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Boeing 787 battery lags behind evolving lithium-ion technology

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As the grounding of Boeing's 787 fleet stretches into its second month, the planemaker faces a painful paradox — its most advanced jetliner relies on batteries that are in many ways outdated.

The technology of lithium-ion batteries has advanced far beyond what it was when the 787 was designed nearly a decade ago.

"Just about everything has improved" about lithium-ion batteries since then, said Frank Puglia, director of research and development for Yardney Technical Products Inc., a battery builder in Rhode Island.

It's as if Boeing's 787 were stuck with flip phones while the world upgraded to smartphones. The good news in this for Boeing is that in the long run, the company's basic bet on lithium-ion technology may prove a viable choice for the Dreamliner and future aircraft. But the bad news is that simply incorporating battery updates is unlikely to be a quick and easy task in a $200 million aircraft interlaced with complex systems that must pass muster with safety regulators worldwide.

Interviews with leading battery experts, in fact, make it clear that Boeing might have been better off had it started designing the Dreamliner a few years later than it did.

Ahmad Pesaran, who leads a team of 14 at the National Renewable Energy Laboratory in Golden, Colo., said lithium-ion batteries have gotten dramatically safer since the Dreamliner's electrical system was designed.

"Things have improved since 10 years ago," he said, "and will improve further." Which brings home another irony for Boeing: One reason the Dreamliner's battery design was cast in place so long ago was to accommodate the lengthy

safety-testing regimen required for airliners by the Federal Aviation Administration.

“Once you get into certification testing, you really lock it in, unless you have a reason to unlock it,” said aerospace analyst Hans Weber, president of Tecop International Inc. in San Diego.

On top of the lead time needed for FAA certification, the 787’s first delivery was delayed for more than three years by an unrelated series of problems with Boeing’s supply chain. So despite the fact that Boeing was ordering batteries for the Dreamliner in 2005, the aircraft didn’t carry its first paying passenger until October 2011.

During the years of Dreamliner development and since, furious efforts have been under way around the world to make lithium-ion batteries more efficient and safe. But it was back in 2005 that Boeing and the Dreamliner’s French power system supplier, Thales Group, announced they had chosen Japan’s GS Yuasa to produce the 787’s lithium-ion batteries, with prototypes to be delivered that year.

A key to the advanced plane’s greater efficiency was cutting its weight. Boeing engineers decided to do this not only by making a lighter carbon-composites airframe, but by replacing traditional heavy hydraulics with electrical controls, which would require an extra-powerful battery system to provide backup power.

The answer seemed to be lithium-ion batteries, but the technology was new and prone to fires, and this made many people, including pilots, nervous.

The FAA, tasked with the dual missions of advancing aerospace technology and guaranteeing passenger safety, in 2007 issued a special certification process for the Dreamliner’s batteries, which it called a “novel or unusual design feature” in commercial airplanes.

So touchy was the issue that language from the Air Line Pilots Association, inserted in the FAA special certification document, said: “We are very concerned with a fire erupting in flight, and being able to rapidly extinguish it.”

Lithium-ion batteries’ power is what makes them prone to problems. A charged battery is packed with energy, and any one of a number of aberrant conditions, from puncturing to overheating, can cause that energy to suddenly leak out.

Refinements continue. For example, the 787’s cathodes — the source of lithium ions during the charging process — are made from a nickel-cobalt material that’s now considered among the most dangerous types, said Jim Manning, president

and CFO of Lithium Battery Engineering LLC, in Randolph, N.J. New materials release ions of energy at different rates. Nickel manganese, for example, is more tolerant of damage, overcharging and other mishaps, Manning said.

“If you overcharge it a little bit,” he said, “it doesn’t catch fire as easily.”
But the down side is these new cathode technologies, while safer, so far don’t hold as much energy.

And for the other terminal, the anode, where ions are received during charging, researchers are moving away from the Dreamliner’s graphite carbon material to more exotic substances.

Brian Landi, an assistant professor in chemical and biomedical engineering at Rochester Institute of Technology, said his group is developing ways to make anodes from carbon nanotubes, cylindrical carbon structures on the molecular level. These structures, he said, will dissipate heat 30 percent to 40 percent faster, which can reduce the risk of fire during charging.

Researchers also are making progress with lithium-ion batteries’ electrolytes, the medium through which lithium ions move, allowing the batteries to be rapidly charged. Traditional electrolytes — including the 787’s — are flammable, especially if they’re heated enough to vaporize.

This propensity partly explains why the fire in a 787 battery spread from cell No. 6 to the other eight cells.

“If you want to make lithium ion batteries safer,” the National Renewable Energy Laboratory’s Pesaran said, “you have to change the electrolytes.”

Of course, before Boeing incorporates any of these new technologies into an upgrade or fix, the planemaker will have to know exactly what caused the batteries to overheat in the first place on 787s in Japan and at Boston. National Transportation Safety Board Chairman Deborah Hersman said last week that an internal short circuit in the lithium-ion battery had caused the Boston fire, but investigators don’t yet know whether the cause was a manufacturing glitch or a design flaw — or both.

Time is not on Boeing’s side: Each week the 787s are grounded is costing Boeing millions of dollars in penalties and deferred revenue, not to mention the hit to its reputation.

It’s also unclear if the FAA will conclude that lithium-ion batteries — of either the original design or an updated one — can be made safe enough for recertification

at this time, or if Boeing will be forced to substitute an older technology such as nickel-cadmium, which would add hundreds of pounds to each aircraft.

Whatever that outcome, if might come as some solace to Boeing's leaders that the new lithium-ion research suggests they chose the right basic technology, even if it might have been at the wrong time.

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