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"My role is to create design requirements based on the feedback that I get from customers and dealers. I would say that communication, that interaction with the end user, is the most enjoyable part of it."

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1. WHEN WILL THE REQUIRED U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA) TIER 4 FINAL AND INTERNATIONAL MARITIME ORGANIZATION (IMO) III ENGINE EMISSIONS STANDARDS GO INTO EFFECT? AND WHAT MARINE ENGINES WILL NEED TO COMPLY?

For U.S. flagged vessels, the U.S. EPA Tier 4 Final regulation requires any engine 1400 kW and above must be certified starting January 1, 2016. Starting January 2017, the U.S. EPA will require engines between 600 and 1400 kW to be certified.

On the IMO side, the regulation applies to any marine engine 130 kW and greater to be certified. But right now there are no emissions control areas (ECAs) out there, other than the North American ECA. So if there's a vessel that is not a U.S. flag boat that wants to come into U.S. waters, they need to meet IMO III today – if they're above 130 kW. If they're operating outside of the U.S., say in Europe, we don't expect an ECA zone to be in effect until 2021. It's kind of yet to be determined for the rest of the world.

What this all means for us is Cat® Marine engines that need to comply today are our big ones, 1400 kW and above. So we're working on our 3500 engines and our C280. Next year we'll have to start phasing in our smaller engines. The C32 is designated to come into compliance next year.

WHAT SOLUTION IS CATERPILLAR OFFERING TO MEET THE NEW STANDARDS?

We've been able to meet EPA Tier 1, Tier 2 and Tier 3 regulations by doing in-cylinder type design changes. As we got into Tier 4, we wanted to squeeze as much out of it as we could, but we knew that the Tier 4 requirement was going to force us into an aftertreatment type solution because there are only so many in-cylinder changes we can make. So we decided on Selective Catalytic Reduction (SCR) technology. It basically sprays Diesel Exhaust Fluid (DEF), which contains urea, into the exhaust stream and creates a defined chemical reaction to clean up NO_x emissions from the exhaust.

FOR CAT MARINE CUSTOMERS OUTSIDE THE U.S., HOW DOES THE TECHNOLOGY MEET IMO III REQUIREMENTS?

The main difference between EPA Tier 4 and IMO III is in the NO_x values. EPA Tier 4 requires a 1.8 grams per kW NO_x requirement, and IMO is more RPM regulated. The EPA also has additional requirements for particulates and non-methane hydrocarbon, whereas IMO does not. So the solution that we're developing for EPA Tier 4 will not only meet the IMO requirement, it will actually go above and beyond it.

CATERPILLAR IS USING EXHAUST GAS RECIRCULATION (EGR) TECHNOLOGY IN OTHER APPLICATIONS. WHAT'S THE DIFFERENCE BETWEEN SCR AND EGR, AND WHY SCR FOR MARINE ENGINES?

We chose the SCR path primarily because there are two key design requirements we want to provide Cat customers: increased uptime and a lower cost of ownership.

We do in fact use EGR in other applications and it meets EPA Tier 4 regulations for those applications. However, EPA Tier 4 regulations for marine applications are different.

What EGR technology does, is it basically re-circulates exhaust gas back into the intake of the engine. In order to meet EPA Tier 4 marine requirements, we'd have to do what's called massive EGR, which requires recirculating two to five times more exhaust back into the engine (when compared to today's EGR engines). But because massive EGR isn't proven to be durable at those levels, it's not an option for us – we won't risk engines failing at sea.

ARE ADDITIONAL AFTERTREATMENT DEVICES NEEDED ALONG WITH THE SCR SYSTEM?

There's no need for any additional aftertreatment devices such as a diesel oxidation catalyst or a Diesel Particulate Filter (DPF) filter. The only thing that's required to get the NO_x down is the SCR system. All the other EPA requirements on particulate and non-methane hydrocarbon are met with the in-cylinder design changes we've already made.

WHAT BENEFITS DOES SCR TECHNOLOGY OFFER VESSEL OWNERS?

Probably the largest benefit is being able to lower the fuel consumption enough to offset additional operations costs incurred with the SCR system. Since the late '90s, customers have known that when there's an emissions change – from a mechanical, non-regulated to a regulated engine – there's a loss in fuel efficiency in order to clean it up. With the SCR aftertreatment, we can scale back on all the design changes we made with Tier 2 and Tier 3, and we can clean up the exhaust afterward. So we're getting that fuel efficiency close to where it was before we were regulated, and that obviously decreases the total cost of running the engine.

WHAT ARE CAT MARINE CUSTOMERS SAYING ABOUT THE TECHNOLOGY?

Marine customers like that it's easy to install and it's flexible enough to install it in many different vessels. Other systems on the market today don't have the ability to be integrated in different positions and orientations. With ours, you can mount it horizontally, vertically or even on its side. The number of ways to mount it is almost infinite, only the service door just can't be pointing downward.

The biggest concern for marine customers was that the SCR system, unlike the EGR system, is an aftertreatment type product that requires space to store the system itself and space to store the

[DEF] fluid. To counter that, we gave the engine more back pressure capability so we could put something a lot more restrictive behind it, which means we're able to have a more dense SCR catalyst that can be more compact. We've also integrated the SCR mixing into the package, if you will, where that DEF injection mixes into the exhaust stream to further reduce the total size of the system.

HOW DO VESSEL OWNERS CALCULATE THE AMOUNT OF DEF THEIR ENGINE WILL CONSUME?

Marine customers can give their Cat dealer specific information on their vessel and operation and their dealer can calculate how much DEF they would consume and estimate its annual costs. Dealers can also use this information to help customers calculate how big their [DEF] tanks will need to be based on how many stops they might make on a trip – let's say from Seattle up to Alaska – and where the DEF will be available.

AND HOW SHOULD DEF TANKS BE STORED ON BOARD?

Typically, I think the best option is to use stainless steel tanks. But there are marine customers who don't want the expense of having a stainless steel tank so we've looked at different ways it can be stored on board. On a lot of vessels, there are ballast tanks or unused storage tanks. It seems that everyone who's wanted to has been able to use the ballast tank space or some of the additional tank space that's already on board. If it's a carbon steel tank, what customers need to do is coat it with a polymer to make sure it's compatible with DEF.

WHERE CAN MARINE CUSTOMERS PURCHASE DEF?

They can get it from many distributors. Our dealers have several sources, especially here in the U.S. Because the on-highway truck market is also leveraging this technology, there's distribution for DEF all over Europe and the U.S. It's very easy to have it trucked in and available at the ports. So it's just a matter of when marine customers really start to use it – they will have it there.

IF DEF RUNS OUT OR THERE'S AN ISSUE WITH THE SCR SYSTEM, WILL THE ENGINE SHUTDOWN?

No, that's one of the beauties of the SCR system being post-engine. In the event that there is an issue or it fails, the engine is still the engine; we're not adding any technology to it, so it will continue to perform as it does today. That's a disadvantage of the EGR technology. If there were an issue with something like the EGR cooler, your vessel's kind of, no pun intended, dead in the water. We needed to avoid that.

HOW EASY OR DIFFICULT IS IT TO INSTALL THE SCR SYSTEM?

The SCR system takes up more room – you have to have space for the [DEF] tank and for the system itself. But we knew that upfront when we started the design phase so we made it as small and as flexible as we could. It's still a space claim but it's a really flexible one. Everyone we've met with so far has been able to design around it, even in some tight confined engine rooms. We service 13 different market segments with probably three or four different vessel types within each, and every engine room is slightly different. Making it adaptable was our goal.

To keep the DEF tank size down, we have a closed loop dosing system, which minimizes the amount of DEF consumed. What is does is senses the NO_x values coming in and out of the SCR system, so we're able to fine tune the amount of dosing required to remain emissions compliant.

HOW MUCH SPACE IS NEEDED IN THE ENGINE ROOM?

It really depends on the application of the vessel and how each customer is going to utilize the engine. There is a defined space for the SCR cabinet itself, but we offer different sizes based on the engine size. Cat dealers can calculate the space a customer needs.

HOW LONG MIGHT IT TAKE FOR A VESSEL OWNER TO RECOUP THE INITIAL COSTS OF THE SCR SYSTEM?

Honestly, we don't really look at it in those terms. The reason why is that the SCR system, or even a system like it, is a requirement to meet the emissions regulations.

The time to recoup the cost of it really would depend on what you're comparing it against. It's primarily due to how you operate the vessel and what type of engine rating you start with; a dealer can take that information and provide a payback estimate.

WHAT ARE THE ESTIMATED OWNING AND OPERATING COSTS OF THIS TECHNOLOGY?

Our goal upfront was to lower owning and operating costs as compared to diesel engines that customers are running today and we've achieved that. We've been able to provide so much efficiency to the diesel consumption of the engine that it offsets the cost of burning DEF. For the most accurate owning and operating cost estimate, a dealer would need to know a vessel owner's application and load profile.

WHAT ARE THE MAINTENANCE REQUIREMENTS FOR THE SCR SYSTEM?

The overhaul life of the SCR system certainly depends on the load profile, but we've aligned that with the major overhaul of the engine. It's a long life type component that's designed to have the same overhaul life as the engine.

WHO SHOULD VESSEL OWNERS CONTACT FOR SCR SYSTEM PURCHASES OR INSTALLATIONS?

Definitely their local Cat dealer. The EPA requires that the OEM supply the system as a serialized system. It's an emissions component in the eyes of the EPA so from a serialization standpoint they require Caterpillar to provide that.

On the IMO side, talking about vessels outside of the U.S., that is not a requirement. A customer could take an existing engine and put a third-party aftertreatment system behind it, legally, but it's probably not the best solution. The way we've integrated Cat engines with the SCR has a lot of advantages – and it's mostly in terms of total cost of ownership and fluid consumption costs.

IS THE SCR SYSTEM SUPPORTED BY CAT DEALERS? AND WHAT SORT OF WARRANTY COMES WITH IT?

It is fully serviced and supported by Cat dealers worldwide, and has the same standard warranty that we provide for all other Cat Marine engines today.

BUILT FOR IT.