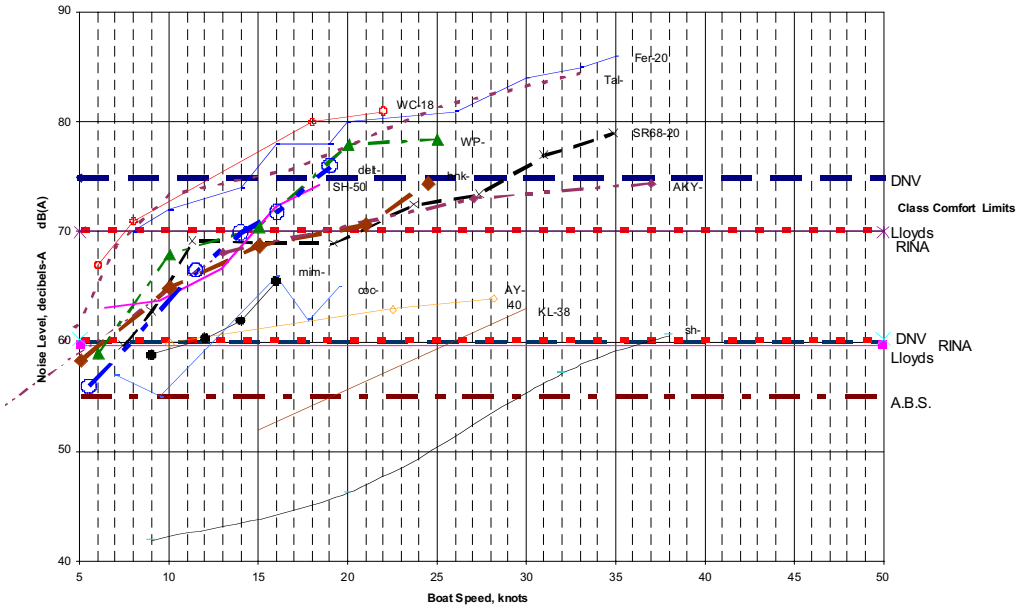


Fig. 4 Noise Levels in Main Deck Salon Semi-Displacement & Fast Yachts
(-XX is length in meters) J. Smullin, J. & A. Enterprises



X

Fig. 5 Noise Levels in Sleeping Cabins Semi-Displacement & Fast Yachts
(-XX is length in meters) J. Smullin, J. & A. Enterprises

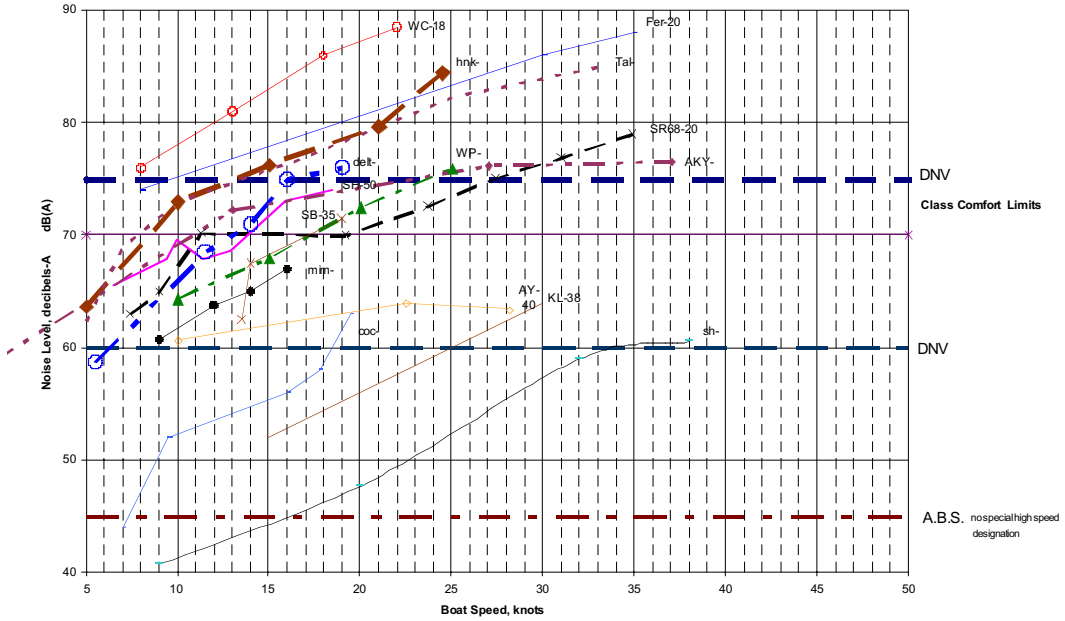


Fig. 6 Noise Levels in Aft Deck (open) Semi-Displacement & Fast Yachts
(-XX is length in meters) J. Smullin, J. & A. Enterprises

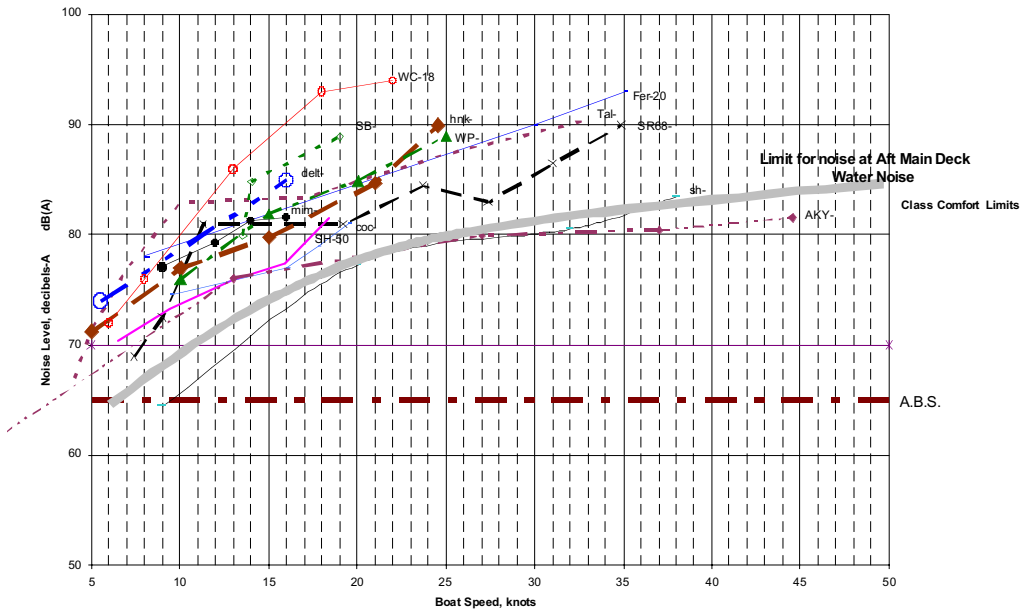


Fig. 7 Comparison of Vibration Limits Which Might Be Applied to Large Yachts