EPISODE 40 OF "ARMED WITH SCIENCE: RESEARCH APPLICATIONS FOR THE MODERN MILITARY," A DEPARTMENT OF DEFENSE WEBCAST HOST: JOHN OHAB GUEST: CYNTHIA LUNDGREN, CHIEF, ELECTROCHEMISTRY BRANCH, SENSORS AND ELECTRON DEVICES DIRECTORATE, ARMY RESEARCH LABORATORY DATE: WEDNESDAY, OCTOBER 21, 2009

MR. OHAB: Good afternoon, and welcome to episode number 40 of "Armed with Science: Research and Applications for the Modern Military," on Wednesday, October 21st, 2009. I am Dr. John Ohab, the Office of the Assistant Secretary of Defense for Public Affairs. Today we are wrapping up our four-part "Energy Awareness Month" series. Joining us today is Dr. Cynthia Lundgren, chief of the Electrochemistry Branch in the Sensors and Electron Devices Directorate at the Army Research Laboratory.

We will be focusing our discussion today on fuel cell research. With the potential to lower the weight burden carried by soldiers, this resulting technology could involve a smaller number of batteries carried for missions lasting longer than 24 hours.

Dr. Lundgren, we've had a really interesting exploration into some of the energy and power research being conducted by the services, and we're very excited to have you here to discuss some very important work taking place in the Army's laboratories. How are you today?

MS. LUNDGREN: I'm doing great, thanks.

MR. OHAB: Just a quick note to our listeners: If you have questions for Dr. Lundgren, please tweet them to @ArmedwScience and we'll get those answers to you by the end of the show.

Dr. Lundgren, we're going to get into some details of your work in just a moment, but I was hoping you would indulge those of us who aren't familiar and give us a quick primer on the field of electrochemistry.

MS. LUNDGREN: Well, electrochemistry basically involves either creating electricity from the energy stored in chemicals or using chemicals -- using chemicals to make electricity, or using electricity to drive chemical reactions. It could go either way. And so batteries typically are an electrochemical reaction, fuel cells are based on an electrochemical reaction; but then one can drive chemical reactions with an external voltage.

MR. OHAB: Now, you're currently the chief of the Electrochemistry Branch, as I mentioned before. Can you tell us about this organization and what kind of work you do in this role?

MS. LUNDGREN: The Electrochemistry Branch is part of the Power and Energy Division, and, as such, our work involves research and technologies that span microwatts for micropower, all the way to megawatts capacitors for pulse power. And so basically the research areas that we tend to focus on are batteries: increasing the energy density and power of batteries by doing research in new components; fuel cells, doing the same thing. Everything is, you know, driving at -- to make it lighter and more energy-dense.

We also do work in reforming complex fuels into fuels that could be used by fuel cells. And then we do research in capacitors to provide large amounts of pulse power for specific applications.

MR. OHAB: And you're currently conducting research now?

MS. LUNDGREN: Yes. We have a number of research programs within the branch. We have approximately 20 very, very top scientists in the field in our branch, and they're really great to work with. And we -- you know, we try and transition our products through the different RDECs and through the different PMs and our industry collaborators.

MR. OHAB: Can you tell us about some of these current projects you guys are taking on?

MS. LUNDGREN: Well, for batteries -- specifically for lithium-ion batteries -- we want -- we're trying to make them safer. Lithium-ion batteries -- if punctured, lithium is very reactive and will react with moisture in the air. Anybody who's seen some of those or heard of those battery fires from the laptops will appreciate that. So what we're trying to do is to make those batteries last longer, to be lighter and to be safer.

And so our battery is composed of two electrodes and electrolyte. And we do work in all those areas as well as additives to try and make them safe, both for small-power -- soldier-power applications and for ATV power applications.

The fuel-cell work -- we're currently working on next-generation fuel cells. Some of the fuel cells that are around now are somewhat fairly mature, and so we're working on the next generation, how to make them cheaper, how to make them, again, more energy-dense, being able to use more complex fuels.

And then we're working on methods to convert complex fuels into simpler fuels that could be used by the fuel cells, and then working on materials for capacitors to make them more power-dense. So we have research programs in all of those areas.

MR. OHAB: For those who might not be familiar, can you give us a working definition of a fuel cell?

MS. LUNDGREN: A fuel cell is basically an electrochemical device that creates electricity from a fuel and from air. And so with those two components, the electrodes will directly, without any external energy, convert those things, the fuel and the air, into electricity.

The fuels are very limited, however. We have -- most fuel cells run directly on hydrogen, which is really not a convenient fuel for the Army, and so we need to convert other chemicals into hydrogen. There is a few small fuel cells that can work directly on some small alcohols. And so we have programs in that.

And so basically you have two electrodes and you have a membrane in between them that separates them to keep them from shorting out, but it has a specific function in that it has to be able to conduct ions. And so we have research going on in both the electrodes and in the membrane itself.

But that's basically how it works. It's really a rather simple process. When you put it in a system, however, it tends not to be too simple.

MR. OHAB: You mentioned that hydrogen was not ideal for the Army. Can you elaborate on that a bit?

MS. LUNDGREN: Hydrogen's a pretty energy-dense fuel. However, you have to have it -- it's a gas, and so it has to be condensed, and you know, carried in, you know, a vector bottle. And that's -- that's not really very convenient, besides the fact that the Army doesn't have hydrogen-filling stations anywhere that I know of.

And so it's -- logistically, it's not a friendly fuel. And safety, of course, is always an issue. Carrying, you know, hydrogen gas bottles around is not something the soldiers tend to want to do.

MR. OHAB: Right. And that touches on the issue of personal safety. How about environmental friendliness?

MS. LUNDGREN: Well, the fuel cells that run off of hydrogen and air are actually the most environmentally friendly, in that the by-product is strictly water. If you have to convert other fuels to hydrogen, there's always some by-product, such as CO_2, carbon dioxide, some carbon monoxide and some methane. You try and limit the amount of fuels that aren't used, however. And so, certainly as far as once we get the efficiency up and can actually use as much of the fuel as possible, they're environmentally more friendly than, say, the exhaust of an IC engine.

MR. OHAB: Obviously, if my laptop were to catch on fire, the problems would be a lot less than if a soldier deployed had something like that happen. Can you talk about why it's particularly important for the size, shape, the weight and safety of a battery to be considered for a soldier?

MS. LUNDGREN: Well, there are some concerns, of course. You know, the more -- the bigger the battery, you know, the more hazard there is if there's an incident, because there's more energy in there. One of the things -- one of the challenges in creating technology that is more energy dense is that if it's more energy dense, it's inherently more reactive and there's more energy that can be released if it's released all at once. And so there's -- you know, that's part of the challenges of our research, is to try and make these technologies as safe as possible.

For the batteries, we're looking at different types of technology -- different separator materials, different chemistries. We've been working with TARDEC, looking at safer battery chemistries, and in fact they have looked at changing some of their proposed battery chemistries for the ATV applications to ones that are more safe.

And so it can be done, but it's an ongoing process, as I said. As we want to go to higher voltages and more energy, that just adds more challenges to try and make them safe. MR. OHAB: So you're doing basic research, but are you also following the translation from this into practical applications as well?

MS. LUNDGREN: Absolutely. We currently are working directly with PEO Soldier on some technologies. We were their technical support for a defense acquisition challenge program that they had to develop a direct methanol fuel cell, which was geared towards soldier portable power. And so we also work very closely with Natick Soldier Center, and we work with them in assessing some of the technical issues of the systems that have been developed and making recommendations about what can be done to make the systems more safe and more user friendly and also to increase the technology readiness.

MR. OHAB: Can you talk about some of the fuel cells that are actually deployed right now and maybe some of their different characteristics?

MS. LUNDGREN: There are currently -- I mean, right now you can buy a direct methanol fuel cell. Actually, commercially available; a company in Germany makes them. And that's a 60-watt unit. And it runs on methanol, which is a simple alcohol very much like rubbing alcohol.

The units -- there is currently a reformed methanol fuel cell that CERDEC has currently in evaluation in Afghanistan. And they are getting feedback from the soldiers that are working with those units.

We have had some of the direct methanol fuel cells evaluated by the 82nd Airborne. And they have given us recommendations on what they would like to see improved.

And so you know, they're not quite ready for deployment yet. There are still issues with these units. And so there are other types of fuel cells of course.

There's a solid oxide fuel cell which runs at high temperature. It actually -- there was a wearable power challenge -- a wearable power challenge program held by the OSD, in September, which looked at evaluating technologies for wearable power.

And out of the -- I think four out of the five top placers were fuel cells. And they ranged -- the direct methanol fuel cell was first and third place. And a solid oxide fuel cell came in second place. And that runs on propane.

Now, there are some concerns by the soldiers I know, of propane, some of the same concerns as of carrying hydrogen. The nice thing about propane is, you can get it anywhere.

I mean, logistically it's a very friendly fuel. And so right now some of the applications being looked at for that are for power, for unattended vehicles such as UAVs or UGVs, where some of the safety issues might not be so great.

MR. OHAB: You mentioned some work with TARDEC, Tank Automotive Research, Development and Engineering Center. And that indicates some of these fuel cells are being used to power large vehicles. However --

MS. LUNDGREN: No.

Actually that's -- what they're looking at -- TARDEC is looking at fuel cells for is for auxiliary power units for -- to enable silent watch. And so basically these would be that you could shut off the vehicles and not use the JP-8 that they're running on and use a much more efficient fuel cell.

Those fuel cells -- the small portable fuel cells will run on things like -- fuels that could be packaged and used very much like a battery. You know, you take the old package out, put the new package in. But once you get over a kilowatt, that becomes logistically hard to sustain.

And so any fuel cells over a kilowatt must run off of JP-8. And that's part of what our reformation research is on is, how do we convert JP-8 to a fuel that a fuel cell can use?

And so this is mostly geared for auxiliary power units, which would range from probably 10 to 40 kilowatts.

And that would enable -- the efficiency of that is much higher, of course, than what a vehicle can use, its own fuel, in an IC engine. And so it will -- and it will also enable silent watch, and so that the vehicle could be turned off and the electronics can still run on a fuel cell.

MR. OHAB: And are you able to incorporate soldiers themselves into this kind of research?

MS. LUNDGREN: Well, as I said, the -- the APU's work is really pretty far still in the future. There are still a lot of issues with that. Solid oxide fuel cells are not -- are not as far in the -- in the technology readiness as the direct methanol and the reform methanol. And so we have, as I said, you know, had soldiers actually evaluate these fuel cells and give us recommendations on what they would like to see improved.

MR. OHAB: And how do you balance the safety of those that are involved in this kind of research, when you're dealing with power and energy which can, you know, be catastrophic in --

MS. LUNDGREN: Well, all of -- the -- the fuel cells themselves actually are not as much of a safety issue as maybe some other of the technologies currently being used. The safety is strictly dependent on the fuels, so it's the stored energy in the fuel itself. So a lot of these things can burn very much like gasoline can or JPA. So that's -- that's mostly the issues with the fuels.

But any of the fuel cells that are going out right now and being evaluated by soldiers have all been through a safety assessment -- the standard Army safety assessment that any technology would undergo before it goes out for evaluation.

MR. OHAB: What would you describe as the biggest challenges that you've had to overcome in this kind of work?

MS. LUNDGREN: Mostly, right now, reliability, ruggedness. The actual gut of the fuel cell itself is really pretty reliable. It's the balance of plant, all the peripherals -- the pumps, the blowers -- that one has to ruggedize and -- and then try and make it as light as possible. So those -- those are the real big challenges for -- for the small, portable fuel cells.

For the -- the larger fuel cells, they still need to get their efficiencies up. And then, they have much more ruggedization problems. They're -- they're much further down the learning curve than some of the smaller, portable fuel cells.

MR. OHAB: Now, "ruggedize" -- "ruggeditize" is definitely a new word for me. Does that just mean making it more durable and able to withstand impact?

MS. LUNDGREN: Exactly. You know, to be able to drop it. Currently, Fort Hood has a number of 250-watt direct methanol fuel cells that are running their test equipment. And they're bouncing around in the back of Humvees -- and doing quite well, from what I understand; well enough so that they've ordered some more.

And so -- but the ruggedization adds weight. And you know, that's one of the advantages of fuel cells, is that they're more energy-dense.

But as you have to keep adding stuff onto them, it's kind of like body armor. To make it more efficient, you've got to make them heavier. And so this is to make them more rugged, so that they don't break, you got to -- you got to add casings and shut, you know -- and outside layers that won't break if it drops.

MR. OHAB: You've mentioned a number of scientific disciplines during this discussion. Can you talk about some of the organizations that you work with and that you leverage expertise from?

MS. LUNDGREN: Well, we certainly -- you know, we can't do it all ourselves. And so we work with a lot of universities, a lot of industry, certainly with all of the RDECs that are involved in fuel cells and any of the PM shops that are involved in fuel cells.

And so it's very much a collaborative effort. The universities do some of the more basic research. For instance, one of our new programs is in a new type of fuel cell that requires some very basic research and materials. And so we're working with several universities to try and develop these -- and model these materials. And the RDECs of course are natural transition partners, and then, of course, you know, input from the PMs -- you know, they're the ones that, you know, ultimately will acquire these systems.

The industry are partners -- of course we work with a lot of them and are kind of a liaison between the soldier and industry to translate some of the needs. And so, you know, it takes all of these people to get a technology ready so that it could help the soldier.

MR. OHAB: Now we're going to break out the "Armed with Science" crystal ball here for a second, which we do from time to time. Looking into the crystal ball, thinking long-term, what's the ultimate goal that you want to achieve with this work?

MS. LUNDGREN: Well, certainly, you know it's always about getting it lighter and it's about getting it, you know, to be able to last longer. For right now, for fuel cells, at the current state of the technology, for a 72-hour mission, it would cut the weight of batteries that the soldier would have to carry by a third to a half. We would like to -- that's not near the energy density of the fuel itself, though, and so we would like to be able to approach the actual energy density of the fuels that we're using, which would mean increasing the efficiency of the systems that we're developing. MR. OHAB: We actually just received a question from Twitter which touches on something you just mentioned, which is the weight that a soldier carries. How much does a soldier generally carry? And how much of that is batteries?

MS. LUNDGREN: Well, it depends of course on the soldier's role in the battalion, but some soldiers, for a 72-hour mission, can carry up to 35 pounds of batteries. That's a lot of batteries.

MR. OHAB: That's a lot more than I can carry.

MS. LUNDGREN: (Chuckles.)

MR. OHAB: So --

MS. LUNDGREN: And so, you know, we would like to be able to cut back down to 12 pounds.

MR. OHAB: What would you say is the best part about working at the Army Research Laboratory?

MS. LUNDGREN: It's certainly to be able to help the warfighter, to make their job, you know, easier for what they're doing for us. I also get the opportunity to work with really highly talented scientists, with excellent resources, and I get to work on the cutting edge of a very exciting field of research.

MR. OHAB: If you would, could you tell us a little bit about your background training before you got to your current role? What led up to where you are now?

MS. LUNDGREN: I -- I'm -- I have a Ph.D. in electrochemistry, and I'm actually a trained electrochemist. I spent many years working in industry and in fact fuel cells was one of the areas that I was working in, amongst other fields in electrochemistry.

And then I've actually just joined the Army Research Lab about four years ago. And so I became a branch chief here at ARL, based on the qualifications that I developed between education and working in industry.

MR. OHAB: And what kind of applications or research areas can electrochemistry apply to other than fuel cells?

MS. LUNDGREN: Well, as I said, certainly batteries and capacitors are electrochemical devices.

But electrochemistry can be used in things like sensors. Many sensors are based on electrochemical reactions. A lot of synthesis of chemicals is done with electrochemical reactions. And so there's a wide variety of things that one can do with electrochemistry. Here at ARL, we're mostly focused in the areas of power and energy.

MR. OHAB: As we wrap up today's show, do you have any final comments or thoughts?

MS. LUNDGREN: Well, I just hope to see that this technology actually, you know, bears fruit and can actually help the warfighter in his mission. And we're all working to see that that happens.

MR. OHAB: Our guest today is Dr. Cynthia Lundgren, chief of the Electrochemistry Branch in the Sensors and Electron Devices Directorate of the Army Research Laboratory. Thank you again for taking the time to be here this afternoon.

MS. LUNDGREN: Thank you.

MR. OHAB: Listeners, please tune in to our next show, Wednesday, October 28th, when we are joined by Ron Meyers, quantum physicist at the Army Research Laboratory as well. He will discuss a new way of seeing objects that were once hidden from sight. Through computing the quantum effects of objects, the ghost image has the ability to appear not by actually seeing it but by calculating the light pattern coming from it. Using virtually any light source, from a fluorescent bulb, lasers or even the sun, quantum ghost imaging can give a clear depiction of objects by eliminating atmospheric conditions that conventional imaging can't.

Thank you again for listening today. I'm Dr. John Ohab, and you have been scienced.

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