The Familiarity of Sound, Sensation Without all of the Carbon: Toyota Refines its Hydrogen Engine Corolla Concept

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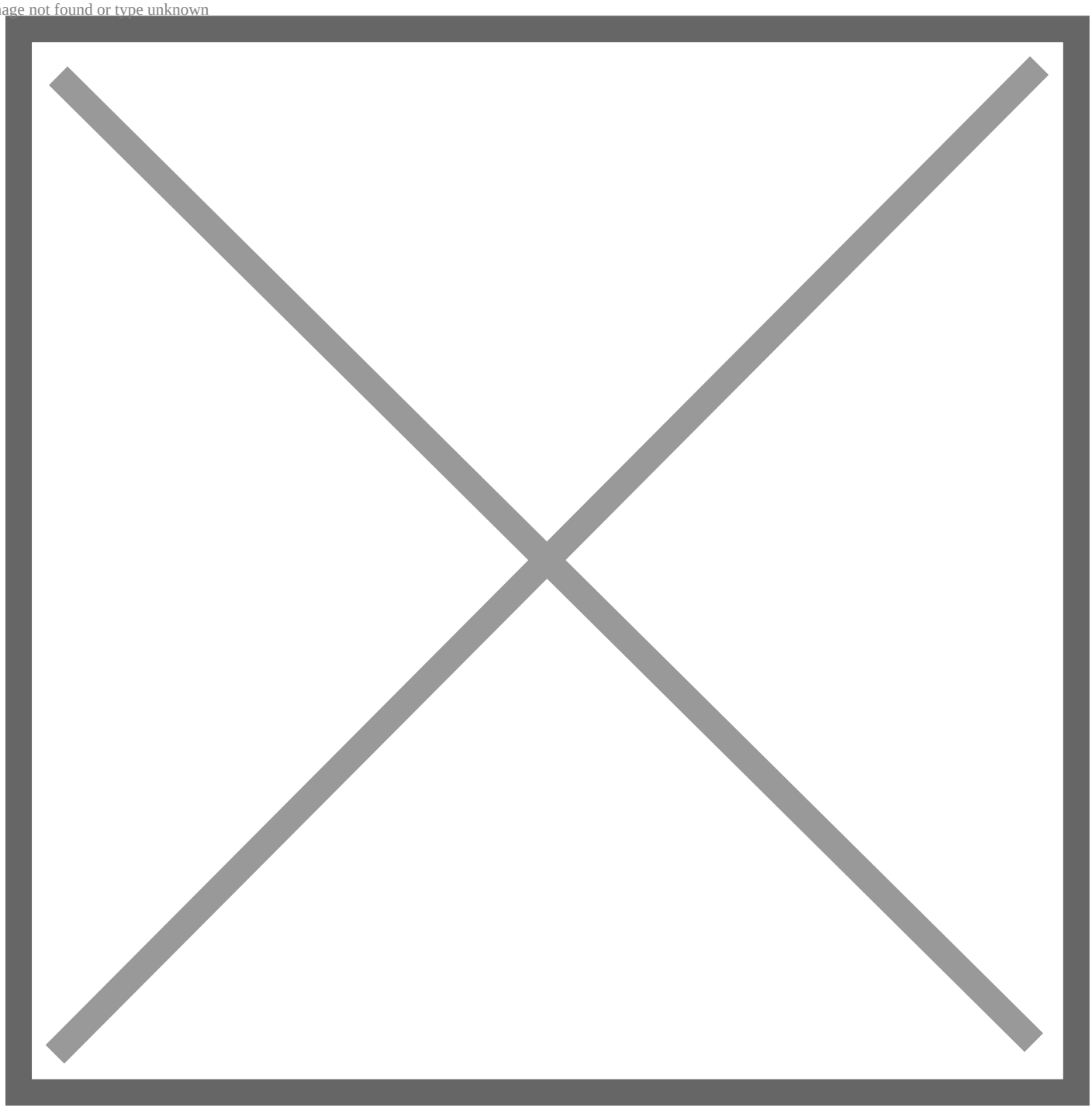


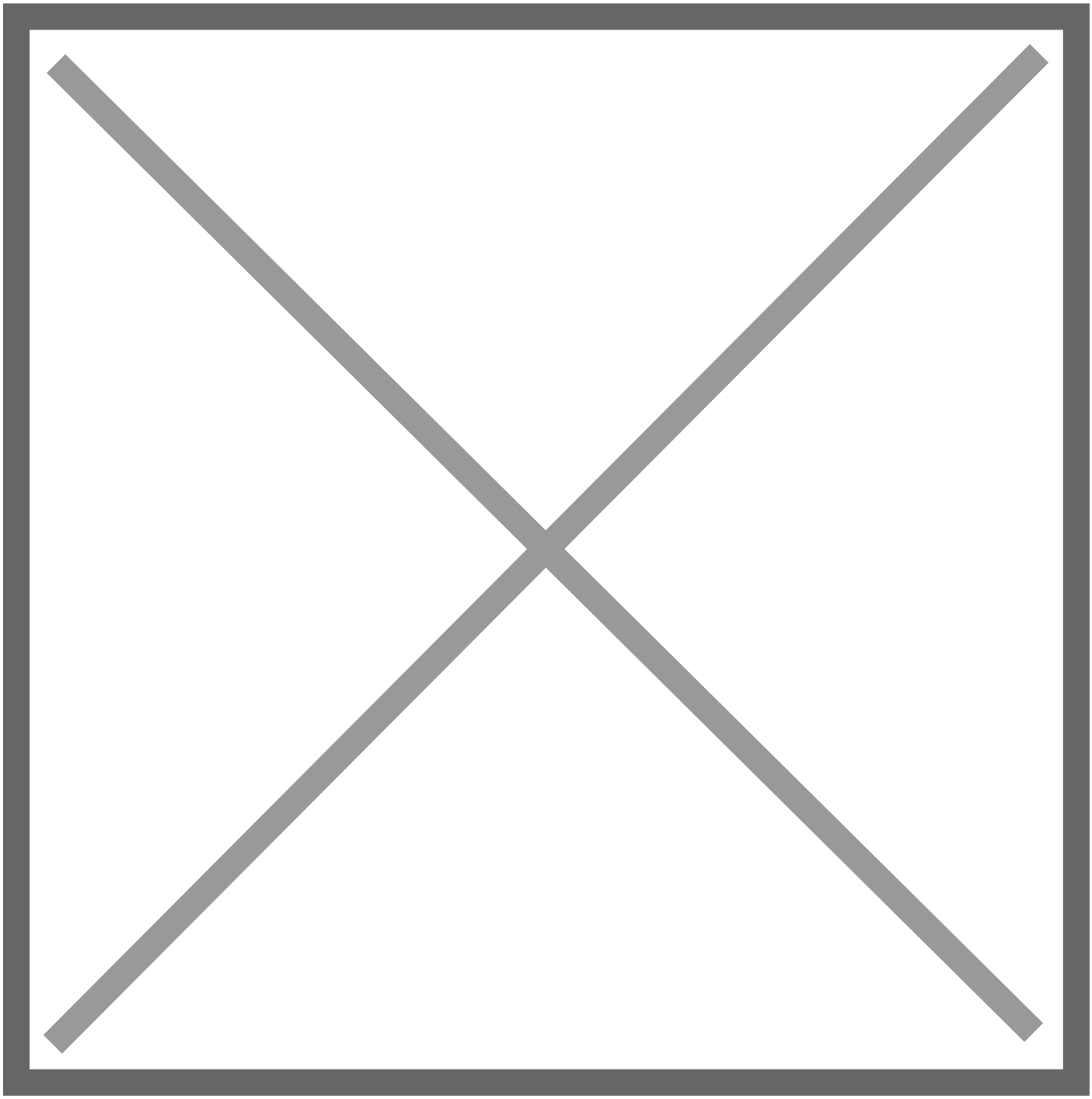
From the noise coming out of the tailpipe, one would never guess that this car is not powered by gasoline. Spectators attending its debut race were also likely to not have known that the vehicle speeding around the raceway was emitting virtually no carbon. This vehicle is not some new-fangled electric car – it is a Hydrogen Internal Combustion Engine Vehicle (HICEV).

The HICEV concept vehicle is another example that demonstrates Toyota's commitment to provide a diversity of powertrain options that include conventional Internal Combustion Engines and Hybrid Electric Vehicles (HEVs) in the short-term, and Plug-In Hybrid Electric Vehicles (PHEVs), Fuel Cell Electric Vehicles (FCEVs), Battery Electric Vehicles (BEVs) in the long-term. Powered by hydrogen yet retaining the basic components and architecture of conventional gasoline-powered internal combustion engines (ICEs), Toyota sees HICEV as another potential technology to help reduce carbon, especially in high performance applications like motorsports, as part of a broader goal to realize a carbon neutral society by 2050.

Carbon is the primary and most significant type of greenhouse gas that's been linked to climate change. Because carbon accumulates in the atmosphere and remains there for many years, eliminating carbon emissions as soon as possible is an important goal for society.

While Toyota remains fully committed to carbon neutrality—HEVs, PHEVs, BEVs, and FCEVs will make up close to 70 percent of the company's U.S. sales by 2030 and it plans to introduce 15 BEVs globally by 2025 — the automotive industry as a whole will face many challenges before it can completely switch over to all electric vehicles. However, Toyota believes a greater net carbon reduction can be achieved in the interim by providing customers with a diverse portfolio of choices that includes BEVs and other options, such as vehicles that use hydrogen. Furthermore, Toyota cites diversity as one of the countermeasures to combat uncertainty, and strongly believes in offering more than one pathway or powertrain to reach carbon neutrality.

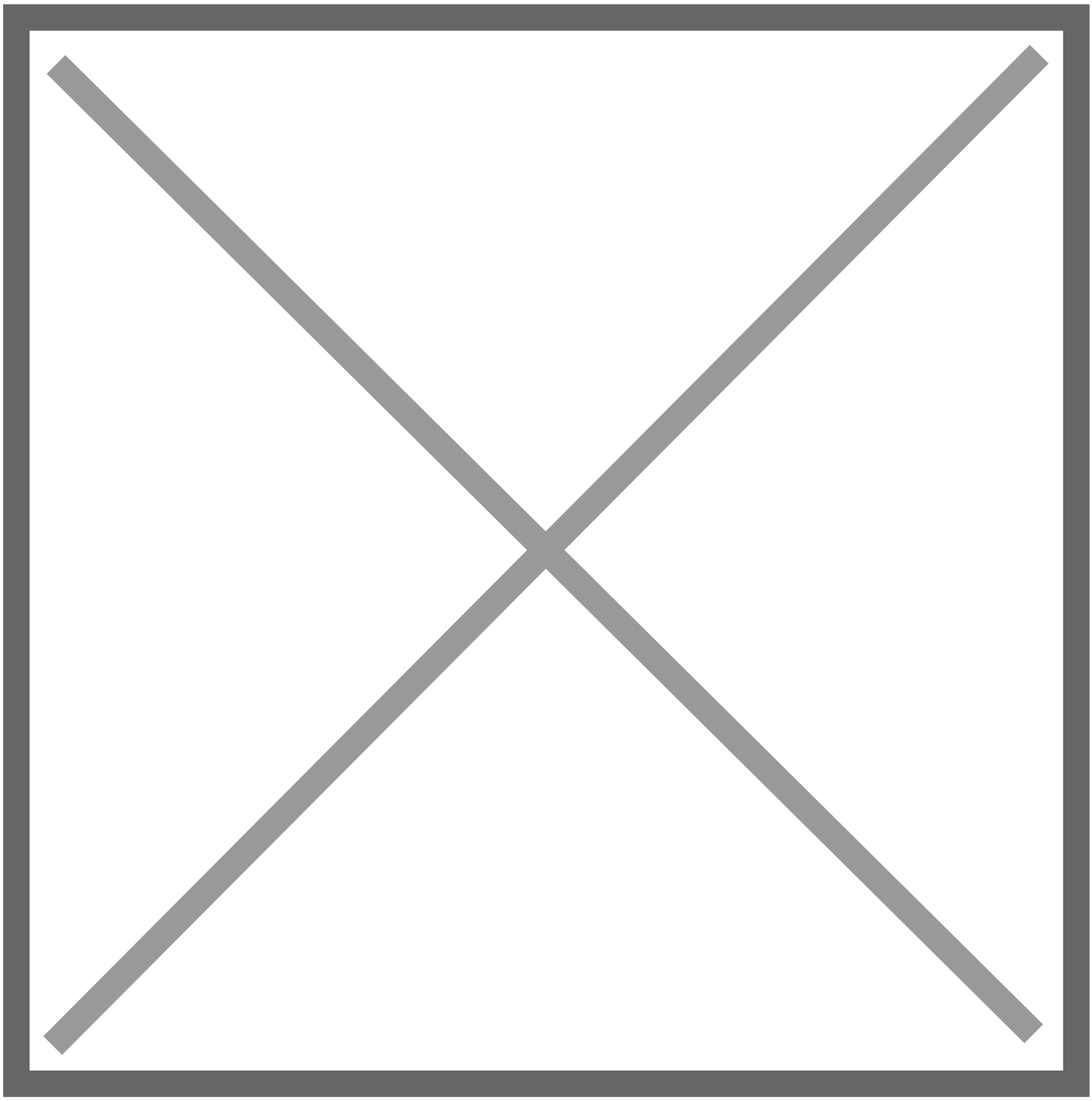
Enter the hydrogen-burning ICE, which generates energy through the combustion of hydrogen instead of gasoline. Unlike fuel-cell systems, such as the one in the Toyota Mirai, it does not rely on a chemical reaction that generates electricity to power the car; instead, it burns hydrogen directly as a fuel, much like a gasoline engine. Except for the combustion of trace amounts of engine oil during driving, hydrogen engines emit zero CO_2 when in use. Since they burn hydrogen while intaking oxygen found in the air, as in the case with gasoline engines, a certain amount of NO_x is created, but in general, they are cleaner than both HEVs and PHEVs.



The HICE vehicle uses gaseous hydrogen as a fuel in a specially-modified engine

Another factor that favors HICEVs is that they can retain much of the performance that drivers are accustomed to, finding potential use cases in motorsports, for example. Also, with nearly every driver having some experience with conventional ICE vehicles, there is almost no learning curve to own or operate an HICEV, nor does it require a major shift in lifestyle. Even the sound from the exhaust is nearly identical to that of a gasoline-powered car, despite the main emission being water vapor.

“Until you’re told otherwise, it feels just like a regular engine. I felt comfortable driving it right away. From the sound of the engine to the sensation when you’re driving, all of that remains the same, so you really feel like you’re racing. I didn’t feel like I was driving a hydrogen-powered car,” said race driver Takuto Iguchi about the ROOKIE Racing Toyota Corolla Sport H2 Concept, Toyota’s hydrogen-engine racecar.



Driver Takuto Iguchi (Photo: Noriaki Mitsuhashi/N-RAK PHOTO AGENCY)

Serving as a developmental testbed for Toyota’s hydrogen engine, racing and motorsports offer the chance to quickly build and test components, systems and vehicles, offering a more rapid timeline for necessary product improvements. In fact, Toyota’s Gazoo Racing development policy is to create ever better cars and new challenges based on motorsports activities. In just this year alone, the ROOKIE Racing Toyota Corolla Sport H2 Concept has already recorded three consecutive finishes in Japan, the most recent in the Super Taikyu Series at the Suzuka International Racing Course on September 18. Previously, it completed the Fuji 24 Hours this past May (its debut race), followed by an impressive showing in Round 4 at Autopolis in August. The car utilizes the turbocharged inline-3-cylinder engine from the GR Yaris, but with a few alterations to accommodate the hydrogen fuel.

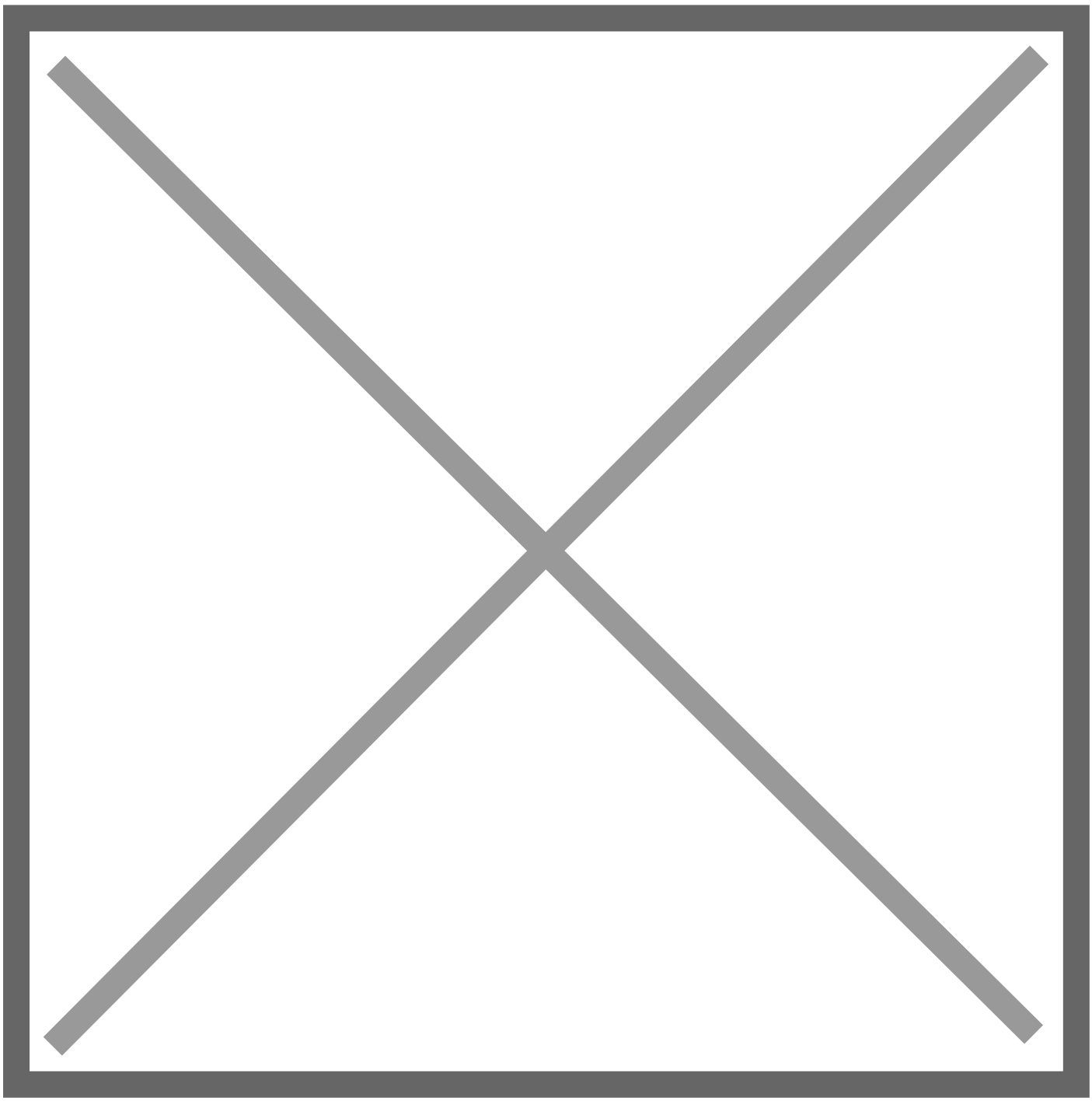


Photo by Noriaki Mitsuhashi/N-RAK PHOTO AGENCY

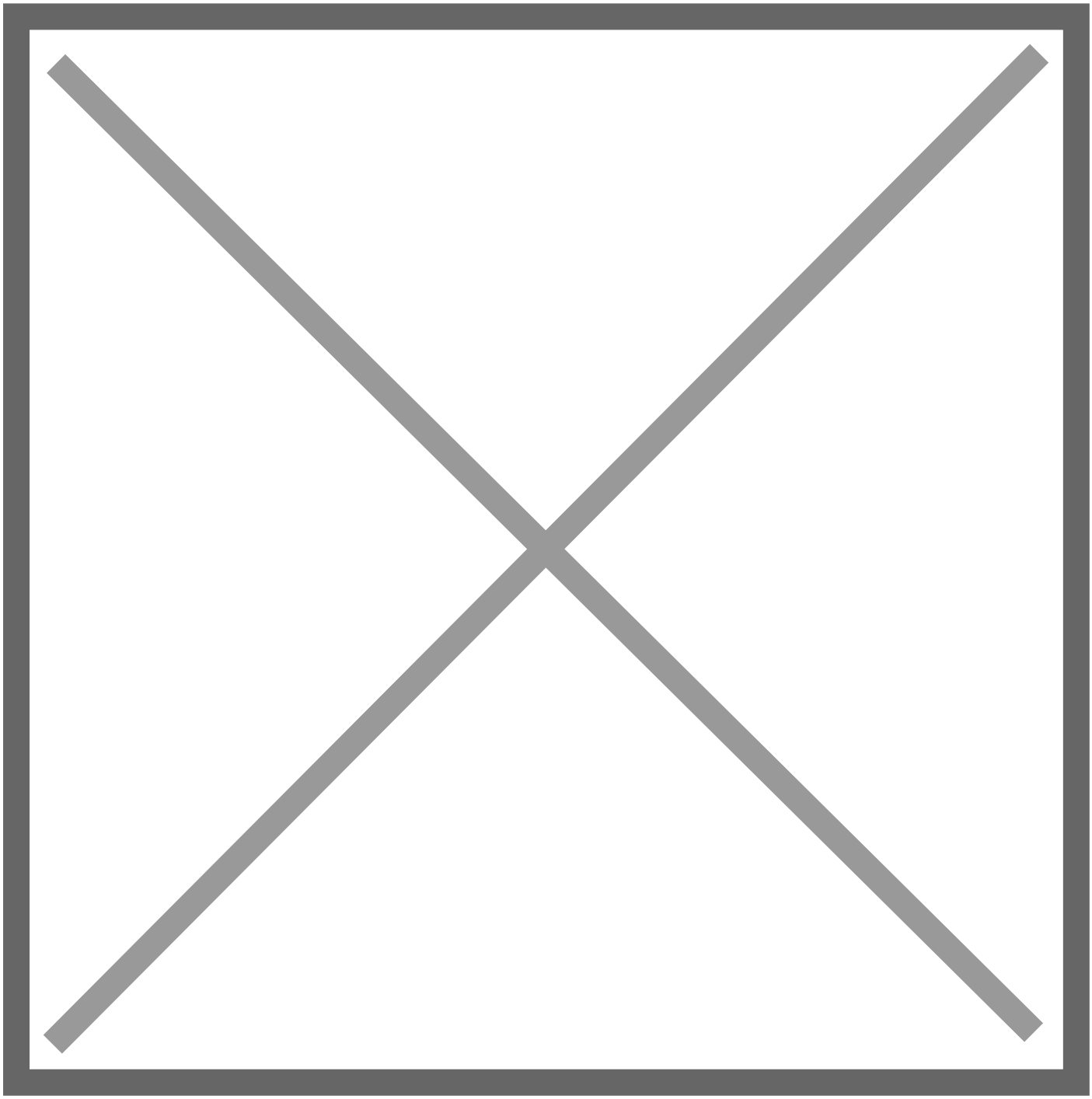


Photo by Noriaki Mitsuhashi/N-RAK PHOTO AGENCY

Because the hydrogen is delivered in pressurized gas form, the same kind used in its Mirai FCEVs, Toyota teamed with Denso to develop special fuel injectors that could safely and efficiently introduce the hydrogen—which has a higher ignition temperature than gasoline and eight times the combustion speed—into the combustion chambers.

“Controlling abnormal combustion is the key to hydrogen engines,” said Naoyuki Sakamoto, the Chief Engineer of the project. “The abnormal combustion has the potential to add stress to the engine hardware. Therefore, we developed high-heat parts as well as adjusted the ignition timing and fuel ratio for the Corolla Sport H2 Concept.”

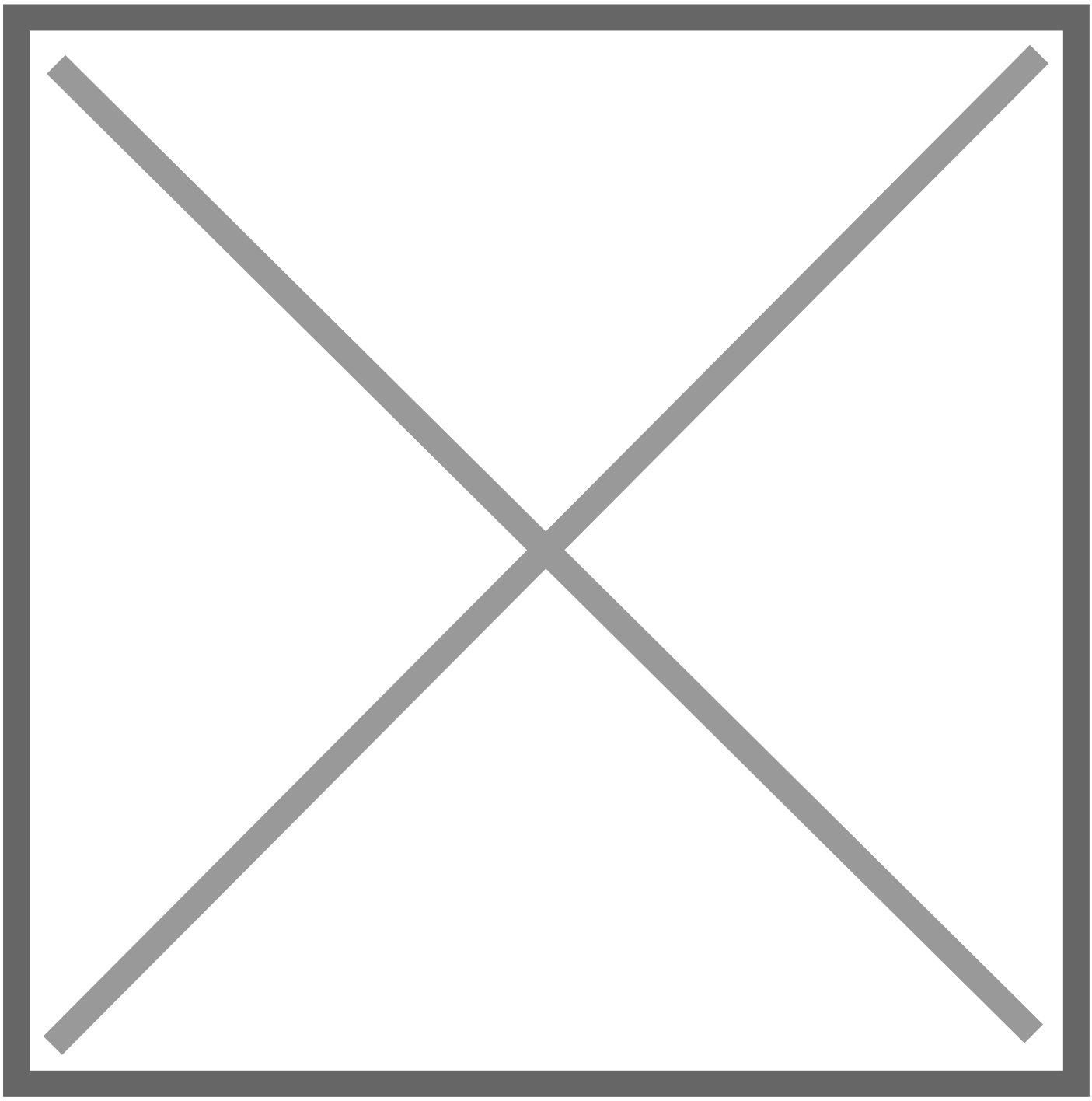


Photo by Noriaki Mitsuhashi/N-RAK PHOTO AGENCY

When asked about the potential dangers of driving around with tanks filled with hydrogen, those familiar with the technology said that it’s no different from driving with a tank full of gasoline. To demonstrate how safe it was, Toyota Motor Corporation president Akio Toyoda, under his driving name “Morizo,” was one of the drivers to race the car.

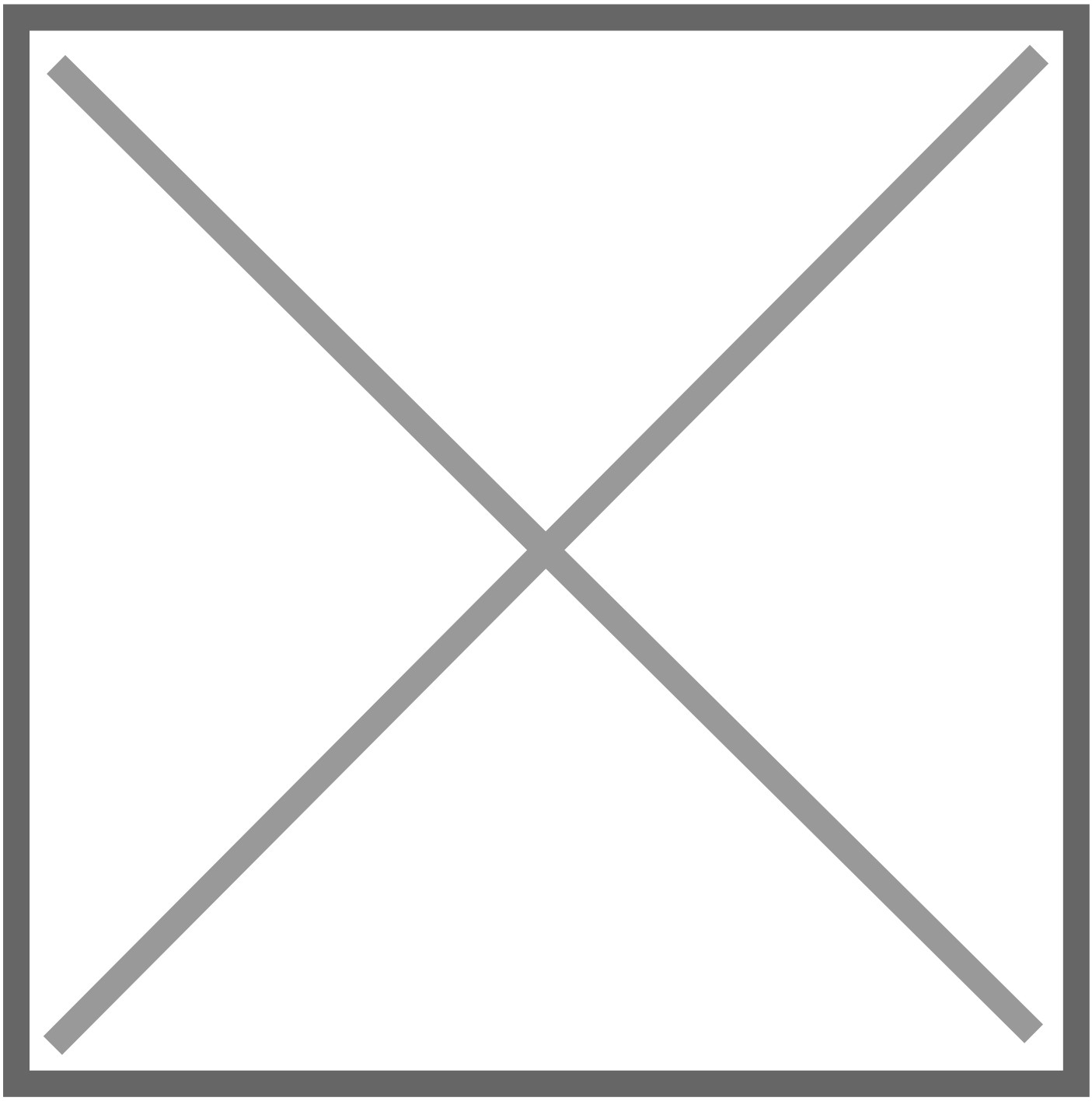
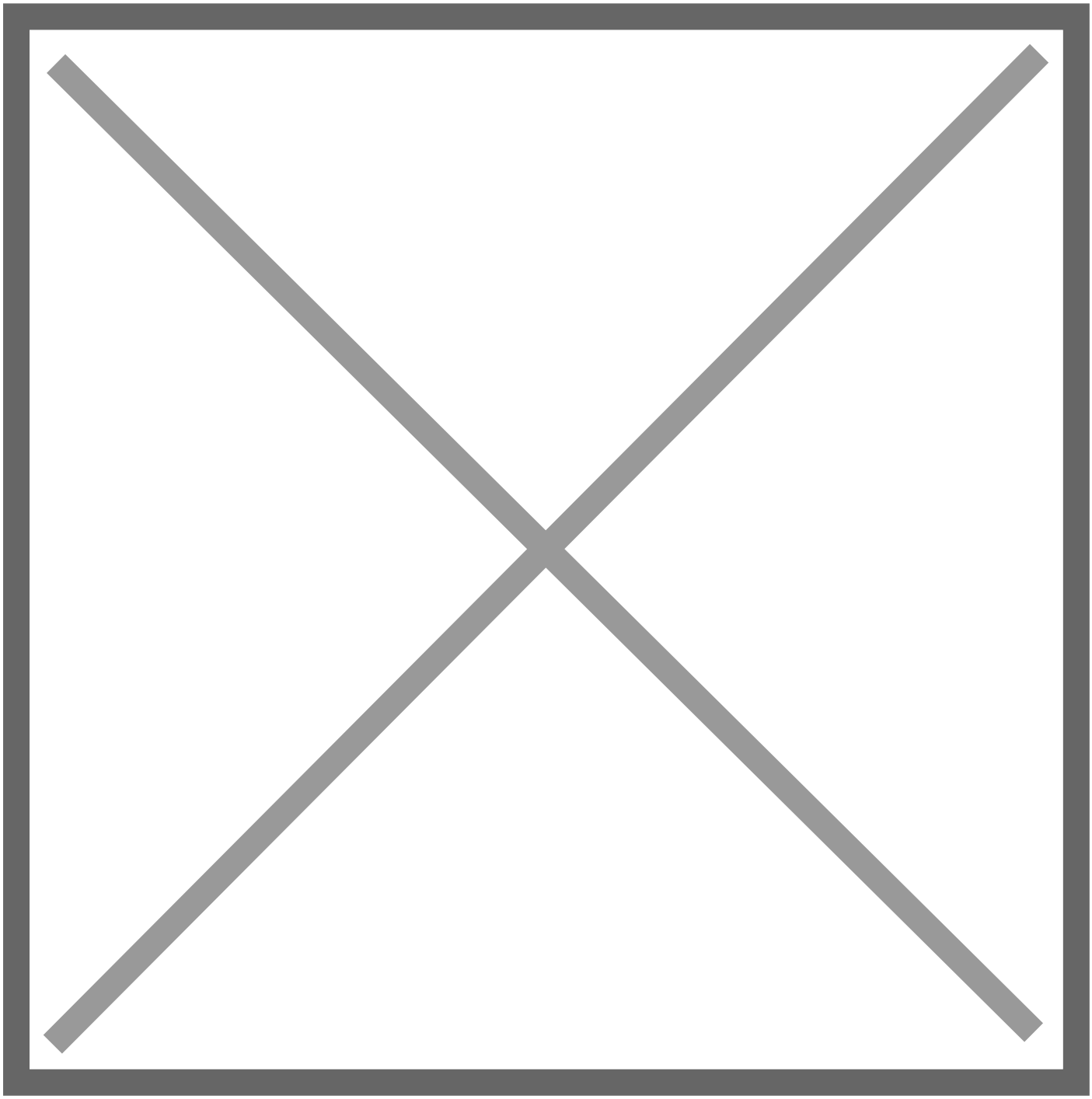


Photo by Noriaki Mitsuhashi/N-RAK PHOTO AGENCY

“Any combustible fuel can be dangerous if handled incorrectly, and of course the same is true of hydrogen. At the same time, I don’t think it’s right to say that hydrogen is more dangerous than gasoline. I believe we can offer safe and reliable cars if they are designed and equipped in a way that is suited to hydrogen,” said Naoaki Ito from Gazoo Racing’s Project Operation Division.

While there are numerous hurdles that still need to be cleared before hydrogen engines can replace traditional gasoline engines in production vehicles, racecars or other forms of transportation, Toyota has already made huge advances through its racing endeavors. Some of the improvements of the special turbocharged hydrogen engine include enhancing power output to a level equivalent to that of a gasoline engine through engine calibration; changing the refueling location to include both sides of the vehicle to allow for quicker fill times during races; and shaving off an additional 88 pounds from the overall vehicle weight.

“One key point was that we reduced the refueling time from an initial five minutes at the Fuji 24-hour in April by 40 percent to about three minutes in Autopolis, and then again to about two minutes (at Suzuka), or a 60 percent improvement, in just three races,” explained Koji Sato, President, GAZOO Racing Company.



In earlier races, the car was refueled by opening the left rear door (left: Photo by Noriaki Mitsuhashi/N-RAK PHOTO AGENCY); more recently, refueling was done through a small window, cutting refueling time (right).

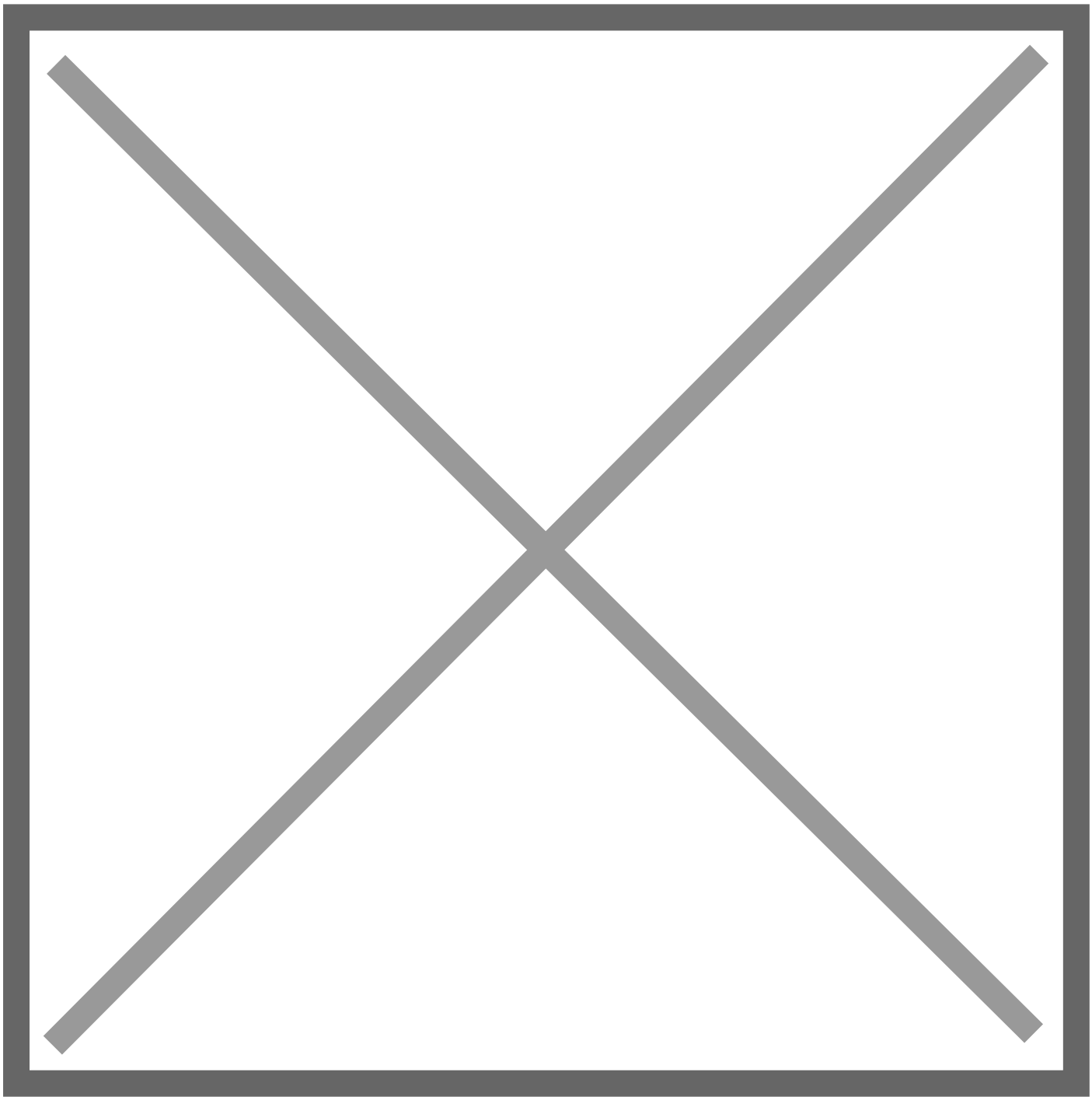
Toyota is also working to ensure that the production and transportation of hydrogen can also be completely carbon neutral, with motorsports being no exception. For the first two races, the ROOKIE Racing Toyota Corolla Sport H2 Concept used green hydrogen derived from renewable energy, produced at the Fukushima Hydrogen Energy Research Field in Namie Town, Fukushima Prefecture. Green hydrogen is generated by the

electrolysis of water using renewable energy (solar energy or wind power generation), meaning that no CO2 is emitted during production.

Thanks to the growing popularity of FCEVs in both the light- and heavy-duty segments, the demand for hydrogen has been continually on the rise, prompting many energy companies to take a vested interest. For example, there are currently 47 hydrogen fueling stations in California, but that number is expected to triple in the next few years. In April, Toyota announced a strategic collaboration with Chevron to explore the development of a commercially viable, large-scale businesses in hydrogen.

“As demand increases, not only will the cost of hydrogen go down, it will most likely lead to the rapid development of the refueling infrastructure, increasing both accessibility and convenience,” said Craig Scott, Director, Advanced Technologies Group for Toyota Motor North America.

Akio Toyoda has notably said: “Our ultimate goal is carbon neutrality. BEVs are not the only path towards carbon neutrality. Another way involves using carbon-neutral fuels such as hydrogen and biofuel… having many options for reaching carbon neutrality is important.”

While Toyota continues to probe the potential of its HICEV on the racetrack, the company will continue to offer and demonstrate a portfolio of powertrain options designed to meet the varying needs of its customers. It is the customers who choose vehicles that suit their lifestyles and geography. And, ultimately, it is the customer who will decide which technologies will carry society toward a carbon neutral future. Toyota intends to be there with the right products and technologies to meet the diverse needs of customers around the world.

“While the main technology being developed in the Corolla Sport H2 Concept is indeed the hydrogen engine, there are other elements being experimented, and perfected, in the racecar as well, and they may just find their way into future Toyota vehicles, no matter the powertrain,” Sakamoto said.