AMERICAN SUPERYACHT FORUM 2008
24 - 27 June 2008 — Newport

Day 2 - 25 June 2008

The Propulsion Summit – Efficiency and Power

Tom Keefer	T3 Automation
Stephen Mazepink	MTU
Rob Rouse	American Superconductor Corporation

Chairman—Martin Redmayne

Good morning everyone. How are we all? Enjoyed our lobster? I'm sorry I'm 10 minutes behind schedule—I was trying to find something. And I found it. My hair. Someone has just spread a rumour that this is a transplant, and I'm just saying, it's not. It's real hair.

Tork

Of course the head is a transplant!

Martin

The brain! Getting straight into the first session of day 2—Propulsion. Sorry—someone's waving something at me. Someone's left a jacket behind somewhere so if anyone's lost a jacket, red lining, very expensive—the money's already gone, we took it. Talk to registration desk if you lost a jacket. OK.

We're going to start off with two short presentations from Tom Keefer and Steve Mazepink—the propulsion summit is mainly about the future of power and efficiency and the applications in the large yacht market—and I'm surprised how many are here, actually, after such a late night last night. Well done. Tom, over to you.

Tom Keefer T3 Automation

Tom Keefer—I'd like to share with you a little bit about marine gas turbine applications— *see if I can drive this. They gave us a little short presentation on how this is supposed to work but it doesn't. Oh, there we go.*

OK. Quick look at the slide here. What is a gas turbine? Lot of times people question me about that and I thought well, maybe everyone doesn't know. Matter of fact when I did my first project I thought it ran on propane, so this big vessel must have a large propane cylinder in it. But actually that refers to it uses hot gases to provide rotational energy. I'll get into some of the details here in a minute but it's a low pressure engine and what we mean by that is, everyone understands the diesel concept where fuel is introduced, pressure happens, and it causes that fuel to ignite. Well, because those pressures operate in tens of thousands of psi, the shell of that engine must be much like an explosion proof container and that adds to the weight and the size of the engine. Our engine only operates—in the front end of the compressor is at 15 psi and a little bit higher as it goes through the engine, but most of that force of the power is immediately directed to the turbine blades so it causes the shell to be much smaller.

Compact design, lower weight, higher powered weight ratio, and for this particular engine here 5600 horsepower in that little spot. A turbine has basically—it consumes, for one thing, fuel. And it really consumes air, a lot of air. 100 lbs a second. And that air comes in from both sides on the inlet, effectively the starter motor engages, air starts to come in, and as that air pressure advances in the gas producer sections—there's two sections of the engine—those fan blades will then direct that air into a chamber where fuel is introduced, an igniter comes on and that ignition happens, a ball of flame is generated into the power turbine section, which it starts to rotate, and absorbs that energy and then the control system ramps that up to idle speed or whatever throttle command you want. In the front end of the engine instead of running at 2300 rpm or some typical diesel speed it runs at 19,000 rpm. And then because no engine is perfectly efficient, that correlates to about 16,000 rpm going out. The exhaust comes out this section here and there's actually a shaft within a shaft so the output shaft going into the gearbox comes out the other side where you can't see that. This is one example of a turbine. It's a modular engine, it has a gas producer section, it has a combustor power turbine section, different gearboxes pull together, you can break the engine apart and reassemble it in less than 8 hours. On board in the engine room. It's easy to install, very compact in design and easily manoeuvred through small hatches. Some examples—for instance some boats only have turbines. This particular Mangusta has twin TF40 gas turbines, the WallyPower, which I have a lot of experience with, has 3 turbines but it also has 2 diesels so there is a provision for low power manoeuvrability in a harbour. Another example is this Cicero, it's a Feadship that has two large diesels and then they combine 2 gas turbines onto a single gearbox. And then recent additions have been this new Pershing that has two—I believe it's MTU 16 V4000 which deliver 32 knots or so of hull speed and then there's the single booster in the engine right below the toy garage for the water jets. One of the things that has happened recently, I mean you saw the engine, it's very very small, but what do you do with 16000 rpm going out. You can't stick it in the water. So you have to have a reduction gearbox. In the past these were monsters. You have an ultra small engine and a gearbox that’s almost the size of a traditional diesel. So what's the cost and other advantage? ZF recently introduced this high speed gearbox—I've talked about this before, we've done articles so I'm going to try and breeze through this as quickly as I can—last time I presented we were going to do it, now we've done it, and here's part of my presentation. Very compact in design, it's much lighter weight, less than one half the size of the previous gearbox. Simplified the operation, we've also added a new integrated turbine control system. We used to have a black box that ran the engine and then another control system that did all the peripheral devices. All that has been combined now. *[Excuse me, I'm losing my voice, hollering and yelling last night at the—*]

So this one unit combines all the functions of the gearbox, exhaust, fuel delivery and air inlets. We've added modular wiring harnesses so they just go to different sections of the engine room and all the componentry inside is built with common off the shelf equipment. If you were in Turkey and one of the modules had a fault, you could field replace it, no problem at all, without changing any wiring, there's self diagnostics, a lot of work has been done to make that the case. I think we've improved the user interface, we've tried to make it as streamlined as possible, not present too much information but make it depictive of the system and it'll help the common user develop a trust and belief in the system. One of the things that we did is use a new ZF control lever and I programmed—my job was the controls engineer over the project—and we put together a very simplified way of using it. Much like a diesel, start the engine, when it comes up we move forward, ahead, it clutches in when it needs power. When it's acceptable to use the power it begins to accept the throttle and apply that to the engine. We have operator stations in the control room area as well as on the bridge. And the result is that for this one Pershing 115 we can add 20 knots of speed in less than 8 seconds. It's a good gear to have, and it's not a very big gear to carry around. So that's a neat thing, can be well adapted and as I have presented in earlier slides, you could mix and match or try to use multiple units, or other things. A turbine is thought to be a very specialised thing, and people are a little bit misunderstanding about it, but every helicopter, every hovercraft, I mean these engines—many of you flew here on turbo props, if you live out in the country like I do and you come in on the turbo prop versus the jet. So what else could we do with the turbine? Cruise ships and many larger vessels now are using turbine electric. Again, if you stick to the classical thought that you need to run at 3600 rpm or 1800 rpm to generate 60 Hertz of power, you know additional gearboxes are going to be needed. But another concept is to use a permanent magnet generator alternator and it's basically a high speed, so instead of running at 3600 or 1800 a turbine's allowed to run at 15000 or 16000 rpm which as the speed of the generator increases so does the power that it generates. Now this is a little bit different thought, because we're not going to produce 60 Hertz of power, we're going to produce 150 Hertz of power and 8-900 volts. So additional power electronics need to be added to make the unit I guess work for the system. So it's directly coupled, there's no gearbox, this little package produces 4 megawatts of power. When I say flexible installation options, this doesn't necessarily need to be mounted in the engine room. If you've got a big enough vessel you could put it up on an upper deck where it can breathe, it doesn't get any salt, you can reduce the air volume requirements by not having the long shafts where you're going to have losses, so it's an incredible way to put a large amount of power in a very small place in the ship. Effectively you've got the air inlet coming in to the turbine, to the exhaust, directly coupled into the generator and then the additional power electronics. Here's an example of one—basically it's a diode bridge and Rob's going to have to help me with some of the electrical things here—but this is a very simple design and it allows—it's a reliable system, it's made with common readily available components that are available today. Here's an example of one at a test rig—this was done at the University of Texas recently. Not very attractive in the way they've laid the piping out in the hoses but look beyond that and you'll see basically you have exhaust here, air inlet coming in to the turbine, to a very small package here producing cooling and circuitry for that. But this unit right here is making 5 megawatts of power. Here's another example, I guess just to take home the point that by using this concept you can dramatically decrease the size and the weight requirements. Going quickly, I mean this unit went from 11,000 lbs to 1,800 lbs. That's a significant change. Last slide here—just a little bit on emissions. This particular engine already meets EPA tier 2 requirements, so you know the future—and I guess we'll talk about this later—is this something applicable for the yachting market? That's all I have for now, Martin.

Martin

Tom, thank you very much. Steve?

Stephen Mazepink MTU

Can I sit down and do this?

Martin

If you want to sit down, you can. Steve is shy you see.

Steve

Good morning, my name is Steve Mazepink, I'm from MTU Detroit Diesel, my corporate office is in Detroit, Michigan but I pretty much stay in the field. I'm going to address propulsion and look at it from the perspective of marine engines, what we're doing today, it's a little bit overlooked right now that we have some green technology available with the existing diesel power that's out there and I want to give you an idea of some of those technologies that could help what we're doing and maybe where the future is going.

I want to talk a little bit about short term, what we're doing and one of the things that we've undertaken at MTU —one of my co-workers is here, Ryan— is we've gotten into looking into the efficiency of the propulsion system. That means the propeller, the shafts, the appendages, the bottom of the hull. We've done 25 projects up to now with existing technology that's out there. And we've been able to find system efficiency anywhere from 5-10% savings. This means a lot. We started this out with a test boat that we did, a 70 foot sport fish boat, and we did considerably better with that, got into propeller design and basically what this all amounted to for us was better fuel economy and less emissions. We do this for a lot of the builders—if they asked us to we'd get involved with their projects and with the whole concept of how can we burn less fuel, what can we do to help you and to maybe help with the environment. This is a pretty easy approach and it's something that's easily done now, we're not trying to be naval architects even though Ryan is a naval architect—he's on our staff to help with propulsion solutions for our customers. And for this industry. The next phase of what we can do today is with emissions—is solutions—we're really looking at combustion and what we can do with combustion. That's something every engine manufacturer works on, the little problem is every time you change something in a combustion chamber you have to go through EPA again and re-certify your engine. We're always looking for a better way to get more out of the fuel, more horsepower out of the engine, and combustion technology is one of the big, big things we do. The next thing that's coming forward—this comes from the on-highway market and is basically where you re-circulate some of your exhaust gases back through the engine. It burns out the particulates, the problem is when you do this you actually have to put more fuel into the engine. They're using it on the highway—unfortunately EPA and a lot of regulatory agencies think if it can work in a truck it can work in a boat—but it really doesn't work that way. But it does involve burning more fuel. These two are very simple for us to do as an engine manufacturer because basically we do those on the engine, it takes no more space really in an engine room but it does cost you in fuel consumption for the second one especially. The third one you're going to see a lot about is basically—this is a urea formaldehyde system which basically injects urea into the exhaust system, this in turn reduces the knocks, we have this in application in a boat. The fortunate thing about this is it does exactly what it's supposed to do, is reduce emissions. The unfortunate thing is as boat builders you come to us and say hey, I need a more powerful engine but I want it smaller. We make the engine smaller and then we're hit with regulations to get rid of emissions and then we have to put something in the engine room that takes up all the space we gained for you by making our engines more compact and more powerful. It's a tough situation but we go into these meetings with EPA and this is what they put in front of us and we battle it for the industry saying who's going to carry bags of urea around on your yacht just so they can do this? Commercial boats can do it, especially boats with defined runs, because they can have facilities there to pump stuff in, to do whatever they have to do. But for a yacht going to some port, probably right now it's not practical. But it could be coming our way. The third one is basically a particulate filter and actually all these things have little abbreviations, it's just like our government, but this one is probably a very feasible project for yachts right now, and these are things that can be done right now aboard a yacht. This particulate filter works with heat—the problem there is you have the sustained 600° temperatures for a period of time in order to burn out the particulates. You can install a filter like this that you can remove and clean but it's a very large piece of apparatus. On top of that in order to maintain those temperatures you'd have to have this basically right up against the engine, wrap it in some way, so now you can't divert water in through an exhaust system where it will cool it because this relies on heat technology. We're only showing you these things because part of this presentation was about green technology. Diesel technology is here, it's not going to go away for quite some time, we're already working on the next tier level for our engines. But we do know that requirements like this are coming our way. So we already have 13 projects that are already out there and they involved I think 43 different engines on these 13 projects. Some are combined systems with filters, some are just a filter, some are a filter with other apparatus but we already are installing these 13 systems in yachts today, that’s strictly in the yacht programme that we're doing that. So the technology is out there, it's being used, we're making you aware of it in the event that it's something you want to know more about, I'm here, and also Ryan's here where we can get you information on that. So that’s what's going on today with our diesel engines that will help with the environment and green solutions to our environment. What's coming down the road? We're involved in several projects right now—this is a medium term project, this basically is L+G—it's basically an offshore supply vessel. This vessel is basically in the works right now, we will I think this vessel is going to be launched in—this is the Viking Energy and it's done in conjunction with another firm and this package is going together. L+G is something they're looking at, a combination of fuels, this particular study here is going to be very easy to do because the boat's going to be up in cold climates—and as you know, storing L+G aboard a boat has some hazards associated with it but it is a future that we probably may see, it'll be combined fuels, low fuel applications in the future but we are looking into this and we are doing this with a group of other people in order to see if it is feasible to do. But this boat is a reality, it's in the works right now and it'll be basically diesel electric drive which we alluded to a little back there.

The next big one we all hear about all the time—we hear about it in cars—and that’s the fuel cell. It is basically in the works—we are doing a land based test cell—the US Naval Research Organisation has contracted for 2009 for a land based demonstration unit. This is probably the real future of what propulsion will be. There'll always be the diesel engines. The tough part about this right now is that when you first saw the first diesel engines, and we supplied many to boat builders, they were enormous. To get this thing down to produce the power we're going to have to produce, and make it a feasible size for yacht application is the challenge. So we're working on it, this ship is a reality, and it started in 2003 and the project will conclude with the installation of fuel cell in a new build L+G ship in 2010. So we are doing these things, but once again our core business is diesel engines and we will continue to develop the diesel engine, continue to make it more environmentally friendly, looking for all kinds of technologies we can add to the diesel engine. We are also aware that this is the future of where things could go. So we're investing money into this and this could be part of our long term solution for the power aboard yachts, it's extremely clean, and so you'll hear more and more about this as time goes on. So there will be land based test cells for this, actually going together very soon and then this ship will be launched in 2010. So that’s kind of where we are, where our focus is, in order not only to supply you with propulsion power but also to supply you clean energy for your vessels going forward for your customers.

Martin

Steve, thank you very much. Rob—add your perspective—a different one.

Rob Rouse American Superconductor Corporation

Thanks Martin. I'm with a company called American Superconductor here, just outside of Boston. I appreciate being offered back—I gave a presentation at the Global Superyacht Forum on what we do at American Superconductor and the key theme— and I'll be here all week, I want to meet with everyone to talk about it—is all-electric ships. Or sometimes called diesel-electric in the yacht industry. All electric ships, as Steve just mentioned and Tom just mentioned, are based upon creating electrical power on your ship, not only for ships' service needs but of course for propulsion. The problem with taking a yacht that has been on mechanical propulsion, diesel engine or gas turbine for example, and going to all electrical, is that there's more stuff. The architect looks at all the different power generators that need to be on board, they look at the converters and the switchboards that are needed to convert a massive amount of power for propulsion and when you go to fit it into the engine room and the electrical service spaces we find that there's less and less room and we're starting to encroach upon spaces that the owner wants to use obviously for other things. Our company, because we use a different conductor, a very lightweight and small electrical conductor, we can make generators and motors very small. We have been funded by the United States Navy for the last 8 years to make compact yet powerful propulsion motors for the US Navy and through the opportunity for dual use, you can use it within commercial cruise ships and yachts. What this effectively does in most cases is for a fairly large yacht we can save a number of metres of length which is usually the key thing on the yacht, in the motor area and often 10-15% in the generator area as well. Doesn’t sound like a lot but when you're trying to fit it all together it ends up being very significant. We're actually fairly close to getting our first yacht with superconductor propulsion motors. Just a word on diesel electric or all electrical—the key to efficiency—I'm not sure that the panel here actually explained it quite right, quite well or sufficiently, is that you have multiple power sources. You may have a couple of tons of gas turbines for very high power for peak loads when you're at flank speeds, you'd have Steve's diesel generators when you're loitering or at cruising speeds, all the power that you generate on ship goes into a common electrical power distribution used by the propulsion motors. Now these gas turbines and diesel engines can be mounted in very multiple ways that remove them from the structure, they're on vibration dampening, they're in noise hoods often, your gas turbine may be up high in the vessel and you're at flank speed so you don’t hear it but the motors are attached to the hull. It's fixed to the hull because it's affixed to the propeller shaft or the water jet and so anything that the motor makes in terms of vibration or noise, immediately gets put into the hull. So one of the attributes too of electrical propulsion is to have a very quiet motor. A motor that runs very smoothly without vibration so we can reduce—in fact in many cases eliminate—effectively the so called structure-born vibration noise. So there are many attributes—obviously at American Superconductor we encourage clients and designers to go to all electric for the attributes of matching the power produced to the power needed, to having a selection of a number and choice of electrical prime movers and generators and then of course taking the opportunity of using smaller generators, smaller motors, to give back some of the space that electrical propulsion requires. If you have a chance this week, I'll be here all week, I have the enemy here, which is copper—I usually pass it around, I'll pass it round if you come by our stand—I've just realised I can't really do it in a group like this, but I can do this—that’s copper. An equivalent amount of superconductors we make in Massachusetts—these are electrical wires, equivalent power to 1200 amps to this much copper and a little different in terms in the ability of that wire to make a more power dense machine. And so please look me up this week and I'll talk to you about superconductors.

Martin

OK, Rob, thank you very much indeed. Can I have bit more light on the audience please. Arms go up straight away.

[From the floor]

Rob, what temperature are your superconductors operating at and what is the cooling source?

Rob

Good question. These electrical wires—the material that they're made of was discovered by IBM in 1986. It's actually ceramic and the definition of superconductor is that it has zero electrical resistance and that's why they're small. But the not so positive news is that you have to be cold. Many materials as they get colder and colder and colder lose resistance—these are amongst the class that lose resistance totally. They're called high temperature superconductors and that's because at the time they were discovered superconductors to that point, which are used in MRI magnets mostly in hospitals, is very cold, close to absolute zero, 4° Kelvin. These actually operate higher than that, we sometimes say 20 times higher. If you multiply 20 x 4 you end up with 80 Kelvin, which is about -200°C. Sounds very cold and very difficult, the reality is it uses the same kind of compressor and expansion valve that we use on refrigeration in the galley aboard ship. And so the maintenance is very much the same. But you do turn it on, you do leave it on, it does create the cold that the motor and the generator need, people ask well, what if the compressor stops? You can run your vessel for days, that's one of the key requirements of the US Navy—that without cooling, to be able to run for days. If it's been on running for days then it does warm up and the superconductors quit and stop being perfectly non resistant.

Martin

Yes, Roger please?

Roger Marshall The Yacht Report

How long does it take to supercool your system before you can use the motors?

Rob

A good question. It really depends upon the size of the machine, generators are fairly quick to cool down, you may have one day. Motors if they're very large, and some of the largest yachts may take as many as 3 days to cool down. But that's why it also takes 3 days to warm up. And so we do recommend, just like you leave the air conditioning on when you're in dock, leave the cooling on to the compressor, it's not a lot of power to keep the compressor running but it does take a few days to cool down, a few days to warm up.

Tork

Rob, in terms of how much power does it take, as a percentage of the motor power, and also when you take into the account the refrigeration plant and the motor, is the power density still greater than it would be with a conventional electrical motor?

Rob

Yes. The rule of thumb there is the refrigeration is .1% of the power of the motor, so if it's a 5 megawatt motor you're looking at 5000 kws of power required for cooling, so a fairly small amount of power. The net efficiency, typical copper propulsion motor is in the neighbourhood of 95% or 96% efficient. By the way that 5% is heat in the engine room, in the motor room. It's heat—you've got water jacketed motors, you've got to get the heat out. With superconducting propulsion motors typically 2% or more more efficient, I've done some work with the cruise ships, we've gotten the propulsion motors up to 99% efficient. And that includes the refrigeration. In terms of physical size, the refrigeration about half the size of this table, and it does not have to be mounted close to the motor or the generator, it can be mounted on a different deck. There's a tube that goes between the refrigeration and the machine and that's an insulated tube so there is some plumbing, but it can be mounted in a place that's convenient for maintenance or even a different deck, to keep it out of usable space.

Martin

Yes, thank you.

[From the floor]

What are the relative efficiencies between the diesel electric and the turbine and the turbine electric—and Mr Rouse just addressed how the superconductors can increase that but—

Rob

If I could just mention about the comparison. And don't think about superconductors for the moment. When you're at flank speed let's say, just take top speed, and if you could do it by mechanical propulsion versus electrical propulsion, then the electrical propulsion would be 4-5% less efficient. Why? Because we're making electricity in a generator and that generator loses power. We're taking the electricity through switchboards and converters which lose power, and then into the electrical motor which loses power. So at the top speeds for example then the efficiency is less for an all-electric vessel. The key to efficiency improvement though is that very often, most often, vessels rarely operate at flank speed, particularly in our industry of yachting. And so you spend most of your time, it depends upon the mission, the work to be done, in a loitering mode. Where there the benefit is we can now turn off the gas turbines which gave us very high power, go to a fewer number of diesel engines, match the number of diesel engine generators to match the load and we save energy tremendously then. So we look at the whole duty of the work to be done, the kind of profile of the propulsion of the vessel and you run the maths, we can have some vessels be quite efficient, with mechanicals such as container ships, which run at one speed from Asia to America and back, to vessels such as Navy vessels which circle around off the coast of Kuwait, making circles in the ocean, which need to be efficient at that point to vessels that I mentioned later. Does that answer your question?

Martin

Any comment from the other two?

Steve

I can just tell you that we've been involved in diesel electric drives for many years, it's something we see more and more demand for, the finite control you have over an electric drive—we see that as something people are really looking for. We also find, as I said earlier, that up until now even though everybody goes out and tries to build the perfect boat, until we got involved and really looked at the efficiencies of what was going on between a shaft spinning in the water, appendages under the boat, struts, whatever, you name it, we came to realise that we demanded more and more power but making that power stick to the water was the big challenge and maybe we weren't all really geared up for it. That led us to go in to our—we call it QED—where we're actually trying to make sure that we get every ounce of usable power out of our engines to the vessel. By that I mean a better cruising speed, alternately we're looking to give better fuel consumption. There is a power loss, you've got a power loss through the gearboxes, you've got a power loss with the shafts spinning in the water, so it depends on the size of the boat, it depends on the size of the appendages and everything else related, whether it be stabilisers, or whatever. They all contribute to the economy of what's going on. So there's power losses, there's no set rule that we have, that can tell you how much we're really losing, but just to support what you're saying we see more and more of the diesel electric drives and the interest in diesel electric drives. That's what prompted a lot of the emission controls, the filter was that they wanted a sound proof enclosure by us, they wanted a filter from us, as well as a diesel drive, so that's all we supply, and then someone else supplied electric power, the motors to turn the shafts and do whatever and it's been another aspect of our business.

Tork

I'd always assumed that the electric ship was the logical way to go, especially for larger yachts. But I recently had a conversation with a naval architect—they actually had designed a vessel, looked at diesel electric power, and moved to conventional power because it was relatively small accommodation for the overall size, it was actually not efficient, they said. It was more expensive, it took up more space. That I sort of found counter intuitive. They said also that cruise ships are the logical candidates for diesel electric because they have massive hotel loads, for their given size, whereas a yacht doesn't have as much hotel loads for a given LOA.

Steve

I think some of the features that have come about in diesel electrical drives was and he alluded to it here that you know, it's a generator, it's isolated, you know when we isolate, we put an engine down in the engine room or you put the engine down there and try to isolate the best you can but there's all these elements that go through the shaft, through the propeller and you always feel this vibration—the one thing I can just support what you're saying is the diesel electric drive, you can mount that diesel engine in such a way that it's confined in its own little container, it doesn't take maybe as much room as the large propulsion engine so you have a very smooth running, a very quiet and for customer comfort, it's great. Naturally to some degree it doesn't matter to us, we want to sell you a diesel engine, so whether you put it on a generator or whether you put it on propulsion is fine. With the new technologies coming out some of the new propulsion systems—we've seen combinations— when I was in Monaco 2 years ago I saw a boat builder that actually had a display where it had basically the equivalent of a dual prop, one of those props that's electrically driven, with an electric motor and a second one was mechanically driven by a diesel engine. There's a blend of everything going on right now and what the ultimate propulsion system will be, is why we're all here to try to find out. But the key thing that will ultimately steer us will be what the EPA environmental people keep dropping on us in order to create, and maybe a hybrid system where we're combining a lot of stuff.

Tork

Actually, touching on EPA and MARPOL, I know they're the 1000 lb gorilla and you can't do much to change them, but I'm left with the impression that actually they focus on one aspect of pollution such as knocks, and by focussing on that they're actually creating a need to use more fuel, therefore producing more particulate matter and more CO2 but we've reduced the knocks. Is that impression correct?

Steve

To some degree, yes. You know, whether you're aware of what has to happen before an engine meets EPA rules, I mean there's considerable amount of testing I thought it very interesting yesterday where people were talking about minimum standards and for us, we get an engine certified for EPA, we certify all our engines to a commercial rating, which is the most stringent ruling, and that way we automatically fall back to recreational. But we make the investment now knowing it's going to get tougher and tougher. We were lucky enough to have some people involved with EPA when they were talking about oh you have to put this on the engine and we were saying whoa—just because it works on a bus it doesn't work on a boat. But EPA I think is becoming more and more aware of what's going on in the marine industry, it's not like the transportation industry, we are strictly at MTU off highway, we deal with the off highway market, so we don't have the same requirements that they may have for the people that are building trucks or whatever. But the marine industry just seems to me, when I talk to our people in Detroit and the people that are involved in this, is they haven't a clue what's going on on board yachts. I heard somebody in one of the things about a regulation yesterday saying they don't really understand what we do, and in some cases they don't understand—how are you going to put this big urea tank in a yacht to ingest this into the exhaust to make it cleaner? You just can't do it unless you're going to build a tanker and ride around for the sake of it. I think ultimately whether it be the multiple fuel systems, or the fuel cells, I think there's going to be combination of what is going to really be the prime movers in some of these things, and that's basically why, it's not just us, Caterpillar etc we're all working and looking to what the future may be.

Martin

Any more questions out there?

Tork

Tom. Your permanent magnet generator system, 4 megawatts. How do we size down to sizes that are suitable for an electric ship installation of multiple power sources?

Tom

Tork, it's a good question. Again I just started to understand this device was out there, the company that I worked with that has the turbines definitely don't have the turbines in all the ranges of power. However if you look at Elliott Micro Turbines or some of these other people, there are a lot of smaller turbines out there that could be adapted to use in a much smaller generator package.

Tork

I mean, it's scaleable? The permanent magnet generator is completely scaleable?

Tom

I think what the real concept is is that you're taking a very efficient generator and a very small size and running it at higher than 3600 or 1800 rpm and generating more power with it in a smaller space.

Tork

But presumably because of the need for the power electronics, there must be a kind of cut off point at which the power trans get too big?

Tom

Exactly. There's certain—and I'm not one to be able to answer that entire question—but there are people, and if there's anyone that wants to find more out about that we can email in and make sure that they have the right contacts with people who will get back to them.

Martin

Steve, we talked about delivery dates and stuff on engines these days. Is that creating a problem with new technologies? Pushing people towards new technologies?

Steve

Well, technology is constant. As you know, there are several engine manufacturers that are strictly dedicated into manufacture, so the technology, in order to—in some of us—I see a couple of customers here who we delivered some of our 2000 series engines which was basically only a marine diesel engine, it's the only thing it's used for, so we constantly, as well as the other manufacturers, are always looking for the newest technology. We run into the same situation that gearbox people run into, and that's the availability of materials. We can't do everything in house. We're not gear cutters, so we don't run into the problem of machining a gear for an engine, we out-source that. Grinding a cam, getting a camshaft. But when Mike needs an engine—we have to forecast, and it's not that we're trying to count our money before we take an order, but a crankshaft for a 4000 series engine, we have to put that order in for that crankshaft a year in advance. Then if you want a certified engine, it has to follow another procedure, so delivery—manufacturing—our facility can manufacture the engines. Delivery, because of materials, is an issue no matter where you go and a factory as big as our factory in Germany can only machine X amount, this is one part of the business. We've got the mining business, whatever. And this is not the major portion of our business so we naturally go on and try to steer towards where we make our cash—we need a lot of support for our research we have to do in the marine market. Because it's unique. But material and forecasting and I think the lady yesterday addressed it, it's a nightmare. And you have to think a year in advance about how many crankshafts. And if I order 8 cylinder crankshafts I'm naturally going to need 16, so it's tough.

Martin

And is it causing a logjam today for you?

Steve

Not so much a logjam for us—we're able to build. But we really do understand, because it's a little more unique—like when we order a transmission and I'm not picking on ZF or anybody, but if we used to supply the gearboxes with our engines at Detroit diesel days, and naturally if you had 50 of a two to one gearbox just as an example, everybody wanted one and a half to one. And the gearcutting became the issue, not so much that the casting that the gears went in was actually cut to the proper ratios, and oddball ratio, that's what took time. So our components basically for an engine, we know a year in advance probably what we're going to build. It's the stuff that we have to bolt on to the engine. It could be a gen set, it could be a gearbox. They're the things that actually put a little bit of a hitch in the pipeline, if people could just take delivery of their engines without some of these other components in come cases we could do it. But we have a policy that in some cases we won't start your engine until we know your gearbox has a delivery date to us because we don't want to build a 16v 4000 and have it sitting in a corner for 4 months waiting to go. It's just that there's no value in that for us. There's no value to you in it either for an engine.

Martin

There's a question over there?

Ken Clark Fuerte Amador Resort + Marina, Panama

Do you see any impact on the changes in propulsion systems for shore based services on fuelling, bunkering and lubricants regarding ultra low sulphur diesel fuel changes in lubricants etc?

Steve

I can't 100% answer that but I can tell you what we are finding. I was lucky enough to be part of a presentation with the people from Burger during the summer when we talked about fuel, and not just fuel, what's available with sulphur, without sulphur, whatever, but some of the quality of the fuel that we were getting, and we talked about fuel polishing and everything else. Yes, there are lubricants, but the fuels that come in, it does affect the quality of the lubricants in the engine, we are constantly constantly testing, looking for lubricants, and we make a list of the lubricants we recommend for an engine, and we try to keep everybody up to speed, but it's not uncommon for a lubricant manufacturer to change his spec a little bit and we don't find out until after we see adverse effect on an engine. It's happened time and time again. So it is a big problem, making sure that we're kept abreast of what people are doing with fuel, with lubricants, and we have a group that just studies that to make sure. We're always doing fuel samples, going back to people and saying you have to do this, you have to do this. Because some of the fuel when you look at it, and engines don't perform right, there's smoke coming out the back, and naturally it's the engine's fault, and you do a fuel analysis and you find out that it's not the engine's fault, it's what you're trying to make the engine do with what you put in there. And it's not your fault either, but we all have to monitor what's going on, because it's naturally when it smokes everybody says oh, there's a diesel boat. And that's not the image we want. So we're paying a lot more attention to fuels and the quality of fuels and right now based on some of the fuel samples we've got around different areas, we have some good fuel here but go to some other countries, other ports, and you'll be surprised at the fuel quality of what you get over there.

Martin

Thank you. Tom?

[From the floor]

Yes, just to add a comment to the delivery lead time issue. I hearken back to what Kirstin said yesterday —if we can't play the blame game on this supply versus demand. There's plenty of blame to go around but the key to this is information, like Steve said, we may be used to providing 2 to 1 reduction gears in great quantities for a builder and all of a sudden word comes out that they're going to 2½ to 1 or 2.75 to 1. Well we have stacks of ratio sets for 2 to 1 that we planned, OK. Well the key to this is, when the builder is thinking about going to 2½ to 1 they need to make that information available to the supply chain. Not when they've made the actual decision to do that, we're thinking about changing the shaft angle so we can put a larger prop on the vessel and we'll need deeper reduction. Now we can tell the factory that we have to change our plan, they're thinking about doing this. And then when the decision is actually made—so the key to this, like Kirstin said, is sharing of information. And certainly as a good partner and good supplier, any one of us should maintain a confidentiality with our customers and that information is something that we keep to ourselves so we use it for planning and in that process we can improve the whole supply versus demand issue here. I have a question for Tom. What are the delivery lead times on those—the gears from ZF for the turbines?

Tom

The ZF gears I believe are available today because they built like 8 or 10 of them at once

[From the floor]

Well you just wait a while and that'll change!!

Martin

Yes, you have a question over there?

Peter Ho Bradford Marine

Steve, is there a percentage for replacement parts when you're placing your orders for cranks for example? Most of them are for new engines but in the refit industry one of the problems we have is getting replacement parts for MTUs and for Cats and for all diesel engines. So do you have a formula where you have X amount of heads?

Steve

Based on a population of what basic engine supplier builds, as far as if we're going to build, say 1000 engines, naturally you know there's going to be a certain mortality rate of those parts so it's a percentage, yes there is. I can't tell you exactly what it is, and keeping those parts and the wearable parts, the part you know will wear out, naturally there can always be a catastrophic failure and that completely throws things out because you don't stock a block or whatever. But over the years and based on our experience because we've been very involved with the military, homeland security here, and different navies all around the world, you get to a point where you kind of understand what more than likely you're going to have to have and you stock those parts. Naturally when something kicks into high gear like the oil industry, parts get gobbled up—you can't avoid it, and they have tendency because they don't want to be down, just as a yacht owner doesn't want to be—they buy up in bulk some case and they just have all those parts in stock ready to go in case they have a failure. But what we try to do is, we try to keep enough parts based on the population of engines that are out there, not just today's engines but because we're so involved with the military we have engines 10 or 15 years old that we just have to keep parts on the shelf for. So we have a pretty good population of parts we continue to develop that, we are even expanding our parts programme because we're finding some engines, because if they re-power they have to meet new requirements with the new engines—instead of re-powering they're just saying fix my engine —it's very economical, it's lasted me all these years. So we find that we're repairing and overhauling and doing different W5s or whatever, required maintenance programmes that we as a factory say here's what you should be doing, this amount of hours or whatever. So because we recommend that, because we know what will be involved when you do those overhauls, we have those parts available. I hope that answers what you're saying. But it's not just us, it's all engine manufacturers. We all know the importance of keeping the customer happy and having everything done in a timely manner.

Martin

Thank you. One last question here.

Don Gale AMSEC

This is a question for you Tom. Just to either verify or dispel something that I've always generally assumed. We all know what can happen when we assume. I just wanted to—is it true that generally for gas turbines while the weight savings over an equivalent horsepower diesel installed is definitely huge? Don't they also have much greater fuel requirements? For example isn't the specific fuel use per horsepower for a gas turbine usually much higher than for a diesel, or is that something that I just misbelieved.

Tom

No, you're right. But the word significant is the question. A turbine typically runs at about 10-15% more fuel than a traditional diesel at that same power and weight. So it becomes a question of available space, available power, and how often you use that power. When you start those weight, those options for instance on this one Pershing, I mean they could achieve 32 knots with this one engine configuration. The turbine was so small that we were able also to fit it into the engine room with the way that they placed the other componentry which gave them an additional 20 knots of power. They don't use it all the time, although for this particular owner he is so happy with it he tends to use it often—but you're able to put 5600 hp and I keep using that one number for that one particular turbine, there's other turbines out there—they do burn more fuel but they're best run at their higher end. There's really no fuel efficiency savings to run a turbine at 50% or 20% or 30%. You tend to run a turbine at the upper end because that's where the engine best performs, and gets its best fuel economy compared with a diesel. You don't tend to run it wide open, not that you're burning excess amount of fuel but that is taking engine life, because you're running the engine at higher elevated temperatures. So you hear terms of mip, and mcp. (maximum instantaneous power and maximum continuous power). Much the same reason that a pilot backs off after he takes off, once he's up in the air. So you're right. A turbine does consume more fuel, however that percentage of 10-15%, maybe 20%, depending on the way the engine room breathes, is something that is just a balance, as again with all these questions. What's the right approach for each vessel.

Don

Yes, it sounds as if you answered one of the other questions I had—roughly 10-20% more fuel consumption per horsepower. It would then be a matter of just making sure that in order to have a reasonable cruising range I would just want to be sure that I'm not adding so much more fuel to my fuel load that I'm offsetting my weight savings.

Tom

That is a calculation you have to do. But often, most of these vessels—for instance one I'm working on, are run in the Med. I mean we go from Corsica to Sardinia in 45 minutes, from Porto Cervo to the other side. We can go from Genoa to Monte Carlo in an hour and a half. So I mean you're doing very short burst runs with this type of technology.

Martin

Do you have a good back surgeon?

Tom

We strap in.

Martin

Alright. Thank you very much guys. We're going to do a quick changeover now for our second panel of the morning. Can my sub contractors and suppliers come up? Ken, Dan, Rick and Wayne. Sounds like a boy band.