9/11/2009

IPRO 313

Project Plan: Zinc-Fuel Cell Powered Car

Galina Shpuntova | Christopher Ragsdale | Brendan Lane

I. Team Charter

1. Team Information

Team Roster

Name	Department
Fracisco Ruiz	Executive
Sithambara Kuhan Sivanyanam	Battery Development
Wai Kit Ong	Battery Development
Galina Shpuntova	Deliverables
Shanon Ludden	Battery Development
Jonathan Price Vetter	Logistics and Fundraising
Joel Sadja	Car Development
Mathew Dado	Battery Development
Oluwafunso Ajigbo	Battery Development
David Fairbanks	Battery Development
Krzysztof Slomiany	Car Development
Brian Bjerke	Logistics and Fundraising
Rodrigo Aihara	Car Development
Christopher Ragsdale	Deliverables
Julia Zaug	Logistics and Fundraising
Brendan Lane	Deliverables
Alexander Rial	Car Development
Erich Ruszczak	Car Development
Kaumil Shaw	Car Development
Jordan Sokolic	Car Development
Marin Assaliyski	Battery Development
Ray DeBoth	Car Development

Team Member Strengths, Needs, and Expectations

See Apendix A

Team Identity

Name: Z.A.P. Car (Zinc Air Powered Car)

Logo:

Motto: Why drive when you can Z.A.P. to it.

2. Team Purpose and Objectives

Team Vision:

To become and be recognized as a unified, efficient, and skilled team capable of confidently approaching, analyzing, and solving a multi-faceted technical problem with a global impact.

Team Mission:

To create a working prototype of a refuelable electric vehicle based on a zinc-air battery, that is comparable to a current consumer vehicle in performance, cost, and safety; and to also develop a system for zinc fuel delivery that requires a minimum of changes to the existing fuel delivery infrastructure.

Team Objectives:

1. To select and acquire a vehicle for conversion either from an internal combustion engine or from an existing electrical drive to a refuelable zinc-air drive.
2. To acquire and install a prototype battery of sufficient voltage and power to drive the vehicle selected in (1).
3. To design a system for refueling the prototype vehicle that is cost-effective, safe, and comparable in ease of use to current gasoline fueling systems.
4. To raise awareness and support of the project through publicity, directed toward potential corporate and non-profit sponsors, as well as the public.
5. Act ethically and legally, respect intellectual property rights, and verify the safety of the product throughout development and testing.

2. Project Background

Modern industrial society is highly dependent on transportation of products and of people. The automobile is a preferred form of transportation for both individuals and businesses, as it can go virtually anywhere at any time. Private automobiles are valued by individuals for convenient, efficient transportation. Tons of goods are transported by trucks across the North American continent daily, making them indispensable to commerce. Buses relieve congestion in downtown areas of large cities, while providing city-dwellers with convenient transportation options.

All these vehicles are major consumers of gasoline fuels derived from crude oil. However, the global supply of crude oil is dwindling and is unlikely to support currently industrialized society, much less the industrialization of developing countries, for much longer. Furthermore, the internal combustion engines used by most vehicles spew hundreds of tons of pollutants into the atmosphere in the United States alone. Worldwide, this amounts to a staggering amount of carbon monoxide, nitrous oxides, volatile organic compounds (VOC's) and other pollutants exhausted into the atmosphere by the global fleet of vehicles. Even without touching on the problem of global climate change, the impact on air quality and health is impossible to ignore. The United States must put considerable resources into regulating and monitoring air quality, to ensure the safety of its citizens. To further add to the detriment of internal combustion vehicles, the United States' national security is placed at risk due to a dependence on foreign oil because of an insufficient domestic supply.

Clearly, an alternative is desperately needed, which is why research into a number of alternative fuel options is currently being performed by every major automobile manufacturer. Biofuel-powered cars, hydrogen fuel-cell powered cars, and plug in hybrid-electric vehicles (PHEV), as well as fully-electric cars are being considered as the successor for traditional internal combustion engine vehicles. However, each of these options has its own fatal flaw.

Biofuels must be eliminated first, chiefly because they do not solve the emissions problem, although they may reduce it temporarily or slow it down. Other concerns with biofuels include the amount of land needed to cultivate the biomass of which they are produced, and the possible impact of this on food production and on the environment, if more land must be cleared to accommodate growing biomass for both fuel and food. There is also at this time a very limited infrastructure for processing, producing, and distributing biofuels, except as an addition to gasoline. Overall, this option does not solve all the problems, and still requires significant capital investment. It is not prudent to put that capital into a technology that offers such limited improvements on its predecessor when there are other options.

Hydrogen fuel cells also seem like an attractive option at first. However, there are several concerns that disqualify it as a solution. Safety is a major concern: hydrogen is a highly volatile gas, and furthermore, it is difficult to contain due to its small molecular weight. The task of designing a hydrogen infrastructure that is safe and easy for the consumer to use is a daunting one. Another major concern is the production of hydrogen: the most energy- and cost-efficient way to produce hydrogen at this time is from hydrocarbon fuels, particularly natural gas, with a byproduct of many of the emissions that alternative fuel technology is attempting to eliminate. Although fuel cell technology is a definite improvement over internal combustion engines—fuel cells have a higher efficiency—they are still not a viable alternative energy source at this time.

Plug in hybrid vehicles are yet another popular solution—and a logical progression from hybrid vehicles of today. There are estimates that plug in hybrid vehicles could eliminate up to 90% of current fuel consumption. While this is clearly an improvement on current technology, plug in hybrid technology is still ultimately dependent on gasoline for trips longer than one battery charge. The technology is a step in the right direction—electric vehicles have been shown to be more efficient than internal combustion engines, even if they are ultimately charging from electricity produced from fossil fuels. Still, they are at most an intermediate step and an extension of the impending deadline enforced by the dwindling oil supply.

Fully electric vehicles (EV's) are the next step up from PHEV's. They run entirely off the electric grid, producing no emissions of their own. As mentioned above, running vehicles off the electric grid is more efficient than having each run off its own combustion reaction. Meridian International Research found in a 2007 report that electric vehicles were the only possible alternative to gasoline-powered vehicles.

The main question facing the electric vehicle market is, what kind of battery will it use? Lithium-ion (LiIon) batteries are a public favorite, but this could be due to familiarity—LiIon batteries power most portable consumer electronics devices. A LiIon battery to power an automobile must be one hundred times larger than a laptop computer battery. This, compared with global reserves of lithium, was shown in a Meridian report to be too scarce a resource to power cars around the world. Nickel-metal hydride batteries (NiMH) and sodium nickel chloride (NaNiCl) batteries are another alternative, but they are heavy, and the nickel supply is only a little less limited than the lithium supply. Both of these options also suffer from a recharge time unacceptable to the average consumer; a problem that has yet to be resolved.

Another alternative is the Zinc-air battery. It is an economical choice because there are no particularly rare or expensive components—zinc is one of the more abundant metals, and the fourth most abundantly mined. The product of the reaction, zinc oxide, is also readily recyclable back into zinc for reuse; this is actually cheaper than using new zinc!

There are several types of Zinc-air batteries—while the rechargeable battery is an option as it is with LiIon and NiMH batteries, the Zinc-air battery can also be used as a reconstructable or refuelable battery. The reconstructable option involves removing the battery and replacing parts consumed by the battery reaction. The refuelable option involves resupplying the battery with a slurry of zinc and electrolyte. Rechargeable zinc-air batteries have recently been significantly improved through the research efforts of ReVolt Technology, currently based in Switzerland; this has eliminated a prior barrier of low cycle life. The company endeavors to market them as a more energetic alternative to LiIon batteries for consumer electronics. Reconstructable batteries have been demonstrated by Electric Fuel, Ltd., based in Israel, which has worked with several organizations and government agencies, to create a zinc-air powered shuttle bus that used replaceable zinc-air cassettes. The technology was fully operational, but the cost involved in recycling the cassettes was prohibitive for most applications. The third option is the refuelable battery, invented and tested by John F. Cooper from Lawrence Livermore National Laboratory (LLNL) in Livermore, CA. A unique battery hardware design allows the zinc to be provided as <1mm sized pellets in a saturated solution of potassium hydroxide (KOH). The slurry of pellets in electrolyte can then be supplied without moving the battery hardware.

For automotive applications, this quality of the zinc-air refuelable battery is very important. Cooper showed that a battery can be refueled in less than 10 minutes, comparable to the amount of time spent by a consumer at a gas station today. The battery has sufficient energy density for the range per tank to be comparable to current values as well. The fact that the metal is recyclable means that after an initial input, a minimum of new material would be required on a regular basis to sustain the transportation infrastructure.

The battery is also a good choice ethically. It is clean, safe, and environmentally friendly by virtue of having no toxic components and producing no emissions. It also contains no reactive materials—there is virtually no risk of fire or explosion, as there is with current gasoline usage and with hydrogen gas. There is one danger, and that is that potassium hydroxide is a corrosive substance. Attention will need to be paid to re-engineering pump nozzles to avoid human contact with the chemical, which could cause chemical burns.

The battery is also an ethical choice on a social level—the abundance of the materials involved worldwide means this technology is accessible to developing countries as well as to industrialized countries. Intellectual property rights would of course need to be considered on an international level for this to occur legally and fairly, with due respect to the patent-holders.

The zinc-air technology is brimming with potential, but seems to have largely been overlooked in the public search for solutions to the gasoline problem. Consumer gasoline prices spiked to $4/gallon in some areas of the nation over the summer of 2008, as compared to around $1.30 in 1998. Prices of consumer goods have risen as well, sometimes as much as doubling, on products including food, toiletries, clothing, and school supplies; life's necessities. The public is paying the price for a continued reliance on oil. The public is also paying in healthcare costs and in lives due to poor air quality, particularly in cities. Ultimately, dependence on oil is costing in quality of life, and that is the most valuable thing.

The plan of the IPRO project is to demonstrate the potential of the zinc-air technology in a public way. The team will solicit the help of interested sponsors, including but not limited to, automotive manufacturers, local electric car groups, government offices, transportation services (CTA, etc), and Power Air Corporation, the company that currently holds the rights to the ZARB technology. The team will, with the cooperation of Power-Air Corporation, acquire a ZARB, and will also acquire a vehicle converted to electric drive. It will subsequently replace the battery technology in the vehicle with the ZARB and any required control systems, designed by the team. Simultaneously, the team will also work on designing a safe, efficient, and easy-to-use refueling system that is as similar as possible to gas pumps. Lastly, the team will use every possible opportunity to publicize the project and its potential, mustering public enthusiasm for this elegant solution to a complex problem. The finished prototype will be test-driven in a public way as a part of the publicity goal.

This project does not, at this time, have a concrete sponsor, although Exelon Corporation, Argonne National Laboratory, and Power Air Corporation have expressed some interest in the endeavor. The project is actively looking for more sponsors and more support.

** See Appendices B, C, D, and E for more documentation **

3. Team Values Statement

- There must be a bi-weekly cost review to determine what has been spent and what needs to be allocated where to complete the project.
- All new parts and reports need to be shared with the team in an efficient file system so that the team can assess the changes and incorporate them into the rest of the design.
- The IPRO sub-teams are responsible for the on time and on budget delivery of their section of the project.
- If there are any problems regarding expenses or design flaws they must be brought to the attention the rest of the team immediately so a solution may be found.
- A Computer Aided Design (CAD) based assembly model should be made to ensure part compatibility and to reduce the cost associated with prototype changes.
- A unified system of CAD file storage should be established and all parts should be uploaded to and available on a central storage sever.
- A detailed schedule should be posted for each sub-team and for the team as a whole and any changes should be posted and announced as well.
- Every week a sub-team meeting or gathering should take place where individual issues as well as progress can be assessed and modifications discussed.
- Bi-weekly(at least) a team meeting should take place where the progress for that period will be assessed and where changes and new designs are discussed as a whole group.
- All documentation used or created for the project should be uploaded to iGroups to aid in centralizing the information used in the design process.
- The Discussions Forum on iGroups are not to be used to discuss personal matters (ie. personal disputes, anger or frustration, emotional conflicts) that may erupt to a larger incident.
- If there is a conflict that goes beyond the scope of engineering and design resolve it in person using the sub-team leaders or other mediators as needed.
- If any design problems can be resolved as a sub-team do so, only involve the whole team when the problem results in changes that affect the other sub-teams or the overall project, budget, and schedule.
- Remember that time and money factor into everything you do and there is a very limited amount of both, if something is taking too much time to design move on to something else if possible or ask for more help (there are a lot of talented people working on this).

II. Project Methodology

1. Work Breakdown Structure

A. Major Tasks

In the design of the Zinc-Air Fuel Cell Car there will be three major tasks that need to be completed.

1. Research, Procurement, and Funding

- Purchase Vehicle and Parts
- Purchase Battery and Parts
- Actively seek funding and donations
- Consult with experts
- Explore all options
- Narrow down possibilities

2. Design and Verification

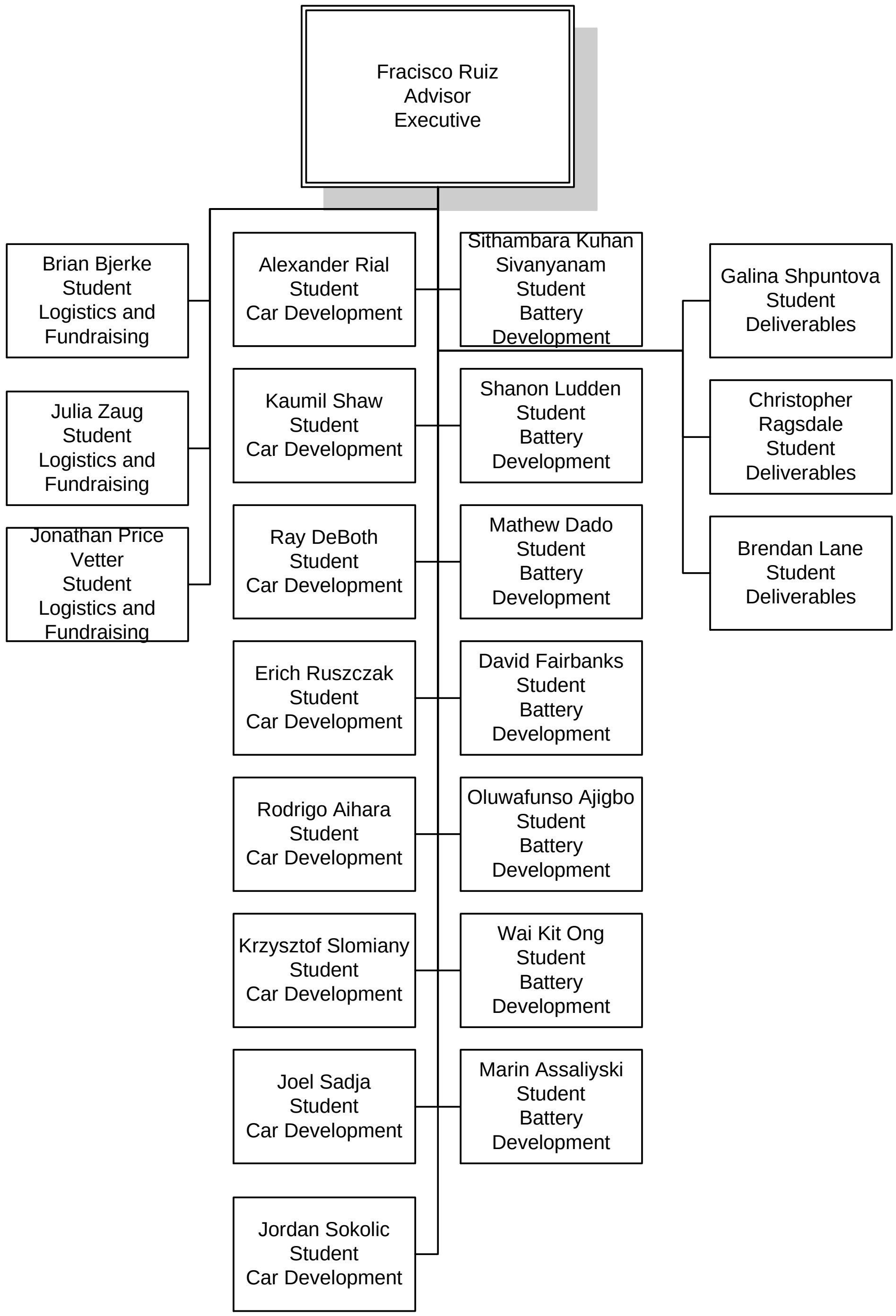
- Compile research and prepare solutions
- Begin designing parts (CAD based methodology)
- Begin construction and/or testing of battery
- Use a systems engineering approach to design
- Refine design using an iterative method
- Perform CAE simulations and analysis

3. Fabrication, Assembly, and Testing

- Remove unnecessary components from vehicle
- Using CAD files begin fabrication of parts
- Install parts and test for compatibility
- Construct refueling station
- Test vehicle for safety and performance
- Create report on both vehicle and refueling station

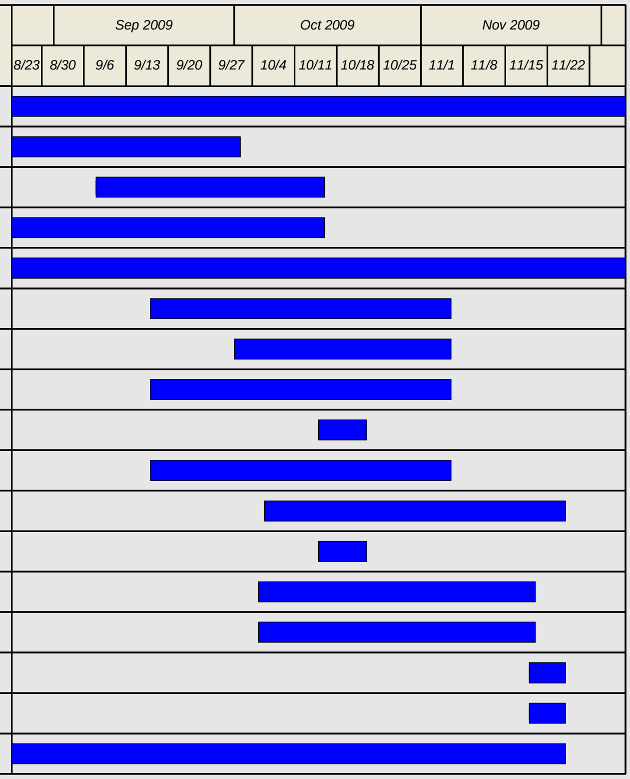
Depending upon the procurement of the vehicle and battery the team should be able to complete a prototype vehicle and refueling station by the end of the semester. However there are major hurdles that must be overcome first, the largest of which is the procurement of the battery which depends majorly on outside sources. The second major hurdle is funding the battery if it can be purchased might be expensive, but it we make it in house it might cost even more, because of this the funding being gained quickly and in full will be crucial to the success of this project. If these problems are overcome in a timely fashion then the rest of the project should fall into place rather quickly.

Team Structure



Work Breakdown Structure

ID	Task Name	Start	Finish	Duration
1	**Research, Procurement, and Funding**	8/25/2009	12/4/2009	14.8w
2	Initial Research and Planning	8/25/2009	10/1/2009	5.6w
3	Purchasing Vehicle and Parts	9/8/2009	10/15/2009	5.6w
4	Purchasing Battery and Parts	8/25/2009	10/15/2009	7.6w
5	Fundraising/Promotion	8/25/2009	12/4/2009	14.8w
6	**Design and Verification**	9/17/2009	11/5/2009	7.2w
7	Compile Research and Prepare Solutions	10/1/2009	11/5/2009	5.2w
8	Design Parts using CAD Techniques	9/17/2009	11/5/2009	7.2w
9	Initial Battery Testing/Prototyping	10/15/2009	10/22/2009	1.2w
10	Simulation and Modeling	9/17/2009	11/5/2009	7.2w
11	**Fabrication, Assembly, and Testing**	10/6/2009	11/24/2009	7.2w
12	Prepare Vehicle for Assembly	10/15/2009	10/22/2009	1.2w
13	Fabricate Parts from CAD Files	10/5/2009	11/19/2009	6.8w
14	Construct Refueling Station	10/5/2009	11/19/2009	6.8w
15	Test Vehicle for Safety and Performance	11/19/2009	11/24/2009	.8w
16	Create Report on Test Results	11/19/2009	11/24/2009	.8w
17	Compile and Prepare Patent Information	8/25/2009	11/24/2009	13.2w



2. Expected Results

The ultimate objective of the team is to have a complete drivable Zinc-Air Powered vehicle that can be used to demonstrate the technology and the capabilities of the power system. This should enable us to make a good demonstration of the viability of the Zinc-Air Fuel cell and lead to more development by both later IPRO's and by industry. We also aim to prove the ease in which the United States infrastructure and indeed the World's can be adapted to fit the Zinc based fuel system. To accomplish this the team must complete many smaller tasks. Some of the more important tasks are the successful procurement and/or construction of the Zinc-Air Fuel Cell, the procurement and adaptation of the vehicle, and the creation of a working refueling station. If these tasks are met the project can be deemed successful if the testing proves that the concept is viable and efficient.

Some of the testing results we are looking for include the mpg rating, the power output, the acceleration, the handling, the weight of the vehicle, the rate of the fuel consumption, and the speed of refueling. Other results that are important are the ease at which existing infrastructure can be changed to Zinc-based, the possibility of recycling and reusing Zinc, and electrolyte, and the overall environmental impact of the design. These could be used in a report to Government officials and industry as well documenting the success and revolutionary results of this project and could lead to major changes in the way electric vehicles are thought of.

Some assumptions that are being made for this project are that the Zinc-Air power system will be able to fit in a vehicle, and can be made scalable. Also an assumption has been made about the availability of the fuel cell for use in this project as there has yet to be one procured. There are many risks including sudden failure near the end of the project due to unforeseen problems, not getting a battery in time, not getting the funding required for the project, and not having very good test results in the end of the project.

Even if the project is not completed on time this semester it will at least be well on the way to be finished next semester. Already we have made big leaps in our understanding of the system and in the implementation of the fueling and storage. If we can finish this semester or at least early next semester a test trip to Washington D.C. will be the victory march of the IPRO team and will be a triumph for electric vehicles.

3. Project Budget

Item:	Cost(estimated):	Description:
Car	$20,000	This is an estimate of the cost of an already converted electric vehicle to ease the transistion to Zinc-Air power.
Battery and Power System	$40,000	For a completed Zinc-Air Fuel Cell or for parts to make it in house. Not definite as we have not gotten the non-disclosure agreements needed to discuss the project with the company who has the battery.
Car Parts	$10,000	To fascilitate the merging of the Zinc-Air fuel cell into the power train. This includes the materials for parts and tooling.
Promotion	2,000	Cost of promotion supplies and equipment. Includes the sponsors vynl stickers for the vehicle and the cost of displays.
Total:	$72,000	

4. Designation of Roles

- **Minute Taker:** Matt Dado
- **Agenda Maker:** Christopher Ragsdale
- **Time Keeper:** Dave Fairbanks
- **iGroups Moderator:** Galina Shpuntova

Appendix A

TEAM INFORMATION

Name: Sithambara Kuhan Sivanyanam

What team do you belong to (i.e. Car, battery)? Battery

Are you the leader of this team? No – We have not decided on a formal leader as of now.
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: ssivanya@iit.edu

Phone: [redacted]

Individual strengths: Knowledge of chemical reactions and their scale-up, as well as ability to adapt to various teams.

Skills that you will develop: Determining actual power output of batteries and their efficiencies.

What new knowledge will you gain form this IPRO? The practical application (in this sense, retrofitting a battery into an automobile) of a new technology, and how to deal with the potential problems that may arise.

Overall expectations about the project: To complete as much of the work as possible within the semester so that early next year we could realize the dream of driving a Zinc-Air powered vehicle all the way to Washington D.C.

[optional]
Possible team motto (i.e. Got gas?): Zinking Ahead

Name: Wai Kit Ong [First name: Wai Kit Last name: Ong]

What team do you belong to (i.e. Car, battery)? Battery

Are you the leader of this team? No leader.......yet I suppose
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: wong1@iit.edu

Phone: [redacted]

Individual strengths: Major in Chemical Engineering, have a better understanding of the chemistry involved in the battery, experienced with Matlab if ever needed to simulate anything with it,

Skills that you will develop: electrochemisty calculations on a fuel cell, conversion of a car

What new knowledge will you gain form this IPRO? Increased knowledge of the workings of a car, extended understanding of how a fuel cell works, how to modify parts of a car, steps taken to change an idea into a product.

Overall expectations about the project: May be a very difficult project, yet it is very exciting to know that I would be able to learn and be part of something that has the potential to be really successful.

[optional]
Possible team motto (i.e. Got gas?):

Name: Galina Shpuntova

What team do you belong to (i.e. Car, battery)? Deliverables.

Are you the leader of this team? We don't have a leader since there's just 3 of us and we're cool :)
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: gshpunt0@iit.edu

Phone: [redacted]

Individual strengths: I have an aptitude in fluid mechanics, thermo, and heat transfer; I'm also good at writing reports and making presentations clearly. I am fond of chemistry and I participated in a fuel cell IPRO last semester, so I have a basic familiarity with electrochemistry of a similar flavor to the one used in this IPRO.

Skills that you will develop: Project management and organization, efficient communication in and between teams.

What new knowledge will you gain form this IPRO? I'm excited to learn about a new technology that definitely holds a lot of potential.

Overall expectations about the project: I hope to see us really demonstrate the technology we are studying, and showcase its potential in a way that is attractive to both businesses and the public.

Name: Shanon Ludden

What team do you belong to (i.e. Car, battery)? Finding car, will later be involved in battery

Are you the leader of this team?
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: sludden@iit.edu

Phone: [redacted]

Individual strengths: determined, able to negotiate and compromise, work well with a team

Skills that you will develop: being more open to new ideas, creating and meeting reasonable deadlines, working in a team

What new knowledge will you gain form this IPRO? understanding cars, practical uses of electrical engineering, bringing a project from idea to prototype.

Name: Jonathan Price Vetter

What team do you belong to (i.e. Car, battery)?

At the moment I am working on procuring a car but I would like to eventually work on the fundraising/promotion and the legal/logistics teams.

Are you the leader of this team?
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)
No, we have not chosen team leads yet.

Email: jvetter1@iit.edu

Phone: [redacted]

Individual strengths: Communications, Mechanical

Skills that you will develop: I'd like to refine my communications skills and learn to fundraise effectively.

What new knowledge will you gain form this IPRO?

Overall expectations about the project: To fully develop a cycle to support a car using new battery technology to replace hydrocarbon powered cars.

Name: Joel Sadja

What team do you belong to (i.e. Car, battery)? Car

Are you the leader of this team? No, we haven't talked about leadership yet

(If your IPRO team has not chosen to use team leaders or sub-teams,
please indicate why)

Email: jkamsad@iit.edu

Phone: [redacted]

Individual strengths: Power Analysis

Skills that you will develop: teamwork, and a better sense of trade offs

What new knowledge will you gain from this IPRO? at the end of this IPRO, i'd like to have learned how to make an efficient electric car

Overall expectations about the project: build a car with a 300-mile range that can be refuelable in a few minutes

[optional]
Possible team motto (i.e. Got gas?): CHANGE – It could power your car. (Pennies have zinc which is used in a Zn-Air Battery) <-- I second that

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Name: Mathew Dado

What team do you belong to (i.e. Car, battery)? Battery

Are you the leader of this team? No – I don't know who is the leader, if anyone
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: mdado@iit.edu

Phone: [redacted]

Individual strengths: Understanding of the chemical reactions involved in the battery

Skills that you will develop: Determining the power output of the battery based on the chemistry

What new knowledge will you gain form this IPRO? Working as part of a big team, communicating well among team members, and understanding where my expertise fits into the group's goals.

Overall expectations about the project: To come up with a car design that will eventually lead to a drive-able vehicle that could reach Washington D.C. by refueling once or twice.

[optional]
Possible team motto (i.e. Got gas?): CHANGE – It could power your car. (Pennies have zinc which is used in a Zn-Air Battery)

Name: Oluwafunso Ajigbo

what team do you belong to (i.e. Car, battery)? Battery

Are you the leader of this team? Nope
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: oajigbo@iit.edu

Phone: [redacted]

Individual strengths: Strong technical and analytical skill and in-depth knowledge of ASPEN (HYSYS) program for simulation

Skills that you will develop: Better knowledge of electric cars and batteries

What new knowledge will you gain from this IPRO? Better understanding on how to make electric cars run longer without fuel.

Overall expectations about the project: Great learning experience; from learning how the zinc-air battery works to the system integration of the battery with the car.

Name: David Fairbanks

What team do you belong to (i.e. Car, battery)?
Battery

Are you the leader of this team?No, but I do provide kinda lead information
because I was involved earlier, I would do it, although it is not my first choice, and
I believe we are going to choose a leader on Thursday
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: dfairban@iit.edu

Phone[redacted]

Individual strengths: Good auto mechanic, and good at taking a project to completion

Skills that you will develop: Ability to work as a team and be able to bring an interesting
new technology from the drawing board to the street in an actual car

What new knowledge will you gain form this IPRO?
How to put on my hard-earned knowledge to work

Overall expectations about the project: I hope we can either build or get a battery, install it in
a car, and make it drive!

[optional]
Possible team motto (i.e. Got gas?):

“Think globally, act locally”

Name: Krzysztof Slomiany

What team do you belong to (i.e. Car, battery)? Car

Are you the leader of this team?
(If your IPRO team has not chosen to use team leaders or sub-teams, please
indicate why)
I'm unsure if there is a chosen leader yet; however Kaumil (from the summer
ipro) seems like our go-to guy.

Email: kslomian@iit.edu

Phone: [redacted]

Individual strengths: working with engines, welding, troubleshooting, essay writing,

Skills that you will develop: effective fundraising

What new knowledge will you gain form this IPRO? the details of how an electric or hybrid vehicle works.

Overall expectations about the project: would like to have the car finished and tested before ipro day as well as set a record.

[optional]
Possible team motto (i.e. Got gas?): if we used a Ford Focus vehicle, I was thinking the phrase "our focus is your future" would be appropriate.

Name:
Brian Bjerke

What team do you belong to (i.e. Car, battery)?
Sponsorship/Promotion

Are you the leader of this team?
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)
No, but I can take this position if Julia Zaug (the only other member) declines. We did not talk about it, possibly because that we're a group of just two members and we weren't thinking about choosing a leader during our class discussion.

Email:
bbjerke@iit.edu

Phone: ( ) -
[redacted]

Individual strengths:
Great at promoting a product

Good people skills
Good time management
Great at math and engineering (major is CPE)

Skills that you will develop:
(Hopefully) Designing a car
Learning about the marketing world and gaining connections

What new knowledge will you gain form this IPRO?
The challenges of starting a project right from the beginning

Overall expectations about the project:
To gain much more knowledge about mechanical engineering and to get a great head start on what could be the defining IPRO of IIT.

Name: Rodrigo Aihara

What team do you belong to (i.e. Car, battery)? --> Car team

Are you the leader of this team?
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

No.

Email: raihara@iit.edu

Phone: [redacted]

Individual strengths: Experience with vehicle simulations (Powertrain, Driveline and Vehicle-dynamics).

Skills that you will develop: Communication skills using professional engineering vocabulary. Skills to develop a product from scratch.

What new knowledge will you gain form this IPRO?

Knowledge about electric-vehicle (EV) and the Zinc-Air battery.

Overall expectations about the project: The overall expectations are to be able to finalize our Zinc-Air battery EV and drive it.

[optional]
Possible team motto (i.e. Got gas?):

Name: Christopher Ragsdale

What team do you belong to (i.e. Car, battery)? Budget/Deliverables

Are you the leader of this team? It's more of a collaboration.
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: cragsdal@iit.edu

Phone: [redacted]

Individual strengths: CAD skills with Autodesk Inventor, Pro/E, CFDesign 9.0, Rhinoceros 4.0, MatLab, Microsoft Office (including Project and Visio)

Skills that you will develop: Optimization of part design, Business Management, Budgeting, Time Management, and Presentation Skills.

What new knowledge will you gain from this IPRO? New design techniques, actual prototyping experience, fabrication experience,

Overall expectations about the project: We will have a working prototype or close to it by the end of the semester. If we do not get all the parts then at least be well on our way to

a finished product.

[optional]
Possible team motto (i.e. Got gas?): Why just drive when you can Z.A.P. to it.

Name: Julia Zaug

What team do you belong to (i.e. Car, battery)? Sponsorship\ Promotion

Are you the leader of this team? There are only two of us in the team
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: jzaug@iit.edu

Phone: [redacted]

Individual strengths: Chemistry (I am a chemistry major)

Skills that you will develop: I hope on improving my engineering skills greatly during this IPRO.

What new knowledge will you gain form this IPRO? New knowledge on working with others and time management.

Overall expectations about the project:

[optional]
Possible team motto (i.e. Got gas?)

Name: Brendan Lane

What team do you belong to (i.e. Car, battery)? Budget/Deliverables

Are you the leader of this team? There are only three of us in the team
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: blane07@aol.com

Phone: [redacted]

Individual strengths: Aerospace Engineering, Presenting, coming up with creative solutions

Skills that you will develop: team communication

What new knowledge will you gain form this IPRO? Time management.

Overall expectations about the project: Build a vehicle that runs on zinc

[optional]
Possible team motto (i.e. Got gas?)

Name: Alexander Rial

What team do you belong to (i.e. Car, battery)? Car

Are you the leader of this team? No...
(If your IPRO team has not chosen to use team leaders or sub-teams, please indicate why)

Email: minn0wild3hockey@gmail.com

Phone: [redacted]

Individual strengths: Aerospace/Mechanical Engineering

Skills that you will develop: team communication

What new knowledge will you gain form this IPRO? Time management.

Overall expectations about the project: Build a vehicle that runs on zinc

[optional]
Possible team motto (i.e. Got gas?)

Will Power Air's Zinc Fuel Cells Power The Future?

With all the problems related to traditional energy sources, the need for alternatives is clear. One company, Power Air Corporation, looks to enter the growing alternative energy market by providing emissions free backup power to apartments and offices.

BY ANTHONY W. HADDAD

At initial product introduction, zinc power is likely to be more expensive than fossil fuel power. But consider environmental costs, health costs and the increasingly complex geopolitical costs of defending and maintaining oil supplies, and zinc becomes an attractive alternative power source we can't afford to ignore.

Zinc batteries have been used for decades because of their high energy potential (in hearing aids for example), but the batteries could only be used once. Technology now exists to run zinc batteries continuously, turning the zinc battery into a zinc fuel cell that is emissions-free, running on recyclable fuel.

And recycling it is cheap. "Recycling zinc is estimated to be about one tenth the cost of mining it out of the ground," says Donald Ceci, Vice President of Sales and Marketing for Power Air Corporation (OTC BB: PWAC-0.69) Though no recycling facilities specifically for the fuel cells exist, the process of turning zinc-oxide back into zinc is simple and well-known by recycling companies. Power Air plans to implement a system where customers can return spent fuel to the retailer. The customer would receive a credit for their next fuel purchase, and the retailer will send the spent fuel to the recycling plant. Imagine a zero emissions fuel that can be used over and over again.

In addition to being recyclable, zinc fuel has other advantages over alternative fuels used to power fuel cells. Zinc is stable, abundant, non-flammable, non-explosive and non-toxic, and is unlike compressed hydrogen gas, another alternative fuel which is costly to produce, flammable, and explosive, making it challenging and expensive to distribute and store. And most commercially available hydrogen comes from fossil fuels, which are not recyclable.

Remy Kozak, President & CEO

Livermore, CA-based Power Air Corp. holds the exclusive worldwide license to zinc-air fuel cell technology developed at the Department of Energy's Lawrence Livermore National Laboratory for commercialization in all fields of use (portable, stationary, light mobility and transportation applications). The zinc-air fuel cell uses oxygen and zinc pellets in a liquid alkaline electrolyte to generate electricity, and continuously produces electricity as long as zinc (and air) flows into the cell. Through electrolysis, the cell's byproduct (zinc-oxide) can be recycled back into zinc.

To date, over $10 million has been invested in zinc fuel cell technology, which was developed by the Lawrence Livermore National Laboratory in the 1990s and was first publicly demonstrated in 1995. In 1999, Power Air Dynamics Ltd., an Australian company (now Aurora Energy), partnered with HDH Group, a technology acquisition and development company based in New York, to form Power Air Technology and entered into a Collaborative Research And Development Agreement (CRADA) with Lawrence Livermore National Labs

In September 2005, Fortune Business Partners, a Vancouver, Canada investment group, orchestrated a reverse takeover of Power Air Tech and Power Air Dynamics, merging it into a public shell. Following the merger, management renamed the company Power Air Corp. Mr. Haley, who acted as CEO of Power Air Tech, Inc. since 1999, became the Chairman and COO of the public company, and through HDH Group, one of its largest shareholders. In October 2005, Remy Kozak, an experienced senior telecom executive, and Don Ceci, former Director of Sales for Ballard Power, joined Power Air Corp. as its VP Corporate Development and VP Marketing & Sales respectively. The two quickly began implementing a plan to turn the nascent technology into a viable product. "There were many potential applications of the technology but the company needed to focus on the highest probability of success," says Kozak. "Don's knowledge of customer requirements was critical to identifying our path." In June 2006, Kozak was internally promoted to CEO.

In addition to its headquarters near the National Laboratory that developed and incubated the original patents, Power Air opened a research and development subsidiary at the National Research Council's Institute for Fuel Cell Innovation in Vancouver. "Canada offers many incentives to companies trying to commercialize new technologies," says Kozak. "Investors want us to stretch our dollars; and this was the way to do it. The development resources and talent pool there are really top notch."

To expedite the commercialization of the zinc-based power cell, Power Air is initially focusing on a backup power system for use in apartments and small offices. This is an ideal market for Power Air because current indoor options (gas shouldn't be used indoors!) are either costly or insufficient. "We chose to target emergency back-up because its relatively low power and lifetime requirements make it the most readily attainable," explains Kozak.

Power Air estimates the indoor backup power systems will need output to peak between 2 and 3 KW. The company's demonstration systems currently peak at 1 KW, but management believes it will have a functioning 2 to 3 KW system with 1500 hours of reliability in 2007.

To help engineer, manufacture and deploy the zinc-based generator, Power Air is partnering with established companies. Earlier this year, they reached a deal with Schrader Bridgeport, a subsidiary of Tomkins plc, an engineering and manufacturing group with 132 manufacturing facilities around the world and sales of $5.9 billion dollars in 2005. As per their agreement, Power Air will provide the zinc-air fuel cell power supply and Schrader Bridgeport will design, manufacture, and market the backup power generator.

In October, Mid States Tool and Machine Inc. of Decatur, Indiana signed a Development and Pilot

ZAFC Generator

Production Agreement that allows the companies to cost-reduce, tool and manufacture the zinc-air fuel cell/power supply. Mid States Tool and Machine specializes in designing, engineering and manufacturing molded parts.

Power Air's zinc backup power faces competition from Ballard Power Systems, Xantrex, and traditional generator companies such as Honda. However, each of its competitors' backup power products has substantial limitations compared to a zinc-powered system. The Ballard Airgen unit is expensive and contains and runs on compressed hydrogen gas that could be dangerous for indoor use. The Xantrex systems have short battery runtimes and take hours to recharge.

For the initial release of the zinc generator, Power Air expects the generator to be offered at a premium to traditional generator prices. "As volumes grow to over 10,000 units per month, however, we expect to achieve our target pricing for mass market commercialization," says Kozak. "There are currently 42 million potential indoor sites in North America which have yet to be offered an attractive back-up power option."

Kozak adds that once commercial volumes are achieved, zinc-air fuel cells have the potential to be manufactured at costs comparable to incumbent power sources— such as batteries and engines—because they don't contain expensive catalyst coatings such as platinum, and don't have to use compressed hydrogen gas used to power the other fuel cells.

If the backup power generator system is successful, it could lead the way to other backup power applications such as UPS and Telecom backup, as well as stationary and motive applications. What's more, powering automobiles and other major applications might just be a few years away.

Indeed, zinc power could one day replace fossil fuels as the primary means to power our lives. With solid partnerships in place, experienced management and the worldwide license to the fuel cell technology, Power Air Corp. just might be the company to lead us there.

RISKS: *To date Power Air has not earned any revenue; it operates at a net loss per annum of $2.625 million. Management believes that an additional $3.5 million is needed over the next 12 months to reach all their 2007 objectives. If Power Air is unable to develop a commercially viable zinc-air fuel cell based product that can be successfully marketed and sold, the company may not be able to achieve revenues and/or find the necessary funding to continue operations. A mass market for Power Air's products may never develop or may take longer to develop than anticipated.*

MAKE CONTACT

POWERAIR
www.poweraircorp.com

OTC BB: PWAC

COMPANY

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4777 Bennett Drive Suite E
Livermore, CA 94550
Phone: 866-734-7026

www.poweraircorp.com

CONTACT

Power Air Corp.
Phone: 866-734-7026
investors@poweraircorp.com
(Investor Relations)

SHARE DATA

Recent Price:	$0.69
52-Week Price Range:	$2.65-0.69
Shares Outstanding:	45 million
Market Cap:	$31 million

BALANCE SHEET DATA

(As of June 30, 2006)

Total Assets:	US$1.8 million
Long-Term Debt:	none
Shareholders Equity:	US$1.7 million
Book Value per Share:	CDN$0.04

UCRL-PRES-214862

Zinc/Air Fuel Cell

Stationary & Mobile Applications

John F. Cooper
Lawrence Livermore National Laboratory
August 2005

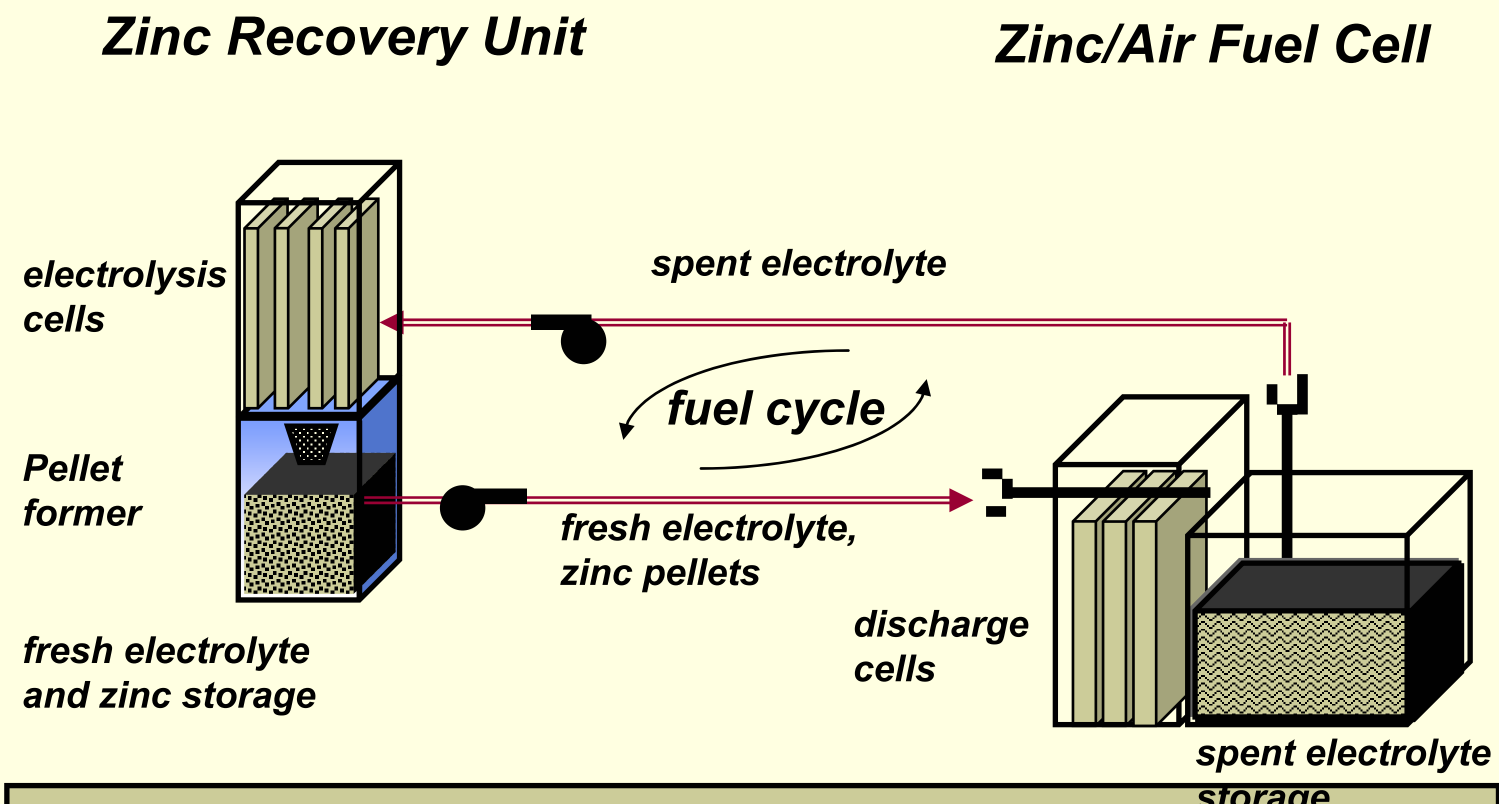
This work was performed under the auspices of the U.S. Department of Energy
by University of California Lawrence Livermore National Laboratory
under contract No. W-7405-Eng-48.

Topics

- Concept
- Technical background
- Status
- Near term applications
  - Mobile fleet applications
  - Stationary and transportable power
- Zinc recovery and recycling
- Plans forward

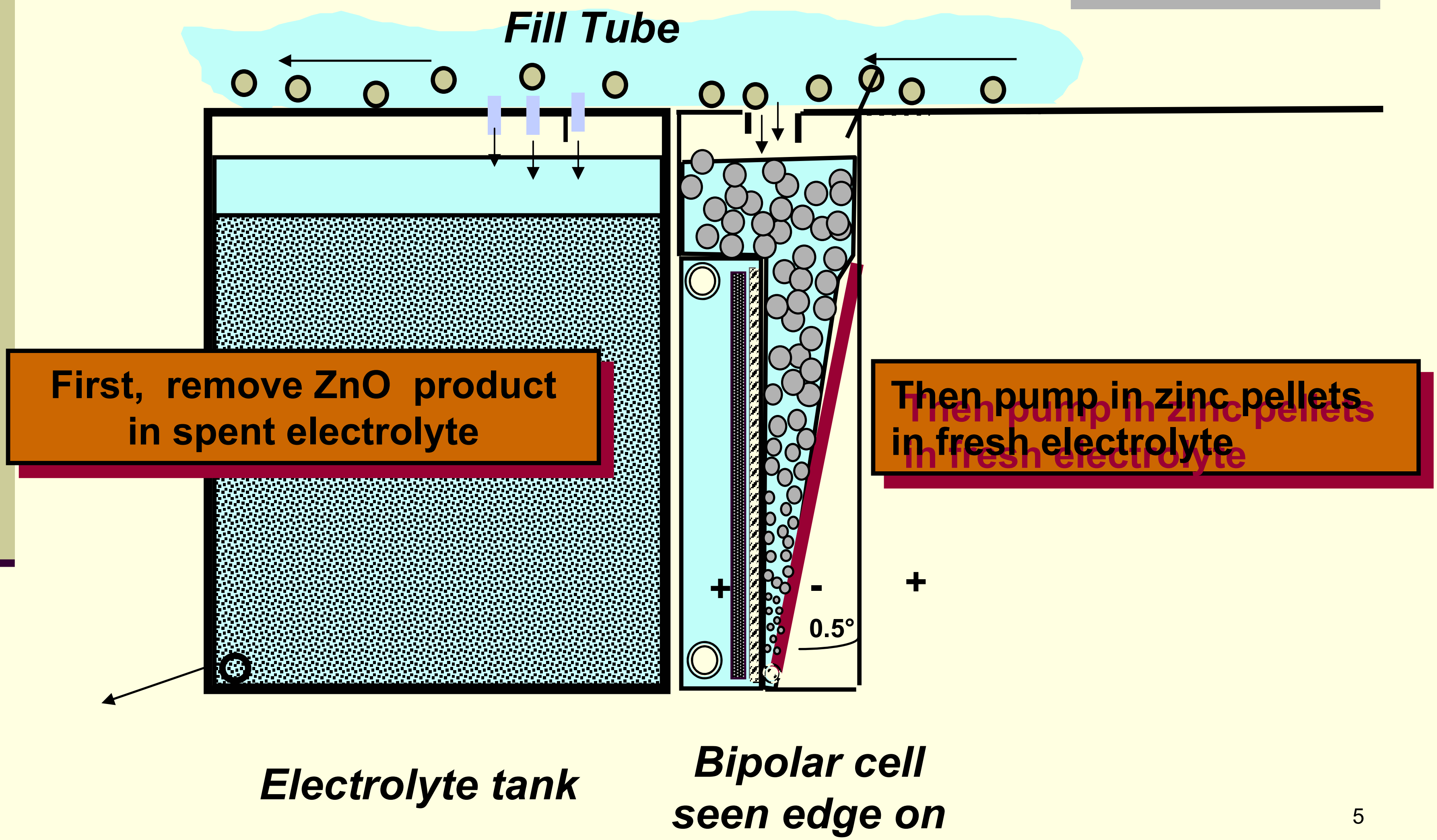
CONCEPT
AND
TECHNICAL BACKGROUND

Zinc/Air Fuel Cell Cycle

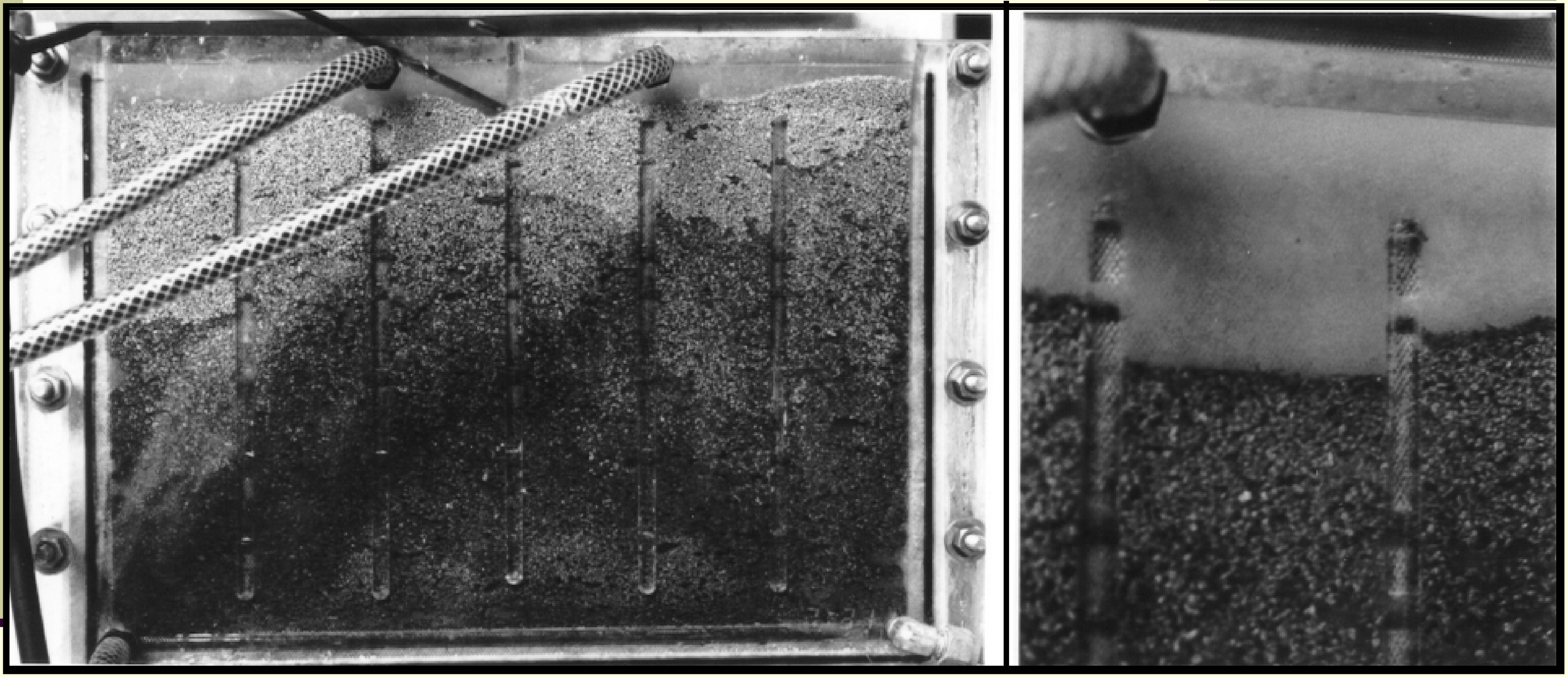


Zn/Air fuel cell is refueled by exchange of spent electrolyte for recycled electrolyte and zinc pellets, using a local recovery unit

The cell is refueled with zinc pellets carried by fresh electrolyte

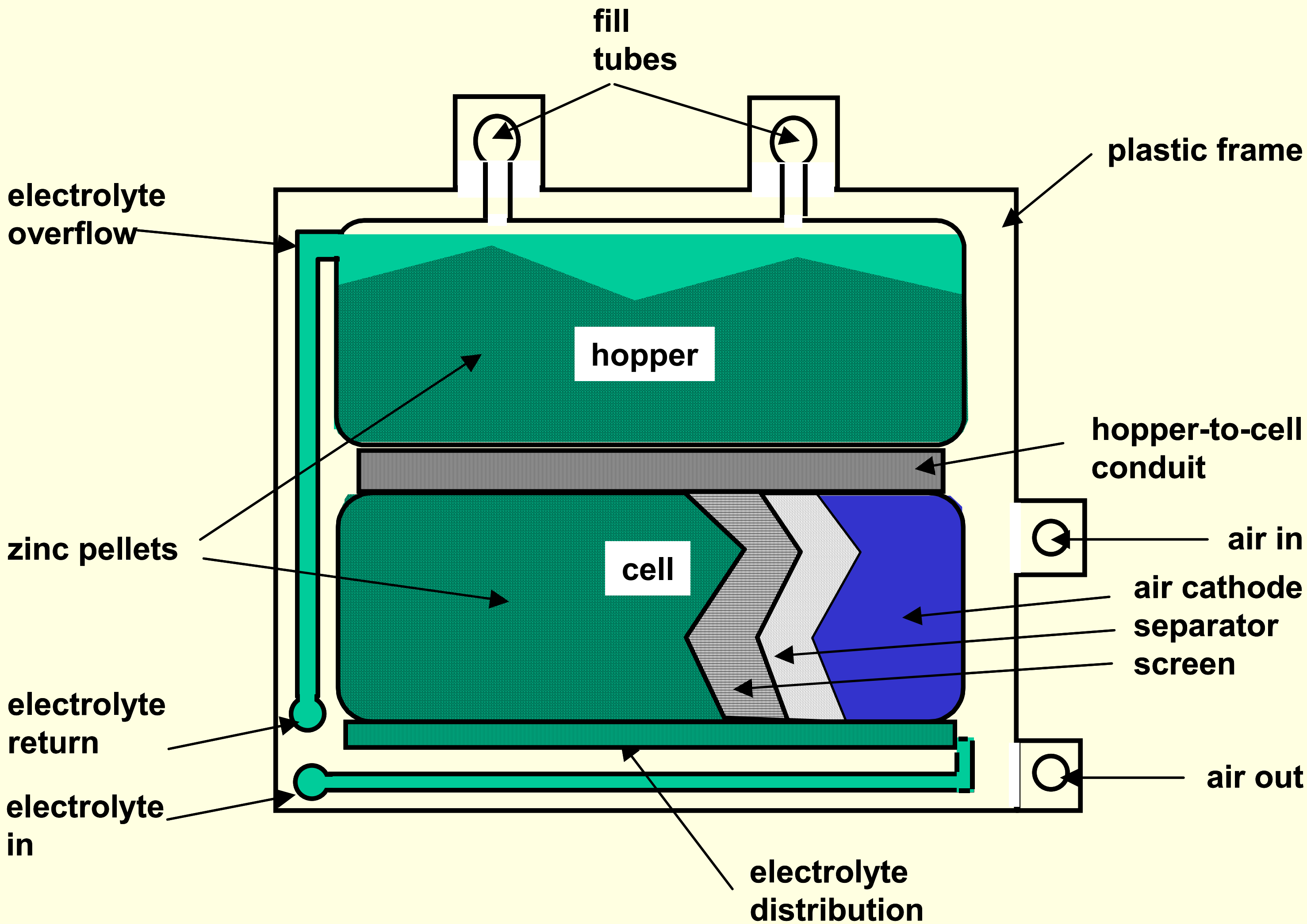


Core technology is the “self-feeding cell”

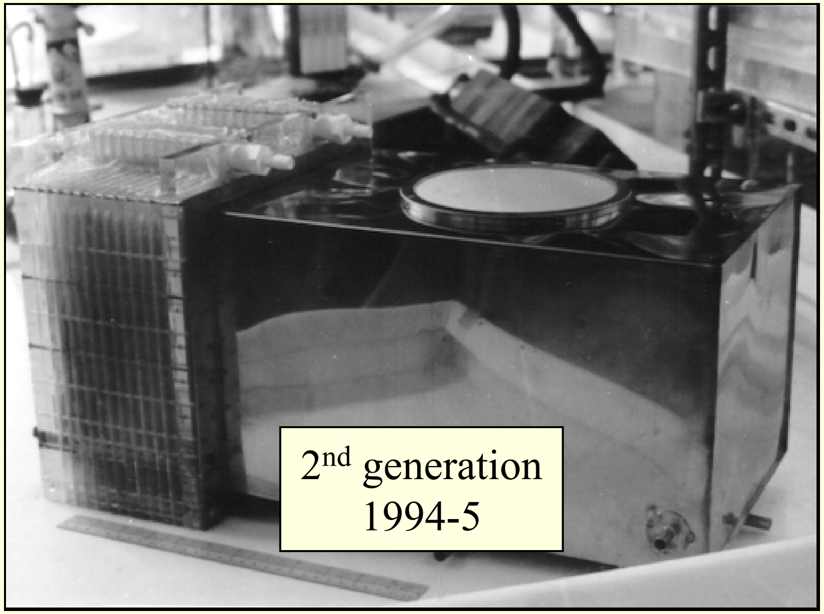


- Voids form and collapse in zinc particle anode
- As particles are consumed, they become smaller. and fall farther down into the tapered cell
- Voids allow flow-through of electrolyte without clogging

Hopper feeds Zn pellets to the cell

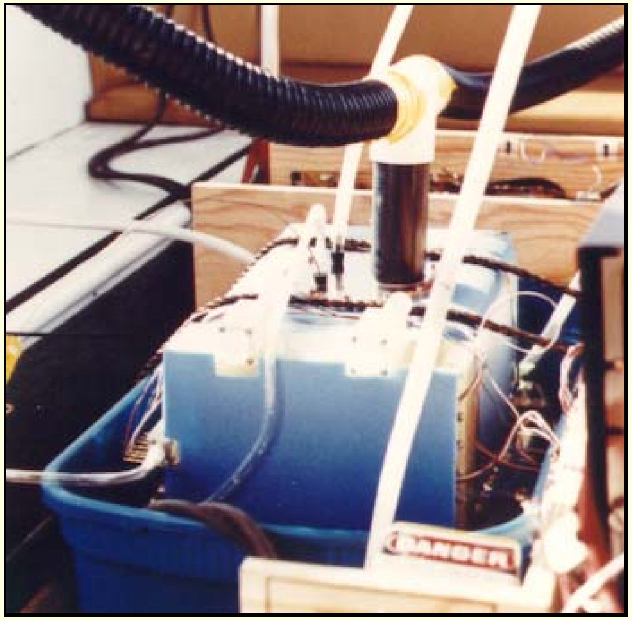


Zn/air tested in the laboratory and on electric bus as part of Pb/acid system



2nd generation 1994-5

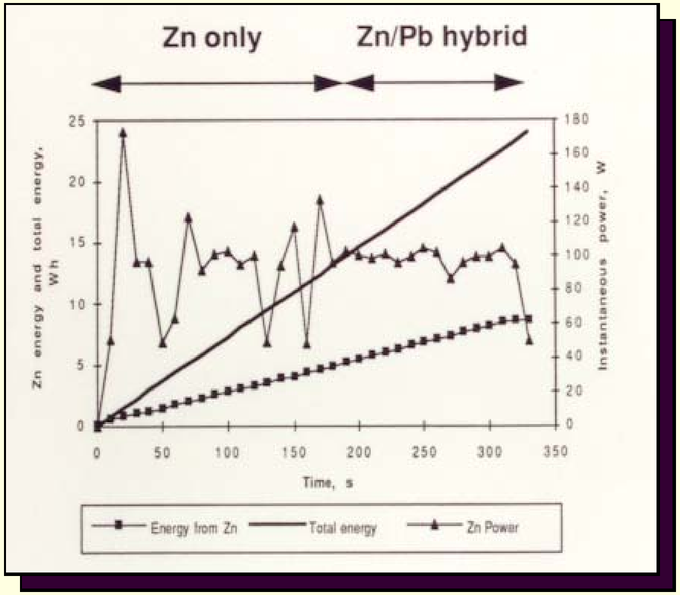
12-cell stack was refueled in 4 minutes in laboratory



6-cell stack was tested as part of a hybrid propulsion system in Santa Barbara Municipal Transit District bus

200 V Pb/acid → 6 V Zn/air → Controller → Motor

The Zinc/air Cell Helped Power a Bus Over a 75 Mile Circuit

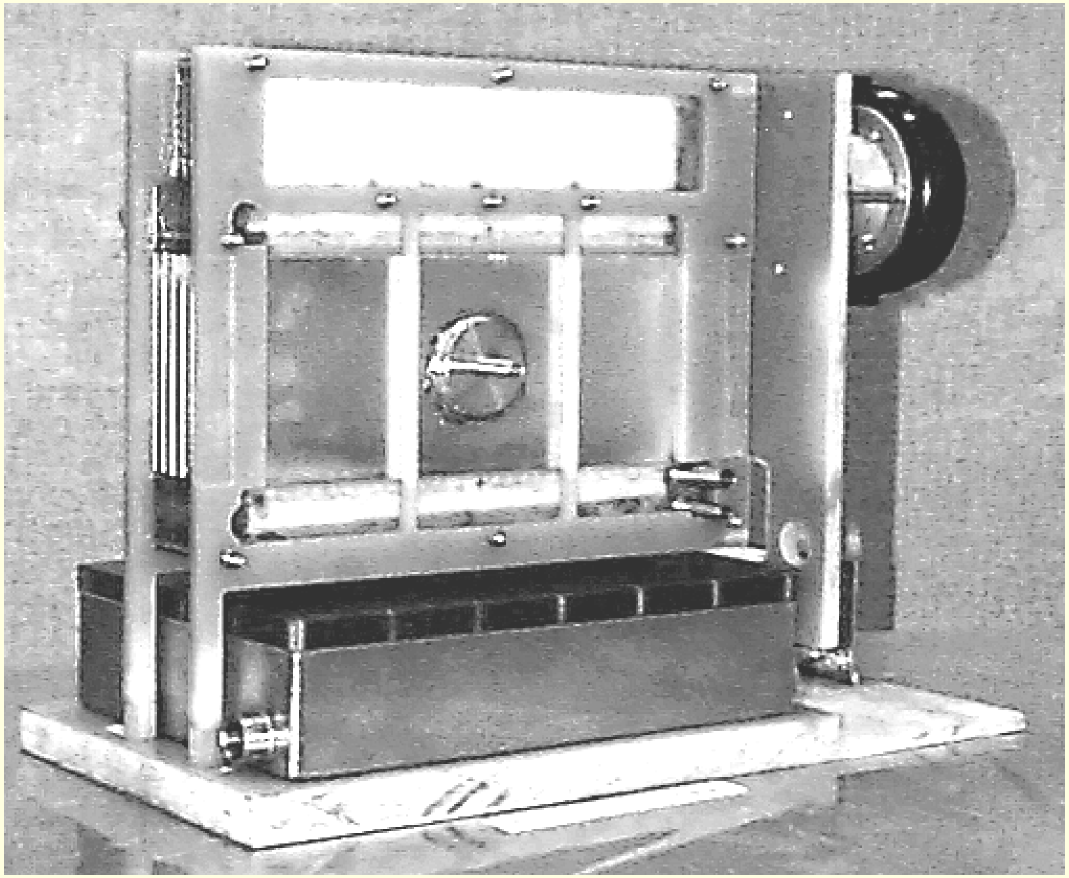


6-ton electric shuttle bus from Santa Barbara Municipal Transit District powered by 108 chloride power cells and 6-cell Zn/air fuel cell

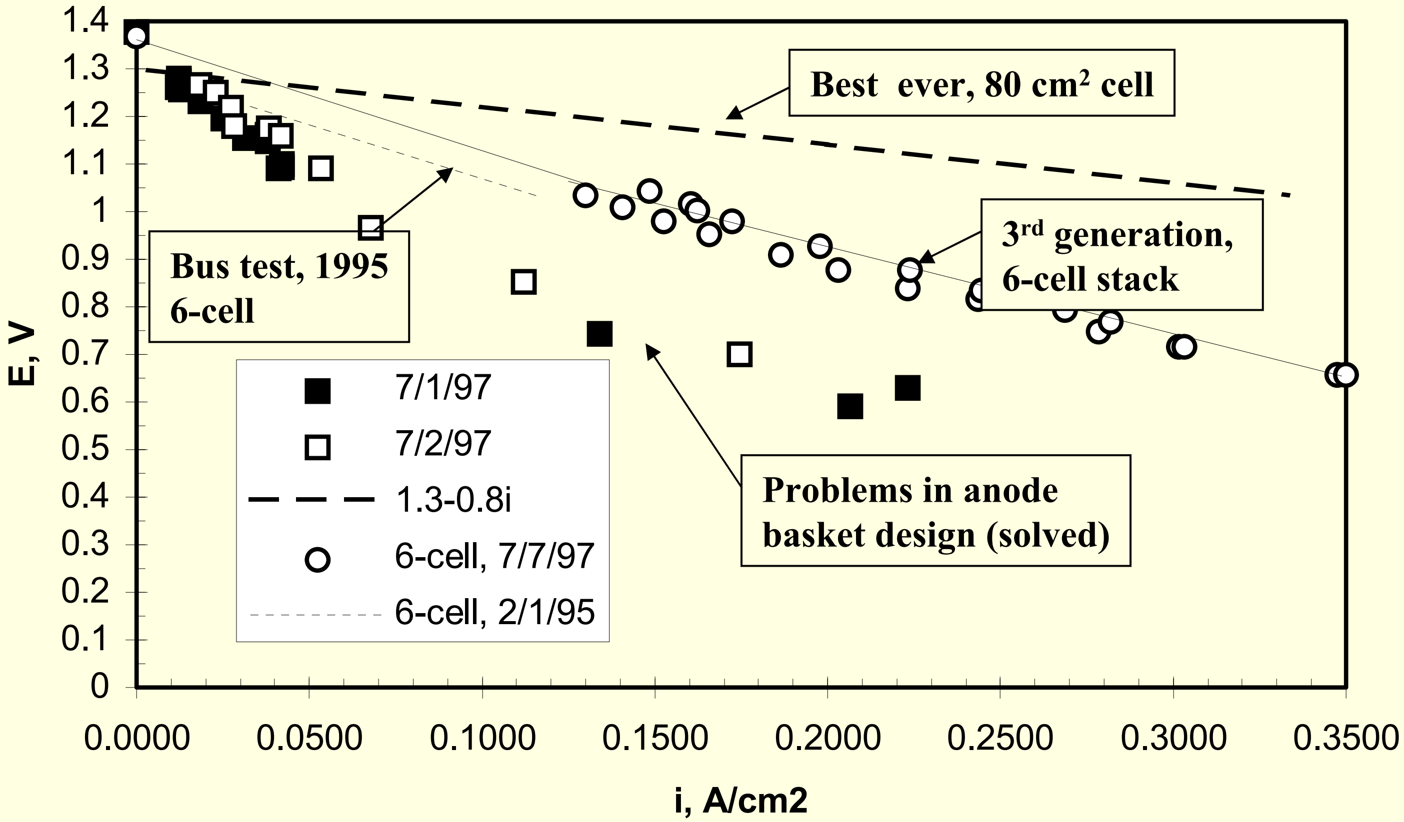
1.8 mile cycle #32 Feb 1 1995
100 W cross-over in parallel hybrid consisting of 7 V Zn/air and 6 V Pb/acid

3rd Generation: a Self-Contained Fuel Cell

- 200 W, 6-cell system
- Plate and frame design
- Integrated air fan and pump
- "Stand-alone" demonstration 1997



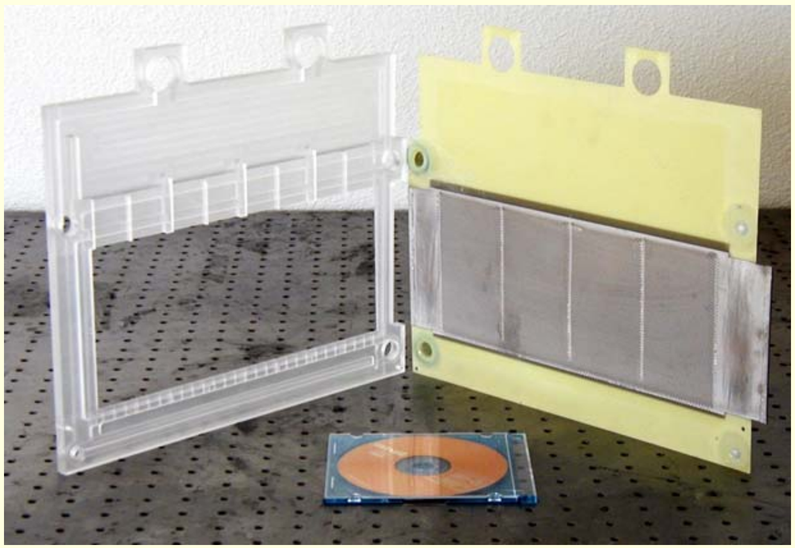
6-cell Stack shows high performance in 3rd generation



Zn/air Fuel Cell: Mass-Producible Design for Independent Testing (USABC), 300-385 W

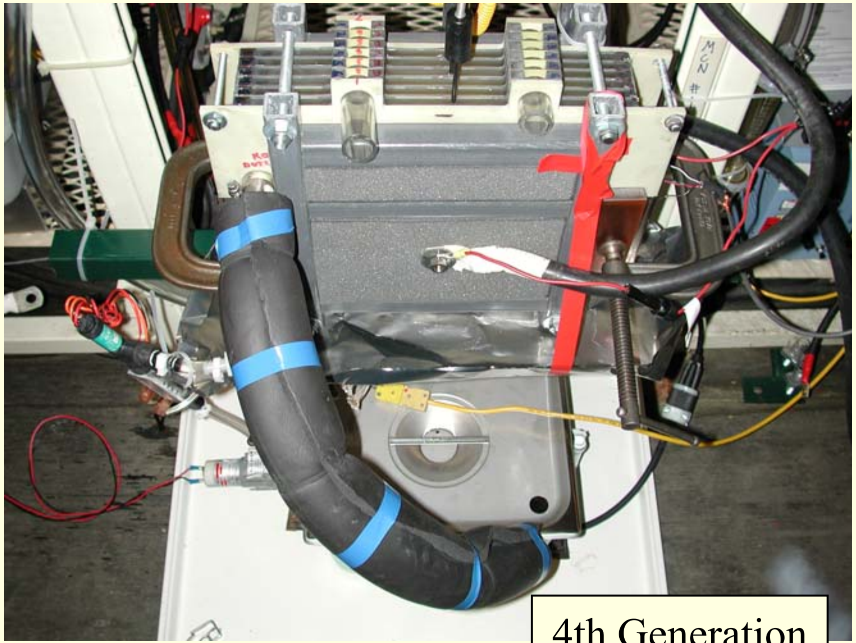
Verification Tests at ANL*

- USABC Test Protocols
- Constant Current , Pulse power, Vehicle Profiles
- 250-W rated showed 300-380 W



Assembled From 2 Mass-Produced Parts

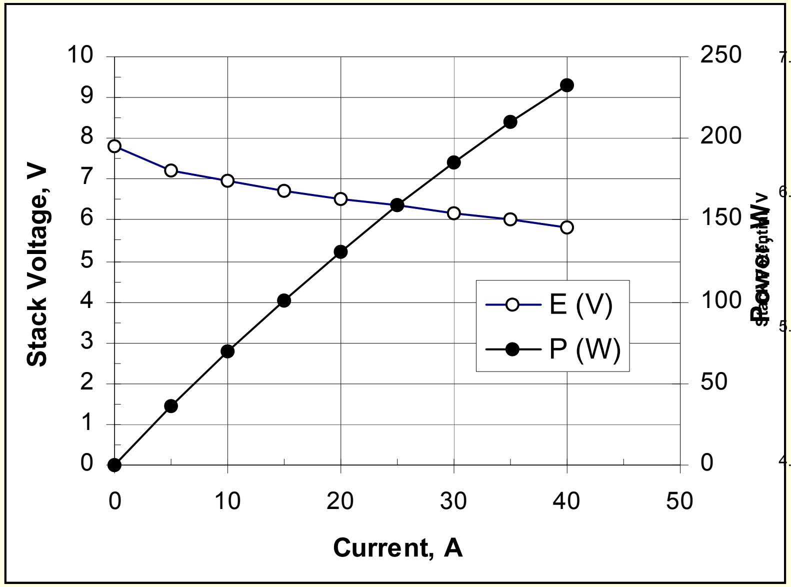
1. Reinforced board carrying electrodes
2. Molded plastic frame carrying hopper and flow conduits
3. External cell-cell connections

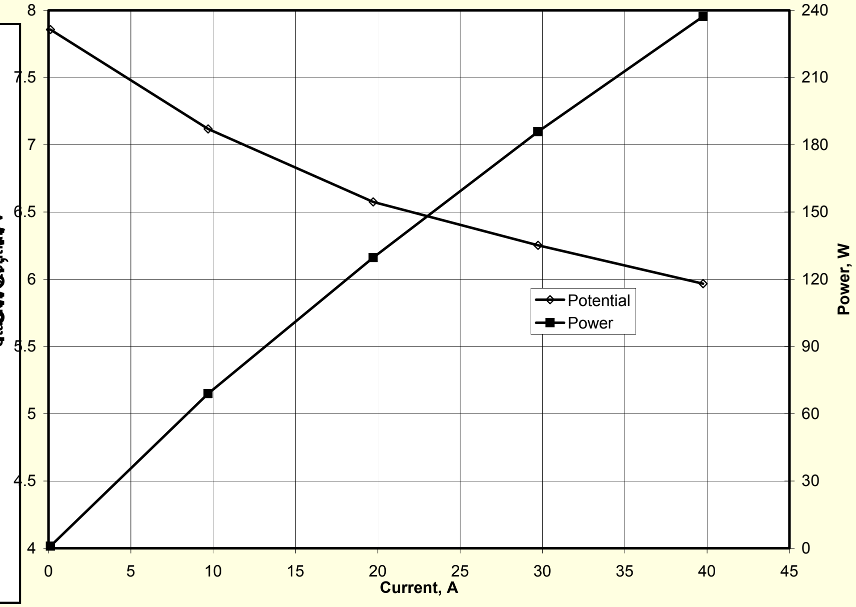


4th Generation
2000-2001

**Argonne National Laboratory, US Advanced Battery Consortium Test Facility, Dr. Ira Bloom, March 2002*

Corroboration of high power capability



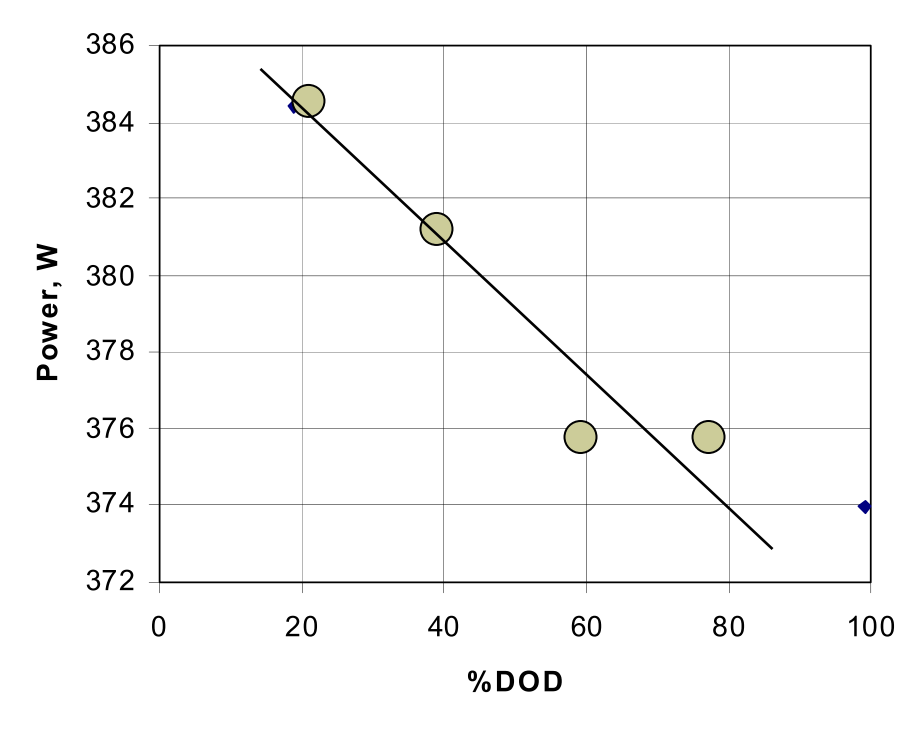


LLNL results
After 888 Ah and 993 Wh
at 59 C, 3/30/01

Independent tests at
Argonne National Lab
(USABC* protocol)
at 59 C, 4/09/01

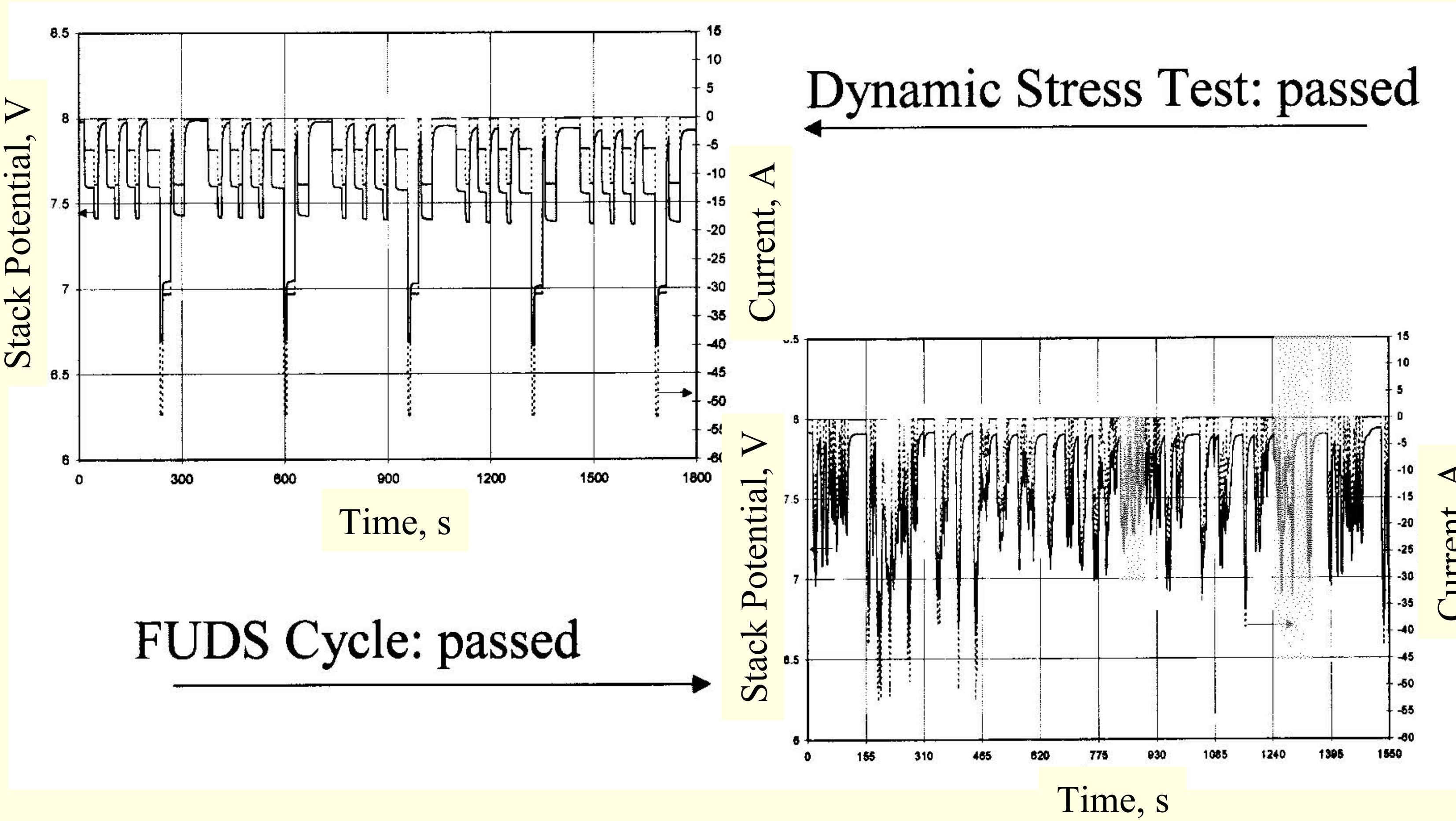
*USABC = United States Advanced Battery Consortium

Very high power throughout discharge

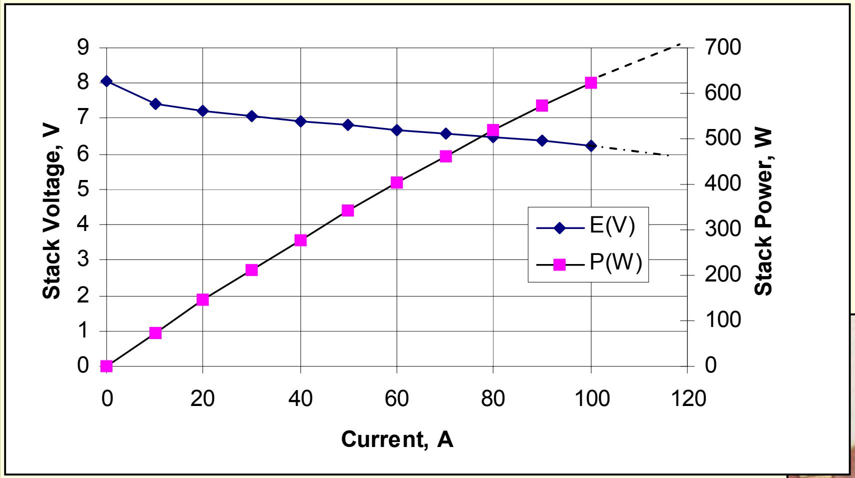


- This 6-cell stack was rated at 250 W
- Tested at 310-384 W by USABC

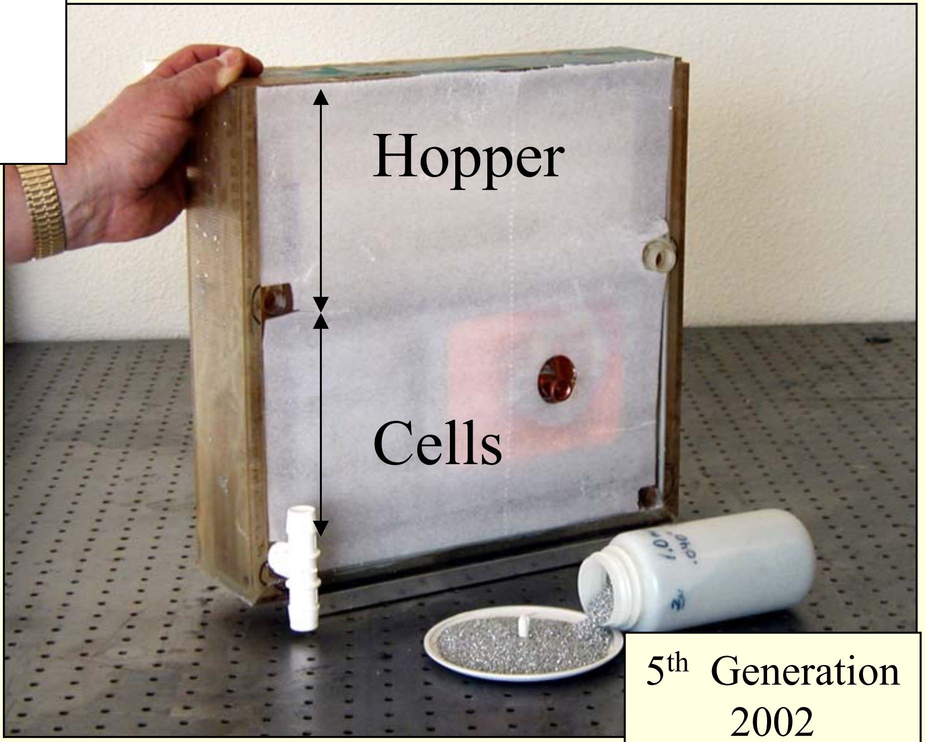
Zinc Air Fuel Cell performs successfully over automotive drive cycles



Current Generation 6-Cells Optimized Bipolar Connections and Flow for "1 HP" Initial Power



Motorcycle Power Source,
Pre-Commercial Demonstration
Feb. 2002



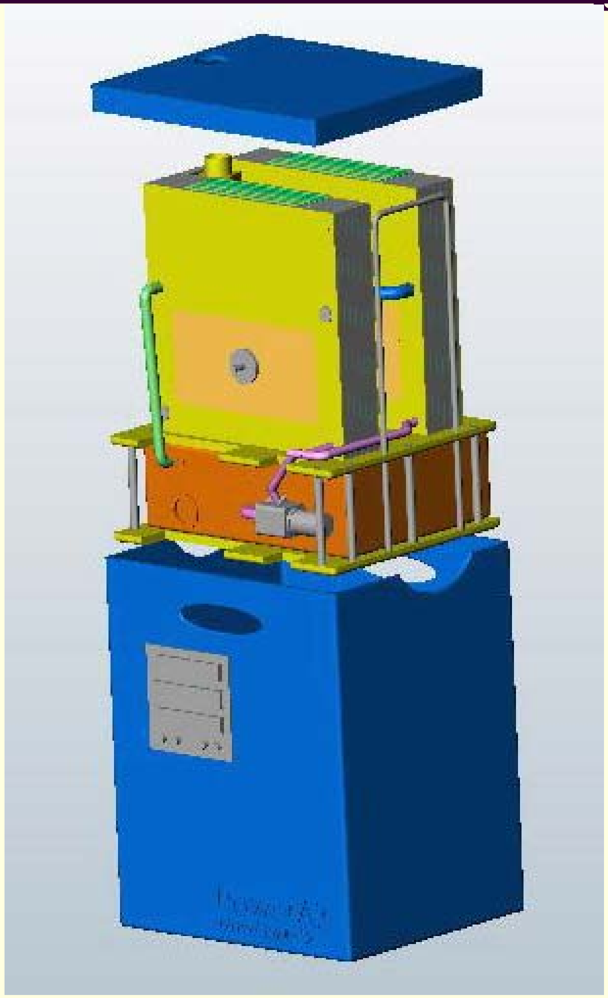
5th Generation 2002

- Cell Rated for 350 W
- Peak sustained >700 W
- New electrode, low AH/liter
- Power falls off with Ah/liter
- Fully-contained stack
- Hopper fed through slots
- *All systems have mass:*

$W(kg)[kW,kWh] \sim 4\,P_{peak} + 5.5E_{nom}$

Source: Power Air Technologies, Inc.

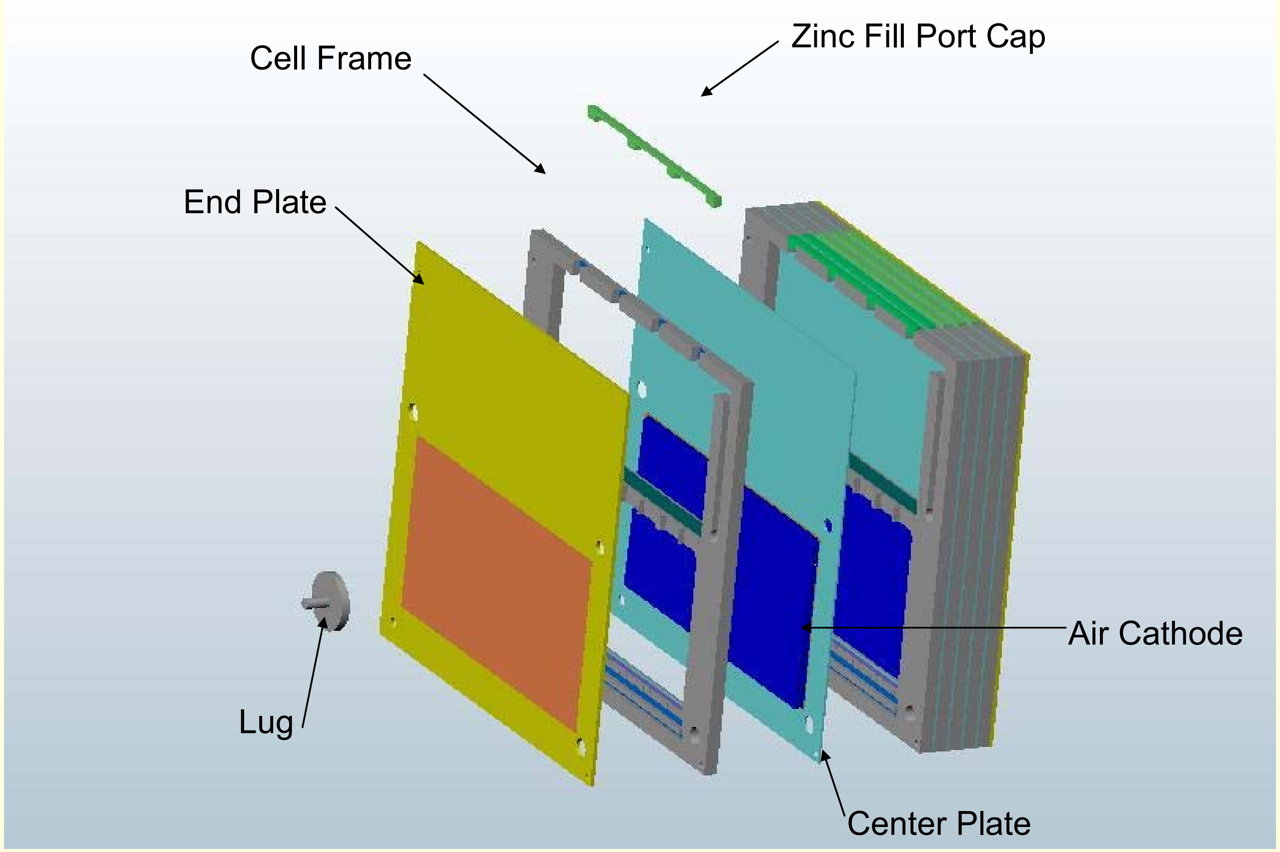
Year 2002 Prototype: Specifications



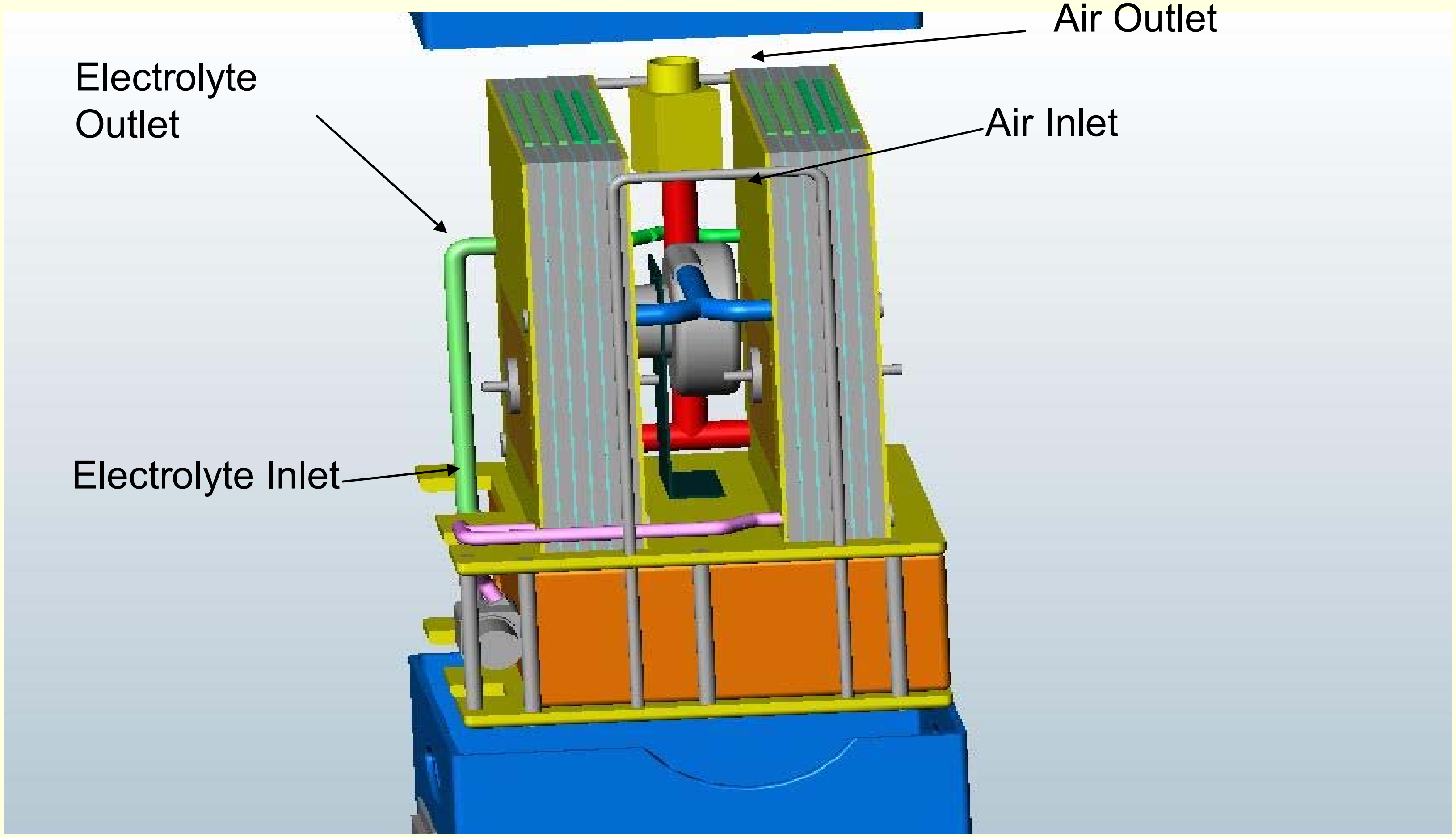
<u>Specifications</u>

- 12 cell stack, 5 liter tank
- 14.4 V @ 20 A, 280 W
- 12 V / 600 W rated
- 14 V OCV
- Capacity:
  - Variable: depends on fill level
  - Up to 8 hour discharge

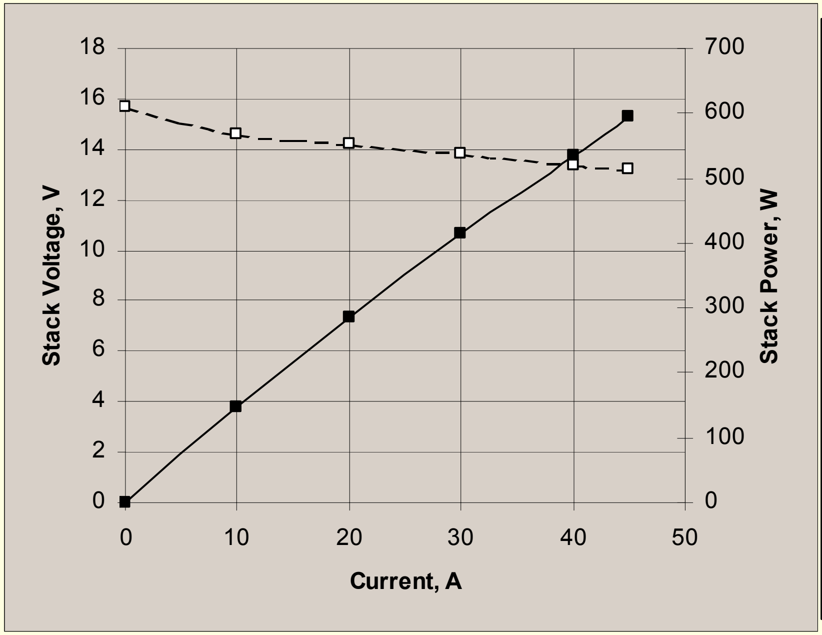
Unit Module: 6 Cell Stack

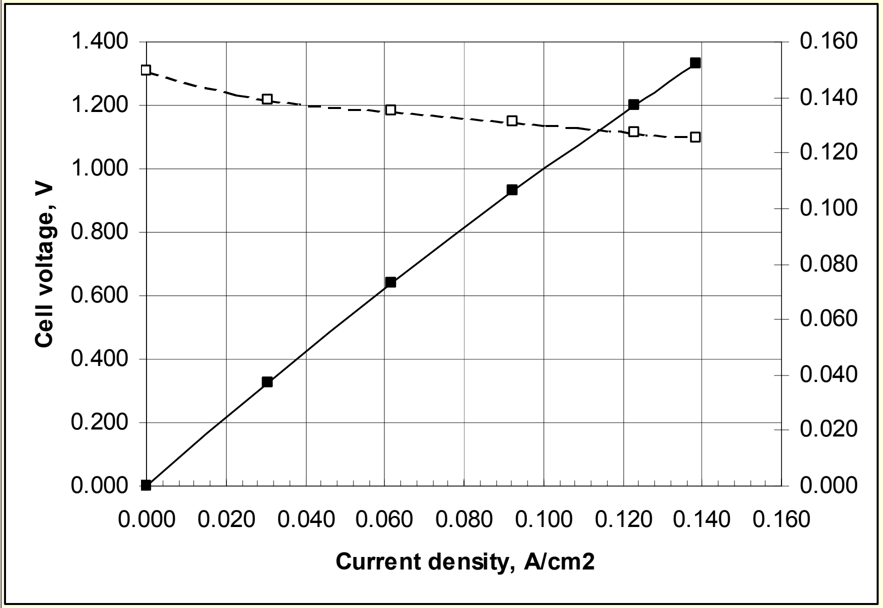


Zinc Air Fuel Cell



Beijing Demonstration Results





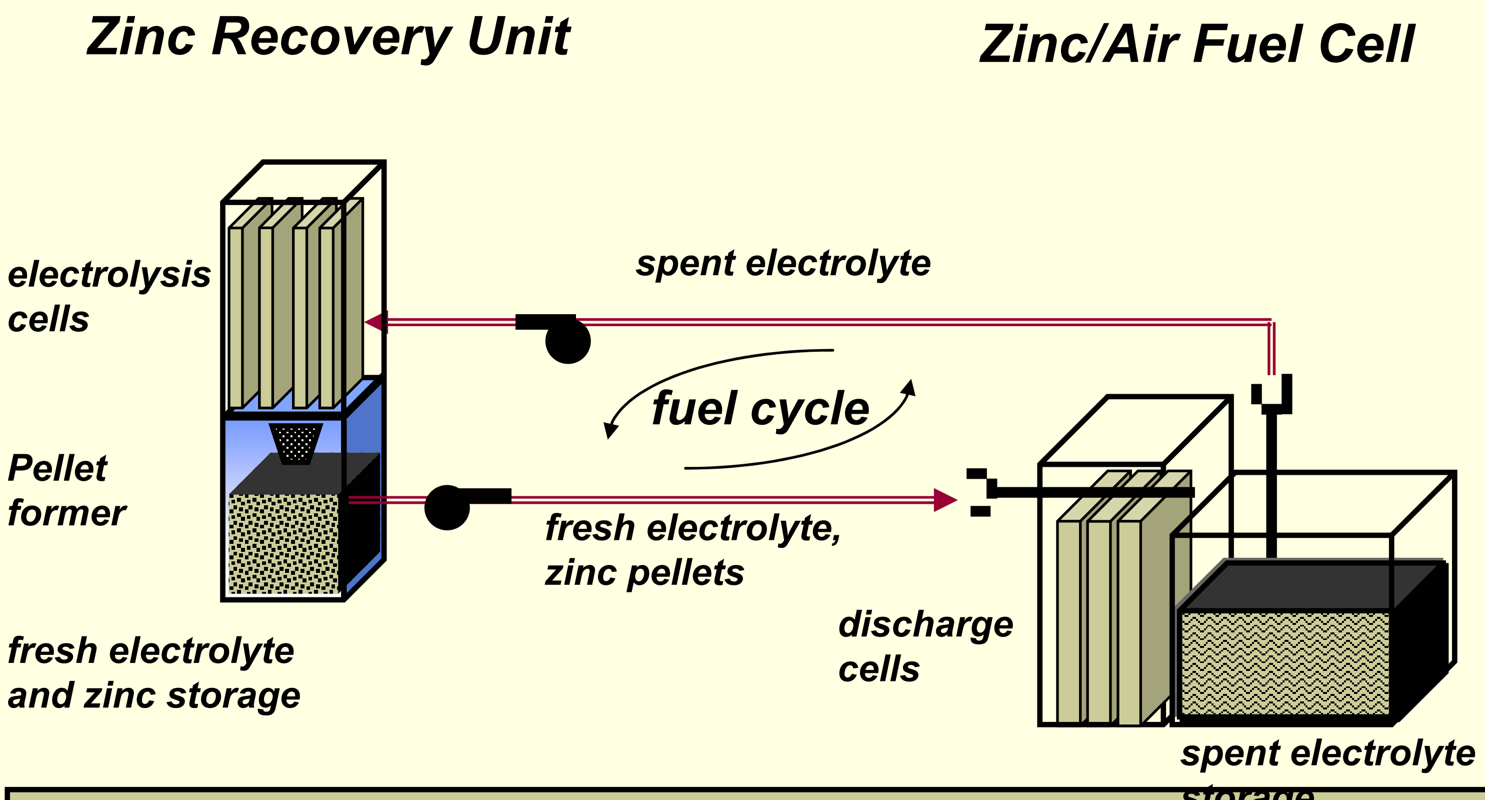
- Fully integrated 12-cell module
- Demonstrated on live television

Zinc/air Fuel Cell has Unique Advantages

Refuels like gas engine but without hazards	▪ Refuels while being operated ▪ "topping off" like gasoline ▪ Emergency range extension: add water
Full consumption of fuel	▪ All zinc is consumed to make energy in single pass through cell ▪ No withdrawal of unconsumed zinc
Low operating cost	▪ 2x cost of electricity ▪ Competitive in fuel cell market
Low Initial Cost	▪ 100-300 $/kW of rated power ▪ Low capital cost of equipment ▪ Cost of zinc capacity: ~$2/kWh

ZINC RECOVERY

Zinc/Air Fuel Cell Cycle



Zn/Air fuel cell is refueled by exchange of spent electrolyte for recycled electrolyte and zinc pellets, using a local recovery unit

Zinc recovery: technology depends on application

- Melt-and-spray: easy, current infrastructure
  - Low technology option, use licensed or franchised cells to plate zinc fines, melt and spray back into ZnO-depleted electrolyte
  - Use LLNL angled cells, lamellar separator
  - Current cost: + 5 cents/kg
- Plate, roll and chop: for captive fleet applications
  - Dedicated recovery
  - Plate out zinc fines
  - Roll to form compacted plate
  - Shear into “cubes”
  - LLNL issued patent

Simple Zinc Recovery by Melt & Spray

<u>Melt-and-spray</u>

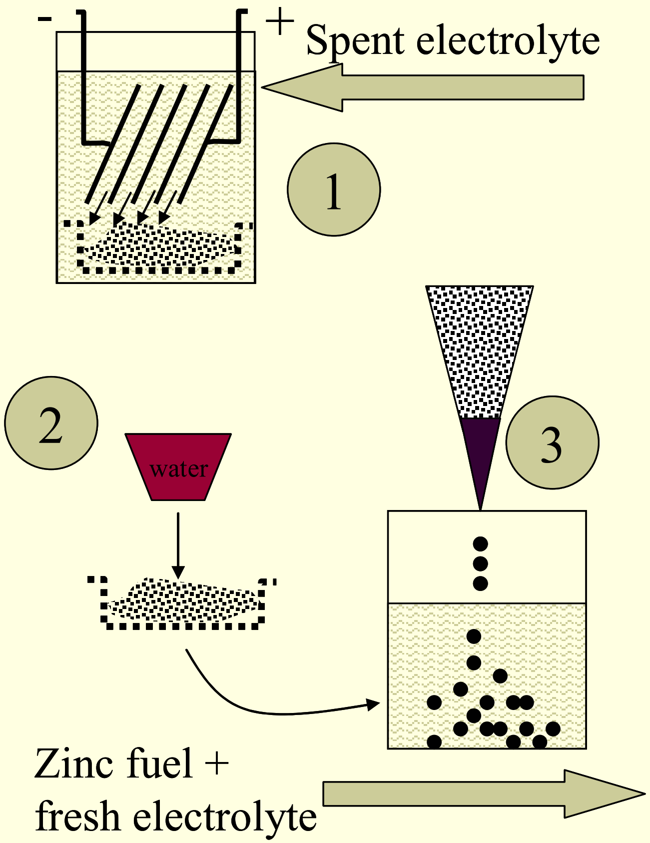
1. LLNL angled electrolysis cell
   --Makes Zn particles, 10 μm, from spent electrolyte

2. Wash with water
   --Make up for evaporation, return wash water to electrolyte

3. Melt and drop into Zn-depleted electrolyte

Low capital- and energy cost, moderate labor

Return wash water to Zn-depleted electrolyte



LLNL Proprietary

APPLICATIONS

DOE/NETL[1] Projects 26 GW/y Market by 2012 for Cost Competitive Fuel Cells

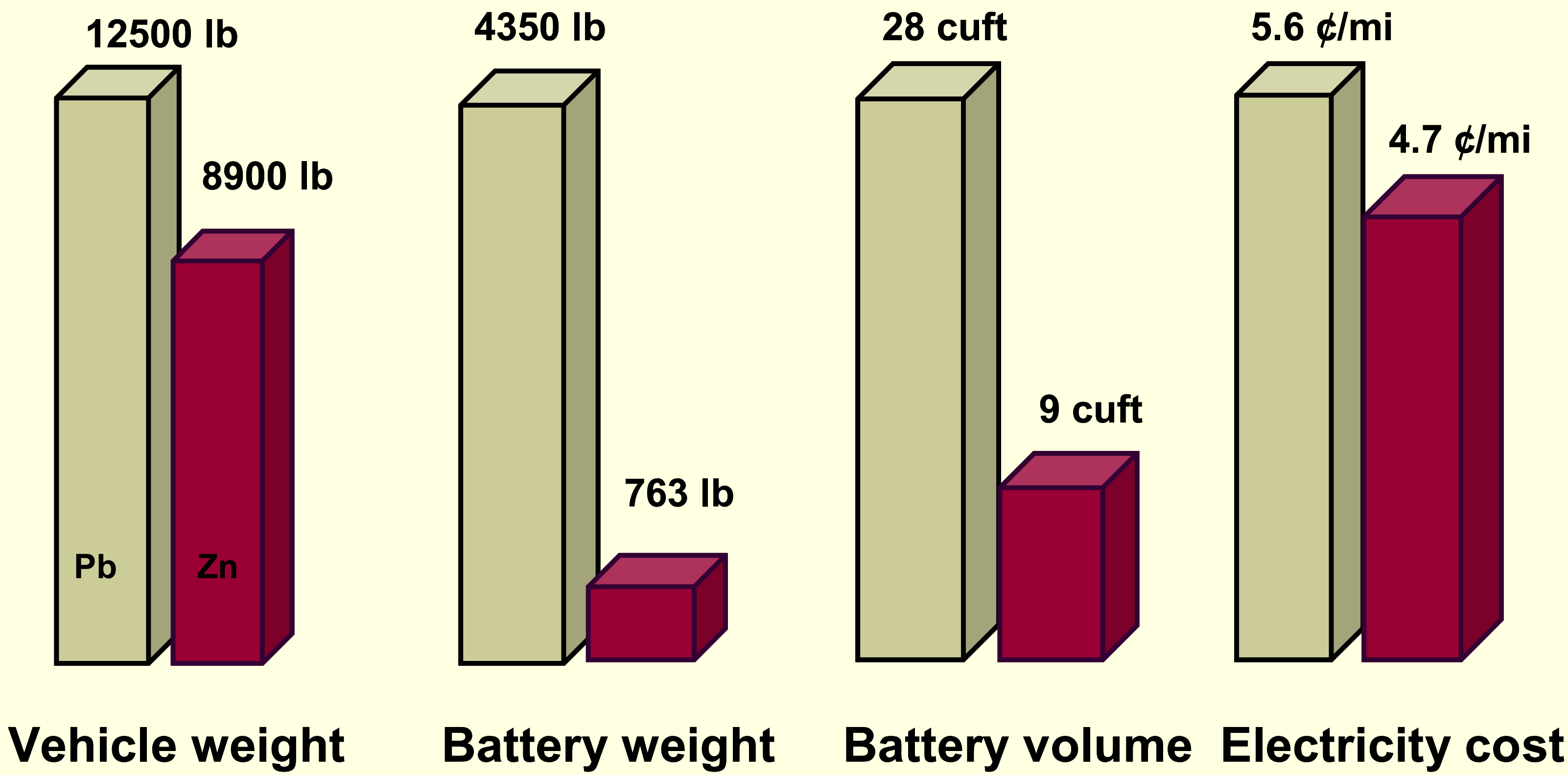
Market	Range (kW)	Units/y	Size (kW)	Total (GW/y)
Remote Generators	0.5 - 10	30,000	10.0	0.30
Telecommunication	2 - 10	30,000	10.0	0.30
Commercial	<100	165,000	50.0	8.22
Residential	2 - 15	1,520,000	10.0	15.20
Back-up Power	<50	80,000	6.0	0.48
SPA (appliances)	0.5	160,000	0.5	0.08
APU's	5 - 15	121,000	10.0	1.20
			Grand Total	**25.78**

[1]Source: Mark Williams, DOE/NETL
2nd International Conference on Fuel Cells, ASME, June 2004

Near Term Applications

- Civilian
  - Fleet Vehicles: *continuous use, no pollution*
    - Hybrid busses and taxis
    - Enclosure vehicles (fork lift trucks)
  - Transportable units ("Gen sets"): *low cost & refuelable*
    - Boats, recreational, remote construction
  - Emergency, UPS backup *low cost, long shelf life*
- Military
  - Stealthy Auxiliary Power (Abrams Tanks)
  - Command Centers (Silent, no thermal signature)
  - Field recharging of secondary (Li, NiMH) batteries

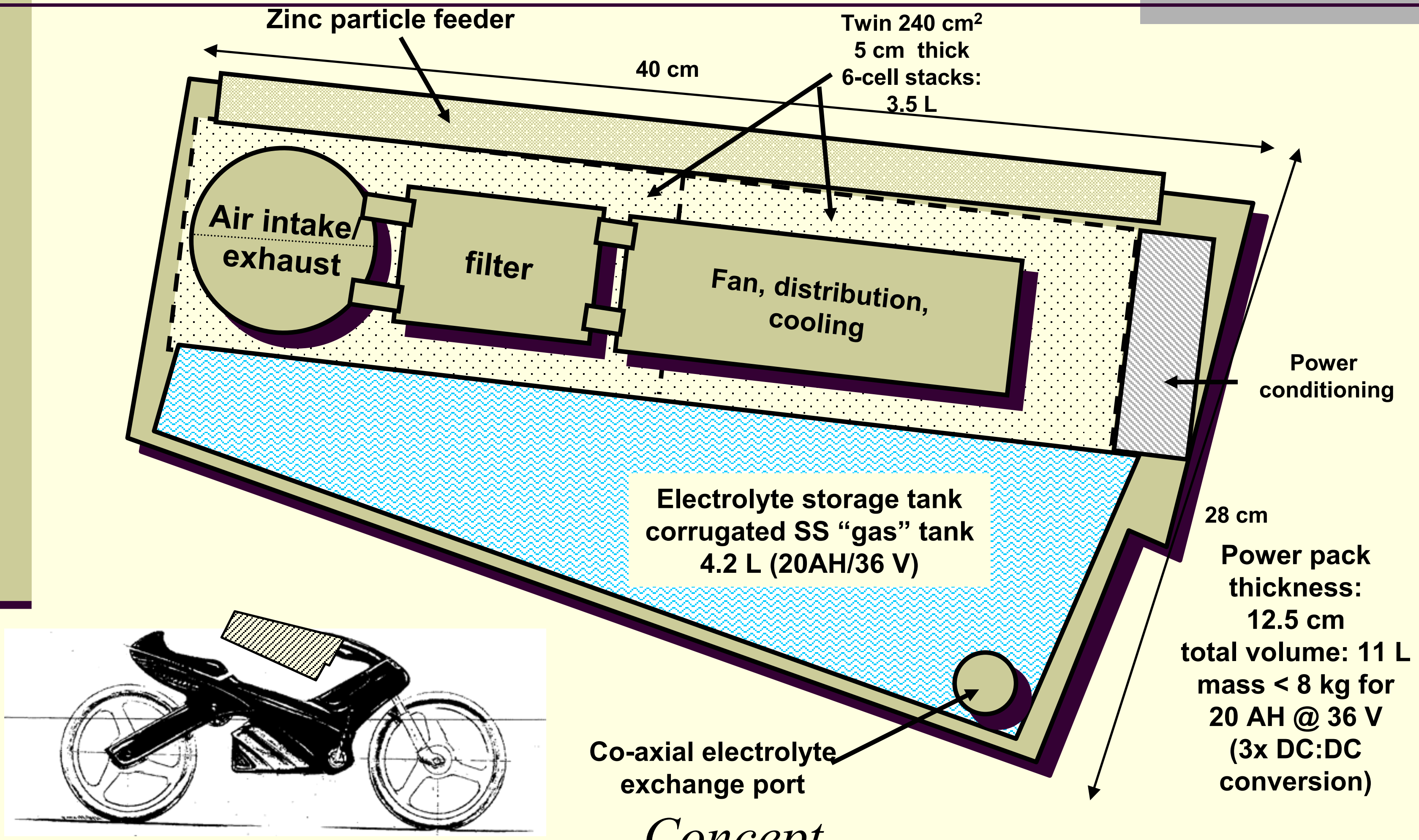
Replacing Pb/Acid with Zn/Air, decreases bus weight, energy use and cost



10-min refueling allows Zn/Air use 24 h/day

Comparison: Chloride Ltd. Model S32Y11; as used on Santa Barbara Metropolitan Transit District 22-ft shuttle, downtown route (72 miles), 27 kW

Electric bicycle concept: 20 AH @ 36 V

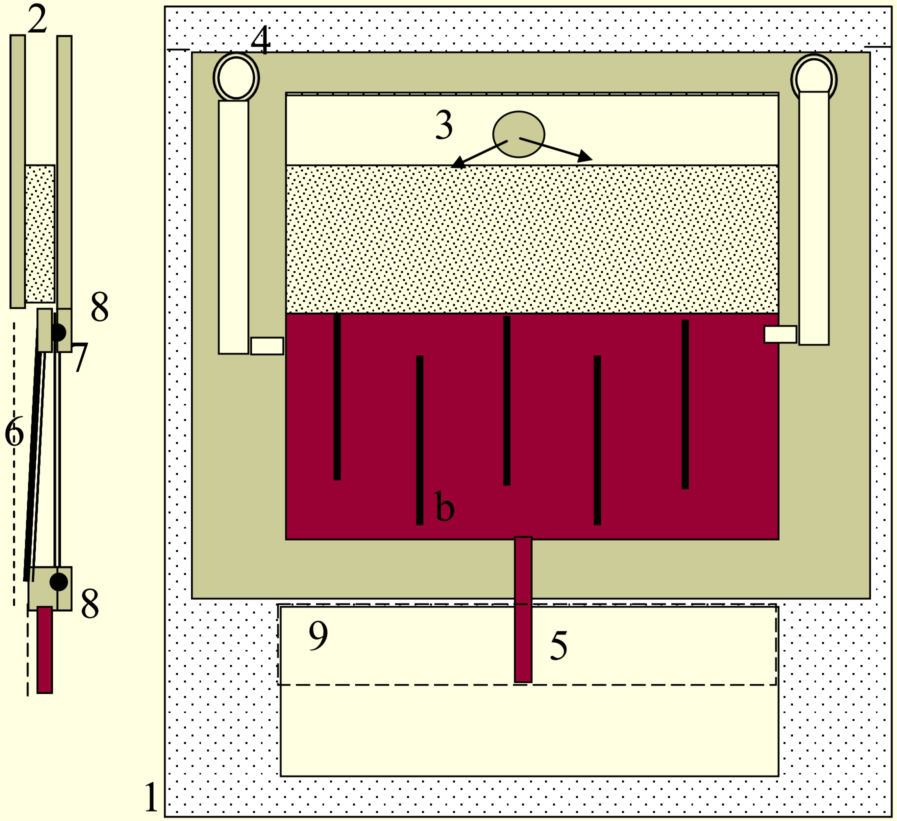


Concept

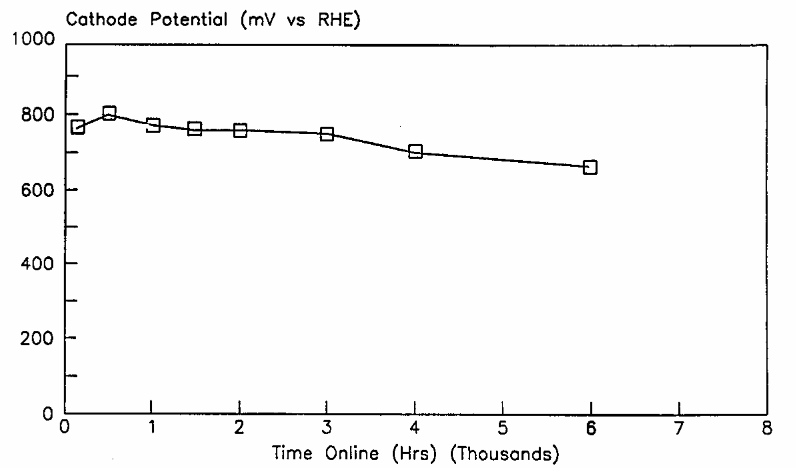
A Monolithic Assembly Avoids Bonded Seals: Key to Manufacturing

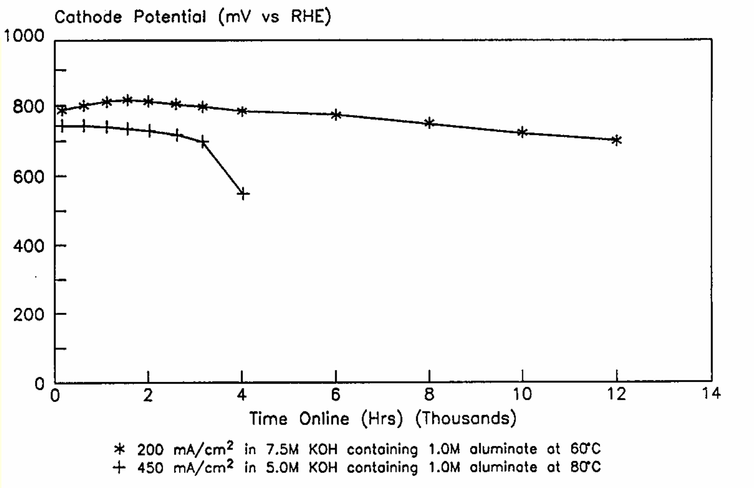
<u>Essential features</u>

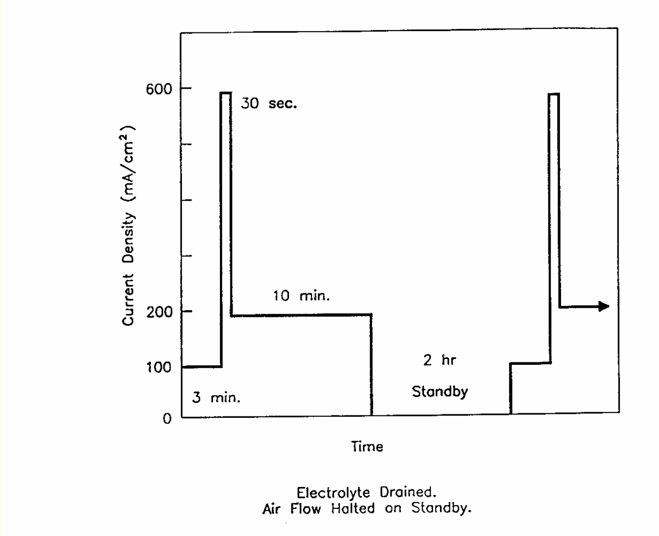
1. Cells, hopper, tank contained within seamless box
2. Cathode cassette: metalized, rectangular, basket flush
3. Electrolyte flow top to bottom
4. Air enters/leaves above electrolyte line
5. Condensation return tube and bypass in cathode
6. Air electrode electrical connections via splines
7. Thermoset frame outside of air electrode



Air cathode: life tests in similar electrolyte







Summary: life tests

1. Basic air electrode performed 12000 h continuous
2. No zinc electrolyte tests
3. High T and/or i <u>shortens</u> life
4. Losses on standby not limiting

Plans Forward

- Establish in-house air electrode manufacturing
- Simplified cell design:
  - Replaceable cathode modules
- Simplified Zn recovery: melt & spray
- Focused development of near term markets
  - Electric bus and scooter fleets
  - Stand-alone generators: emergency, portable
  - Military applications