GSF 2007
12-15 November 2007 Amsterdam

SUPERCONDUCTORS & THE FUTURE 141107

Rob Rouse American Superconductor Corporation (AMSC)

Chairman—Martin Redmayne

Ladies and gentlemen, let's get cracking with our afternoon session; welcome back. We always try and bring to any of our conferences new things, as you know. One of my captain friends who is currently working on a 100 metre project phoned me one day and said I've got something so amazing. You've got to look into this technology. It's incredible. So I said tell me more. He gave me a web link and introduced me to the company and it ended up with us trying to get the guys to come here but there's a clash of events; we thought about a video conference, not quite expert at that yet—maybe next year we'll do more of those. The plan is that Esther is going to be here doing the advancing of the slides of the power point presentation; we have on line Rob Rouse from American Superconductor Corporation—he's going to give you an introduction to this incredibly interesting propulsion technology that's been developed for US Navy and it promises to add quite a revolutionary approach to some of the larger products in the marketplace. Rob can you hear me?

Rob Rouse American Superconductor Corporation (AMSC)

Good morning—or good afternoon for you.

Martin

Rob, just a very quick introduction—Director of Business Development for American Superconductor, the presentation is 45 minutes long, fire away when you want, Rob.

Rob

Do you want to go to slide 2, Esther please? Thank you very much, Martin, for a wonderful introduction and thanks to the attendees for this session of Global Superyacht Forum 2007. A couple of notes before I start—because I cannot be with you today we think it may be best if questions could be kept for the end, so please feel free to remember your questions and we'll have time at the end. This session, as Martin said, is about a new technology but it's not highly technical. We can get into the technology with any of the engineers and captains in the audience but I thought I'd keep it at a fairly high level for this group. Again, I'm sorry I can't be with you, I'm actually in Fort Lauderdale—if you think about that for a moment, Fort Lauderdale or Amsterdam, which would you choose? And there happens to be a conference here called the Society of Navy & Marine Engineers that we participate in and I'm speaking here as well. So I appreciate your understanding and patience in listening to my voice and watching Esther click the slides. We have about 18 slides so we will have time at the end for questions.

We are going to talk about propulsion, a topic that is very near and dear to our hearts and of course very important to the superyacht/megayacht industry. We're going to talk about motors and generators based on superconductors and how, as we see it, we're revolutionising an over-100 year old industry. Motors and generators based on copper. So I'm going to discuss for the early part of the presentation just electrical propulsion in general; why electrical propulsion is very important to the superyacht industry. I'm going to talk about superconductors, again at a fairly high technical level, how they're used and why there is all this excitement and why Martin's captain friend is very enthusiastic about what this does.

So Esther if you would please, slide 3. OK, superyachts. As I said, we all know that propulsion is very fundamental to yacht operation. It's one of those utilities we don't think so much about as long as it's working and working well. It's essential to the purpose and the mission of the vessel. In the superyacht area of course our clients are absolutely expecting comfort, in terms of low noise, low vibration, a very stable platform, they also expect powerful and very controllable. Manoeuvring is key, in a wide speed range, although we need to get quickly from port to port we also need to be able to cruise at a low rate of speed from time to time. Fuel consumption is very important, not only for cost savings in mission length but if we save fuel we become very environmentally friendly, by not burning fuel we have low emissions. So it's a very critical requirement of a yacht. And then dynamic positioning, or station keeping, being able to stay on station, very low speed and manoeuvring for a very large vessel is key. So superyachts as we see it and electrical propulsion are made for each other, so I'm going to talk again for a couple of minutes about electrical propulsion. Slide no. 4, Esther.

This is a kind of an ugly slide, sorry about that, but we have an ugly thing, and that's called mechanical propulsion. I'm going to talk about control first, and then we'll talk about quiet. Mechanical propulsion as we describe it, uses diesel engines to turn the propellers. Could be gas turbines in some yachts, could be jet pumps rather than propellers, but in all cases the speed control is fairly limited by the speed of that diesel engine or that gas turbine and we often use controllable pitch propellers to give us the control we want with the mechanical propulsion system. These have been the workhorse of the industry, they're used of course in 95% of all ships, commercial and naval, in the world. But the reality is, neither are optimised for control and they are fairly complex, changing the speed of the engine as well as the pitch of the prop. Electrical propulsion on the other hand is very smooth. The key here is that the electrical motor can infinitely adjust the speed of the propeller to give us the speed of the yacht that we want, using a fixed pitch propeller. So only one thing needs to change, the speed of the shaft, it can be either shaft if we have a dual shaft vessel, they can be easily reversed, and for very quick stopping or in the Navy we call it crash back, electrical propulsion gives us significant control. Quiet operation—we said one of the other requirements is to be very quiet in our superyachts, our clients are demanding that. If you think about it, the device that creates noise is key to reducing noise. We do a lot to reduce the noise on a ship once we make it, but if you don't make it to begin with, you don't have to deal with it. If you think about that diesel engine and its reciprocating motion, the cylinders that are in there, you know when those things are affixed to the hull there are big gears, controllable pitch propeller, you may have cavitation of the prop, lots of things create noise in a mechanical propulsion ship. The contrary though is the electrical propulsion—again we now have this motor that has no reciprocating action, its rotary motion, very smooth, mostly done without a gearbox, so these motors are very slow speed, we have a fixed pitch propeller yielding low vibration and of course low noise produced. So clearly a major advantage for electrical propulsion both controllable and quiet.

Next slide, Esther. On the right are some snapshots of what you might see below deck in the engine room. And there's some good news and some bad news. Electrical propulsion—we have lots of diesel generators. Lots of diesel engines. So as I said before, those big mechanical propulsion things are noisy and heavy but in this case though we do have to make the electricity for our electrical propulsion ship but we can do it with multiple small diesel generators. It can be as many as 8, 10, 12, depending upon what you're trying to accomplish in your vessel. By having many generators it gives us a major benefit by having a very efficient overall yacht operation. As you might imagine, when we're at high speed we have a lot of the generators running. When we're at low speed we may have only a few generators running. This is the real main way that we save fuel and have low emissions, by having only the number of diesel engines running to match the load that's required. And as you can imagine too, this adds significantly to reducing noise, reducing vibration. I put in a couple of slides—a lot of work has been done by our friends in the diesel engine, diesel generator world, to give us vibration dampening devices, these generator diesel engines do not have to be firmly fixed, they're not connected to the shaft line, noise hoods can be placed upon them and we can make them very very quiet. So the result in terms of the electrical propulsion the way we make power as well can be quiet and vibration free.

Slide no. 6. OK. I'm going to talk about superconductors finally. Well what does this have to do with it? The key thing is that we're taking technology, as Martin mentioned, from warships to superyachts. And I have to say that the cruise ships are in between, which is a real benefit. Technology has been developed in Naval war fighting machines like the photograph in the top left, the United States Navy, the DDG1000, all electric destroyer, similar vessels on the sea right now, the UK type 45, all electric frigate, the Queen Elizabeth 2, has 4 electrical propulsion plants, multiple diesel generators so not only do we have Navy, militarised, but we can also pool from the commercial marine industry. Our friends at Feadship have many choices of electric vessel, you'll probably see them at the conference in the exhibits this year. So electrical propulsion is coming into our industry. The magic of superconductors—what's that about? Let's talk about that a minute.

Slide no. 7 please. No.7—I'm going to talk about my fun stuff now. This graphic on the right, Esther has a display that you all have a chance to take a look at we hope. This superconductor is absolutely magic, I can not describe it any other way. These very small wires on the right side of this photograph have the same power capability as that amount of copper on the left side of the slide. They're significantly smaller, obviously significantly lighter and because they have zero DC electrical resistance they are a perfect conductor of electricity. They were discovered initially in 1911, they've been around almost 100 years—metallic superconductors require cooling at a very low temperature, 4° Kelvin. They're used in hospitals, those of us who've had an MRI have been in a superconducting magnet made of superconductors, the sound you hear in the background is the cooling system making the 4° Kelvin. Those wires were used to make motors and generators but were not successful because of the cooling system being very large, very complex. Good news—in 1986—a new kind of superconductor was discovered by IBM made of ceramics and the promise of this superconductor—and this is the one that we use today in motors and generators and cables and transformers and a wide variety of things—operate at a much higher temperature—a temperature that allows us to have a cooling system that is very similar to the cooling system that we have in the galley of the ship. The same technology, the same kind of maintenance that's used to keep refrigerators cold on ships can be used to keep the superconducting propulsion motors at the temperature they need. At the right temperature these wires conduct over 100 times the power of their size compared to copper. So this is the revolutionising the marine propulsion industry that Martin mentioned. This is why Navies of the world particularly are looking to superconductors to take the weight out, weight that they don't need, for the thirty or forty or fifty years that these vessels are going to sail the high seas, and have a small compact machine.

Let's go to the next slide and let me show you what it does. Slide no. 8. The comparing technologies—I've got a few slides here to compare technologies between copper and superconductors—the big green monster in the background there is the motor that’s used on Carnival Cruise ships, Princess Class. One per shaft. With 180 metric tons, it's 21 Mw direct drive 150 rpm into the water. The small one next to it, in front of it, is the one that is being used by the United States Navy, developed by the Navy for the all electric warship; it's 75 tons, so it weighs under 50% of the big copper one, and if you notice the fine print it's actually 36 Mw so it's almost twice as powerful. So the key, why you're sitting in the audience, why we're all talking about this, it's all about small size. It's all about lowering the weight, high efficiency, and quiet, low noise, a very critical part, the requirement that we have for cruise ships.

OK, the difference. Let's go to the next slide please. This is a little technical; the machine on the left is a copper warship, copper propulsion motor, and the bottom left side shows the rotor. The rotor is the part that turns. Those bars are copper bars, that’s been the technology over 100 years to use copper in the rotating member and of course the copper has losses, they have resistance, and they have to be cooled—the holes that you see right below those copper bars are the holes that are used to cool those copper conductors. On the right hand side is the good stuff, the superconductor. You can see one of our assembly people making a coil out of those superconducting wires, it makes a very large magnet if you will, and that replaces those copper bar conductors on the left. And yes, superconductors need to be cooled as well, so copper needs to be cooled, superconductors need to be cooled. So if we had a choice, which would you want on your vessel ? let's go to slide no. 9 and show you a couple more examples.

Slide 10. Again, on the left are military ship propulsion motors, the one on the left is used by the UK type 45, that ship is about 8,000 tons, two of those drive the ship at approximately 27 knots, all copper. On the right is the machine used by the US Navy, for a frigate, in this case a destroyer, over 14,000 tons, over 30 knots. Twice the power, and half the size. So again, which would you want for your military vessel.

Let's go to slide no. 11. Pop the top and look inside. We'll talk about this machine in a few minutes; this is the kind of rating of superconducting machine we would use in a superyacht. That animation that was running, it shows that the superconductors are on the inside. They are used on the rotor to make this motor much smaller, much more powerful and more efficient. Many of you in the audience know about podded propulsion. All these motors I've been talking about so far are in Hall.

Let's go to slide no. 12. Podded propulsion. We have all been through some of the successes and some of the struggles with pods. The size and weight is a critical thing but if you look inside you may see this animation going where the electrical motor inside by using superconductors can shrink in size thus making the pod much smaller, much higher hydrodynamic efficiency and HDS for pods is coming, and we'll have those in the next few years. OK let's talk for a minute about the motor itself and efficiency.

Slide no. 13. This is a little technical, but have you ever noticed on your ship as you go faster and faster it takes significantly more power to go faster. The engineers call this cubic function. The last few knots of speed is where most of the power is. And this circle on the top of this particular speed –v- power curve shows that when you're running at top speed, all electric ship, almost all of your diesel engines if not all your diesel engine generators are running, now you're at flank speed, you're running full out. Let's just click on that for one moment, Esther. And you'll see that if you're running at about half speed, because of the cubic nature of propellers and ships, if you run at about half speed you actually run at 1/8th the power, 1/8th the load. And so at half speed—well we spend a lot of our time at between ½ and full speed, we operate in a spot where we're not using as much fuel by far and can get a whole different set of operation. How does this affect the motor efficiency?

Let's go to slide 14 and look at the motor in both cases. Slide 14 shows in red a superconductor machine and blue a copper based machine. And where that circle is moved up to approximately again, that’s 20% of full load, which is about ½ speed for the ship, the difference between the 2 lines is energy savings. Superconductor machines are efficient, not only at full speed as are copper machines fairly efficient at full speed, but they're efficient all the way down in speed. And you're not heating up the engine room when you're operating at slow speeds. You heat up the engine room with copper because the motor gets warm because it's losing power, inefficient at the low speeds. So superconductor machines have an additional function—an additional feature is that if the mission of your yacht spends quite a bit of its time below full speed superconductors are very efficient, and again, efficiency is energy savings and fuel savings is low emissions.

Slide 15. I just want to spend a minute looking at this particular machine. It's rated 5Mw at 230 rpm which is a fairly interesting propeller speed and 5Mw is a fairly interesting power rating. A lot of yachts will be somewhere right around this area, sort of the entry power for superyachts, depending upon the top speed of the vessel and the weight, this may be something around 5,000 tons at around 20 knots. What is interesting about this machine, it was the first machine that American Superconductor made for the US Navy. This photograph is of it on test at a place called the Centre for Advanced Power Assistance in Florida. The machine is 2.5 metres long and just under 2 metres in diameter and if you notice the weight it says 23 tons. That’s about half the weight of what a copper machine would be. It's a pretty interesting photograph, you can see the guy on the left, that’s where the cooling comes in and goes out, it's very simple, looks like a standard motor other than that one spot by that guy's elbow. On the right hand side is the load for this superconductor motor. The US Navy wanted it to be tested on land first at full load.

If we go to slide 16 you'll notice from the other direction though it took 2 copper machines to fully test the superconductor machine. So you can see, which would you rather have on your ship. Two very large copper machines or one huge copper machine, or a superconductor machine per shaft.

OK. We wanted to just take another second or two and just give you a short video on slide 17. If you would just click on slide 17 Esther, and press the yes button *[Esther: the audio isn't playing, Rob]. [Rob:- does it say audio On?]*

[Video]
Shipbuilders and operators are constantly looking to new technologies to improve their competitive advantage. One such technology is high temperature superconductor marine propulsion motors and generators. This innovative rotating machine technology lets ship owners and operators lower operating costs and boost payload, while offering shipbuilders more flexibility to design innovative vessels. Best of all, the key to making these motors and generators work is based on well understood technology standard AC synchronous motors and generators. The only difference is that the coils of these rotating machines are made with superconductor wire which means the motor delivers power in a smaller, lighter package. So why all the interest in AC synchronous motors and generators powered by superconductor

technology? Carrying more than 150 times the power of copper wires of the same dimensions, superconductor wires are formed into coils and placed within a standard rotor to create very powerful electrical fields. The result—motors and generators that are powerful, yet ultra compact, measuring as little as one third the weight and one half the size of conventional machines of the same power and torque rating. Exceptionally efficient across the operating speed range, superconductor motors run with higher fuel efficiency and, because detrimental heating in the rotor is eliminated altogether rotating machines powered by superconductor wire will have lower maintenance costs than their conventional copper counterparts. Today, leading users of advanced technology are looking closely at the proven innovation that makes all these things possible. The application of superconductivity to electrical motors and generators, founded with a mission to develop superconductor wire and applications. American Superconductor is the world's leading supplier of HTS wire and rotating machines. In July 2003 American Superconductor delivered to the US Navy a 5 Mw, 230 rpm superconductor ship propulsion motor that successfully completed full load and ship mission profile dynamic simulation tests at the US Navy's Centre for Advanced Power Systems. A similar superconductor machine operating at 1800 rpm was delivered to the---
[Video ends]

Great, thanks. A little recap—and that video by the way is on our website and our friends at The Yacht Report will also have it available for you to take a look at superconductors at your leisure.

Slide no. 18. And so in conclusion, just before questions and answers, I just wanted to recap the main benefits of superconductor propulsion motors. High power density is often talked about, meaning significant weight reduction, significant size reduction, lower shaft heights, your superconductor motor can be further aft in the vessel if you want to, improved efficiencies at all operating speeds, and that yields environmentally green low emissions, and superior acoustic performance. Performance that you can not get with mechanical propulsion or even copper electrical machines. And then lastly, superconductors may enable an engine room layout that you wouldn't be able to get any other way by having a small compact main propulsion machine. OK.

Slide no. 19 and questions?

Martin

OK Rob thank you very much. Can I have some light please and the microphone girls at the ready please. I have a question straight away in the front, Elena?

David Reams Camper & Nicholsons, USA

I was just curious, the temperature range that these are operating at, the cooling requirement and the longevity of the ceramic linings ?

Rob

Yes, very good questions, David. To the yacht, the motor is a motor. It looks like a motor, it feels like a motor, if you put your hand on the outside its warm. It's a standard class F they talk about. There's no place in the motor you can touch that's cold. The cooling system is somewhere else, the architect has flexibility of putting the compressor that makes the cold anywhere, 30-40 metres away if they wish. The wire itself, superconductors become superconducting below 100 Kelvin, we use the word Kelvin—zero Kelvin is absolutely zero. 100 Kelvin is pretty cold, it's minus 200 C, so the inside of the machine is cold. The benefit of that is, it never warms up, never cools down, stays at one temperature, which leads to great longevity, so your last question, David, this has been tested by labs around the world, similarly by the US Navy, and they foresee never having to replace or rebuild the motor in the life of the vessel.

Martin

OK, thank you. Any other questions?

Andy Chase Maine Maritime Academy

Can you run that by me one more time, I'm still not sorting out—there's warmth, and there's cold there.

Rob

Another good question. Motors have two parts to them; the part called the stator, which doesn't move, and these machines are really AC motors, no different than we learned about 100 years ago. The outside of it uses copper wire, that's where the speed control is operating, it's on the outside, the copper wire, the stator, 3 phase marinised motor controller made by ABB, Siemens, etc. That's warm because it's copper, and it'll feel like a normal motor. What's different is the rotors inside, I showed a couple of little videos with the rotors spinning around inside. Those use superconducting wire and so if there's a trick, it's to get the cold into the centre and keep the cold next to the outside, which is very warm. And this has been proven, American Superconductor, we've been making motors now for 16 years. And we've had modal pool references where we've done this and as you develop it over the years, it isn't as difficult as it might appear on the outside, but good question, Andy. Warm on the outside because it's copper, cold on the inside where the good stuff is, superconductors.

Andy

Just to further clarify, so you can achieve that kind of temperature with a normal refrigeration unit, is that right?

Rob

Yep. A single stage high expansion valve as I said, similar to what we have in the galley of the ship—what we have used, frankly, is the same compressors that are used in hospitals, you can get parts anywhere in the world, there's 30,000 MRIs in the world; we use the same cooling system that is used in those hospitals. Very very simple cooling system.

Jeff Partin Bartram & Brakenhoff

If you wanted to put one of these in your superyacht today what's the cost for a 5 Mw motor and lead time for delivery?

Rob

The lead time is very similar to a large marine propulsion motor, probably in the neighbourhood of 30 months. Could be a little quicker maybe. It's not just because of the superconductor part, it's just the process to properly develop the propulsion for the unique space and requirements of the yacht. The motors today are typically about twice the price, prices are coming down every year. The beautiful thing about superconductors is our wire price, this year is dropping 20% of what it was last year because our volumes are coming up. These wires are not just made only by American Superconductor, we're not the only people doing this, by the way. So it's not like it's so unique only the US Navy can afford it or would want it. But the prices are coming down. In the whole propulsion scheme, because the switchboards stay the same, the generators stay the same, the motor controllers stay the same, it probably adds less than 5% to the cost of the propulsion overall.

Tork

One question is, the outer wiring is copper and the inner is superconductor. Is there any particular reason why they both couldn’t be superconductor giving even greater weight and size savings?

Rob

I keep asking my engineers that question too. The difference is, it gets a little technical, sorry. The rotor is direct current, these are AC synchronous motors and a synchronous motor uses a DC inside on the rotor and that DC field—and we can make a very powerful field with the superconductor—exactly locks in on the rotating field that’s in the stator, I know I said rotating and stator, but the field actually electrically moves around the stator and so it's DC, and superconductors have zero resistance when it's direct current. When it's alternating current in many cases they do not work well and so in electrical motors in the stator area, no-one has developed a superconducting stator. So it really comes down to giving—the way I describe it is if I can put these superconductors in the hands of very smart motor and generator engineers they’ll figure out how to do it and the place that they've done it is in DC coils.

Martin

OK any further questions?

Hugo Modderman DVB

This may be a stupid question, I have no idea of technology. Do you use conventional bearings or do you use ceramic bearings?

Rob

No, that’s a very good question. The shafts are standard Ford shafts, the bearings can be standard marinised sleeve bearings depending upon the speed, they can be anti friction bearings, typically not thrust bearings, you know usually thrust is another bearing somewhere between the propulsion motor and the propeller but they're standard bearings, standard lubrication systems, they're fairly low speed in this case, so it's very easy to maintain. The shaft is warm to the touch, it feels like any motor, the maintenance people who deal with bearings see nothing special.

Tom Patterson The Yacht Report

I've tracked a company on the West Coast in California for the last 4-5 years that’s been developing diesel electric power for smaller vessels than superyachts but they use all DC power. You may have partially answered the question two questions ago. But would it not be better to use a fully DC motor rather than a hybrid ?

Rob

Maybe. DC motors—there are many different kinds. If you remember DC about 20 years ago the big problem was brushes. A DC motor requires that electrical power commutates from the outside of the motor to the inside of the motor, so you have very nasty carbon brushes which are high maintenance and it is a device that degrades over life. DC machines typically need to be reworked, first of all maintained, continuously, brushes have to be changed, you may have to—we call stoning the commutator to get it back to life again. But it's been our experience with DC machines that you may have a rebuild somewhere within the life of the vessel, so I don’t know the specific diesel generator company you mentioned, Tom, there are a number of technologies for DC generators that have recognised the problem with commutating brushes and they may have another way but right now most Navy and commercial vessels very much want to not have commutators on their ships.

Martin

OK thank you. Jurgen, you have a question?

Jurgen Engelskriegen ThyssenKrupp Marine Systems

Can you a little bit expand on the classification society requirements for such motors in commercial yachts or let's say yachts, and mode analysis for instance, what happens—I understand the cooling comes through the rotating part so what happens in case of failure of the supply of the cooling liquid?

Rob

I have met with Lloyds and they have looked at our technology and see no problems. Interestingly our friends at Lloyds and Germanischer Lloyd etc—they're almost more interested in the stator which is the copper part. They realise that stators have to get the heat out as well and those of you who know electrical propulsion ships, you see that there are air to water coolers and sometimes oil coolers and all sorts of stuff to get the heat out of that copper. They kind of look at the rotor and say wow, that doesn’t have the same problems. It's kind of nice from that viewpoint. So yes, for certification these machines are made by the same guys who make the copper machines, you know Siemens etc, they use American Superconductor wire and some of our technology but they hold the classification, they make certain that the rules are followed. Second part of your question, the failure part. Yes, you know a yacht owner who has one of these things, if he wants to get dead in the water, the thing that would fail, that would stop him would be the stator part, the outside. If the stator cooling system stops you’ve got to stop pretty quickly and fix that. Because there's no thermal inertia, if you will. It gets hotter and hotter pretty fast. So the maintenance guys have got to get down there and work on the stator cooling system. The rotor is quite different, we're bringing that cooling in but it is so well thermally insulated that typically you don’t have to do any maintenance, even if it stops for 2-4 days. It is so cold it stays cold for 2-4 days. Navies of the world worry about that, because they have other possibilities, if the cooling system is damaged, in a conflict or something the ship captain can still operate his vessel for many days, those motors stay cool. Jurgen your question might then become well, hey, how long does it take to get cold. It takes 3-4 days to get cold. So the good news is you don’t have to worry about it if you're at sea, you can get home. But you can't jump into your ship and turn on the switch, the motors have to be cold. But the way we explain that is that you know you typically leave the air conditioning running, your ship is never at port without power, you leave the cooling system on, it's very efficient, a few tens of kilowatts is what it takes and you keep your motors cold. By keeping them cold it improves their life, you can almost forget about them.

Martin

Thank you. One more question at the back.

Roger Marshall The Yacht Report

I've been hearing a lot lately about advanced induction motors being fairly large for yachts and from what I see here you have a very much smaller motor. Would you care to comment on the differences?

Rob

Yes actually Roger a good question. On the slides I showed I think there may be some literature you can pick up at the end of the seminar—one of those photographs is actually the so called advanced induction motor, that is the motor used by the UK type 45. The beauty of it is that it's been worked on for over 20 years and the idea here was to make a pretty ugly copper machine pretty. And they did a good job, they got out of it as much as they could in reducing the weight and its size but still it is twice the size of a superconductor machine. The only difference is that our superconductors, the motor technology is the same, it's just the conductor that changes.

Martin

OK. One more question.

Tork

One of the major problems of electric ships is the harmonic distortion on the current throughout the vessel caused by the frequency drives. I presume it's no more and no less with this, since you're using fundamentally the same frequency control.

Rob

You're exactly right. There's no difference in the frequency controller relative to this motor or any other marinised motor. The harmonics are on the line side, the bus side. Now there is a benefit though if you go to superconductor generators on your diesel engines. A superconductor generator can absorb harmonics and can provide cleaner power than other kinds of synchronous generators, so there is some benefit to superconductors but you're exactly right, to control the bus harmonics you have to look to the converter manufacturer. They have heard your industry clearly that these harmonics are a problem and are doing lots of investigation in the development to reduce that. But you're right, it's not the motor, it's the converter.

[From the floor]

My question is just answered!

Martin

What size do you think they'll come down to, Rob, to be able to do a generator propulsion system?

Rob

Well you know frankly, our wire is 4mm wide but the wire is basically about 100 amps. And so the practical answer is that OK, where a motor is using coils on their rotors that are 100 amps times the number of turns, so we're thinking that probably, depending upon the speed of the prop, that it starts getting interesting at that 3-5Mw area. And we love large. We really become dramatically different the larger and larger it goes. So I think that's the best way I can describe it.

Martin

OK. Rob, thank you very much indeed. Interesting subject and I think we'll tell everyone there's some information available—if you need anything ask Esther, she has some handouts and stuff. Rob, we'll speak to you again soon, thank you very much.
