

# ***High Efficiency Blowers for SOFC Systems***

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***Phoenix Analysis & Design  
Technologies***

# *Acknowledgements*

- **ARL support on Compressor/Expanders, portable power supplies, and regenerative aerodynamics**
- **DOE support on Cathode Air Blowers**
- **UTCFC support on VGEN and TURBOMIX development**
- **DOE, Travis Schultz, involving PADT in SECA work in 2004**

# Agenda

- Overview of PADT and our Fuel Cell Programs
- Blower Issues and Design Process
- Review of PADT Blower Technologies
- Future Trends: Hot Anode Recycle Blower
- Discussion

# Who is PADT?



- **Incorporated in March 1994**

- Support innovative product development in a wide range of industries through the use of our core capabilities
- Simulation, Design, Rapid Manufacturing, Laboratory Testing

- **Facilities**

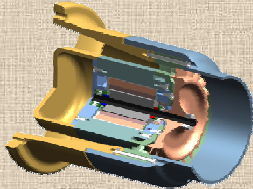
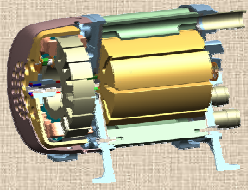
- 24,000 ft<sup>2</sup> at ASU Research Park in Tempe, Arizona
- 60% Office
- 40% Shop & Lab

- **People**

- 48 Experienced and Motivated Fulltime Equivalent Employees



# PADT Fuel Cell Programs



## 1998-2000

- 5 Roots Cathode blowers delivered to Ballard
- 6 Axial Cathode blowers delivered to UTCFC

## 2001-2002

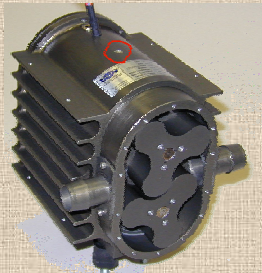
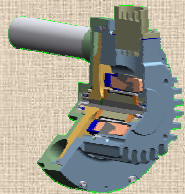
- VGEN Hydrogen Recycle blower (HRB) designed
- UNIROTOR compressor/expander developed
- TURBOMIX and TRILOBE blowers developed.
- MMC modular motor controller developed
- 18 blowers delivered (UTC, Major automakers)

## 2003

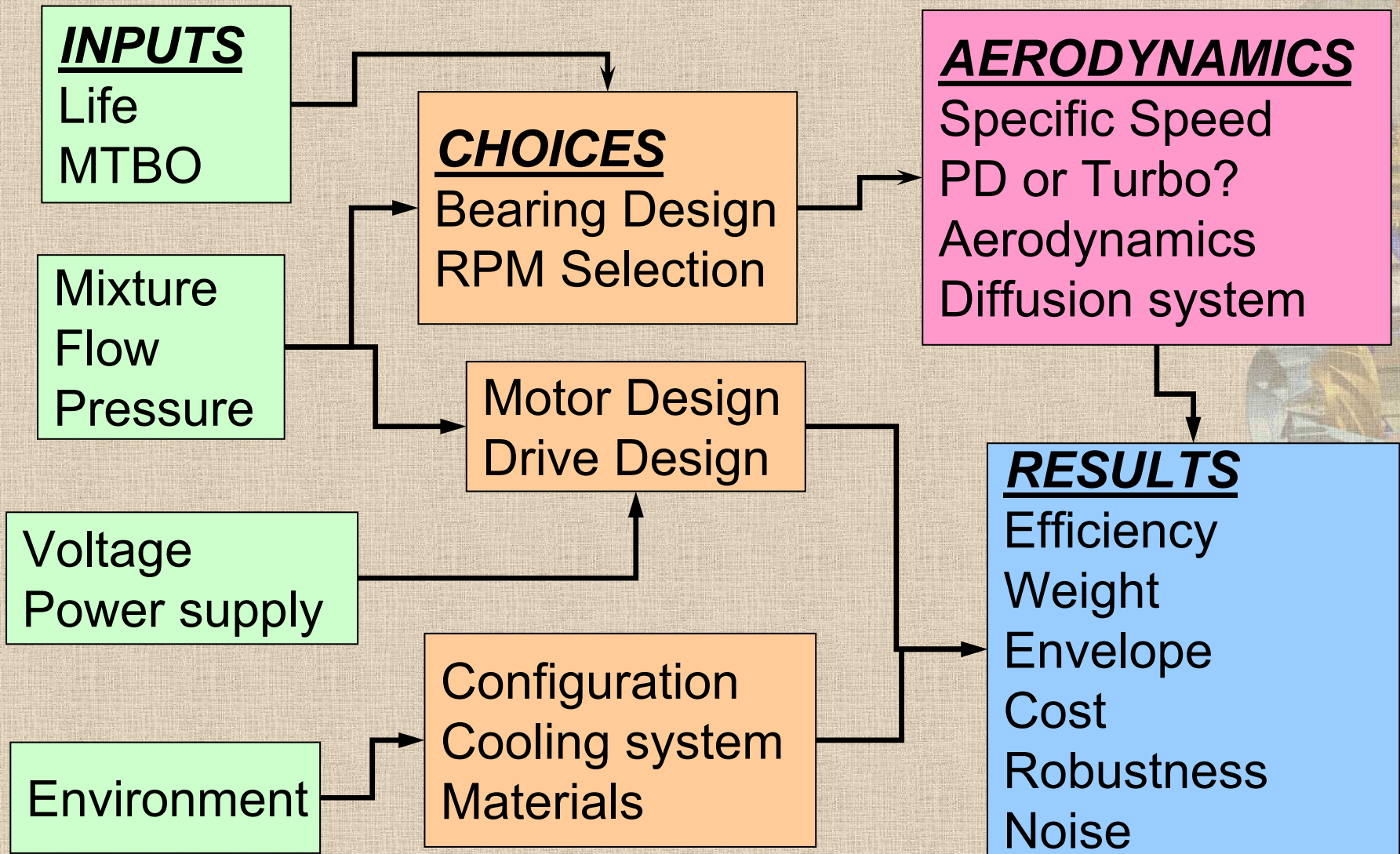
- DMFC system developed for Polyfuel
- ARL Phase II Portable Power supply finishes
- 28 blowers delivered (UTC, Major automakers)

## 2004

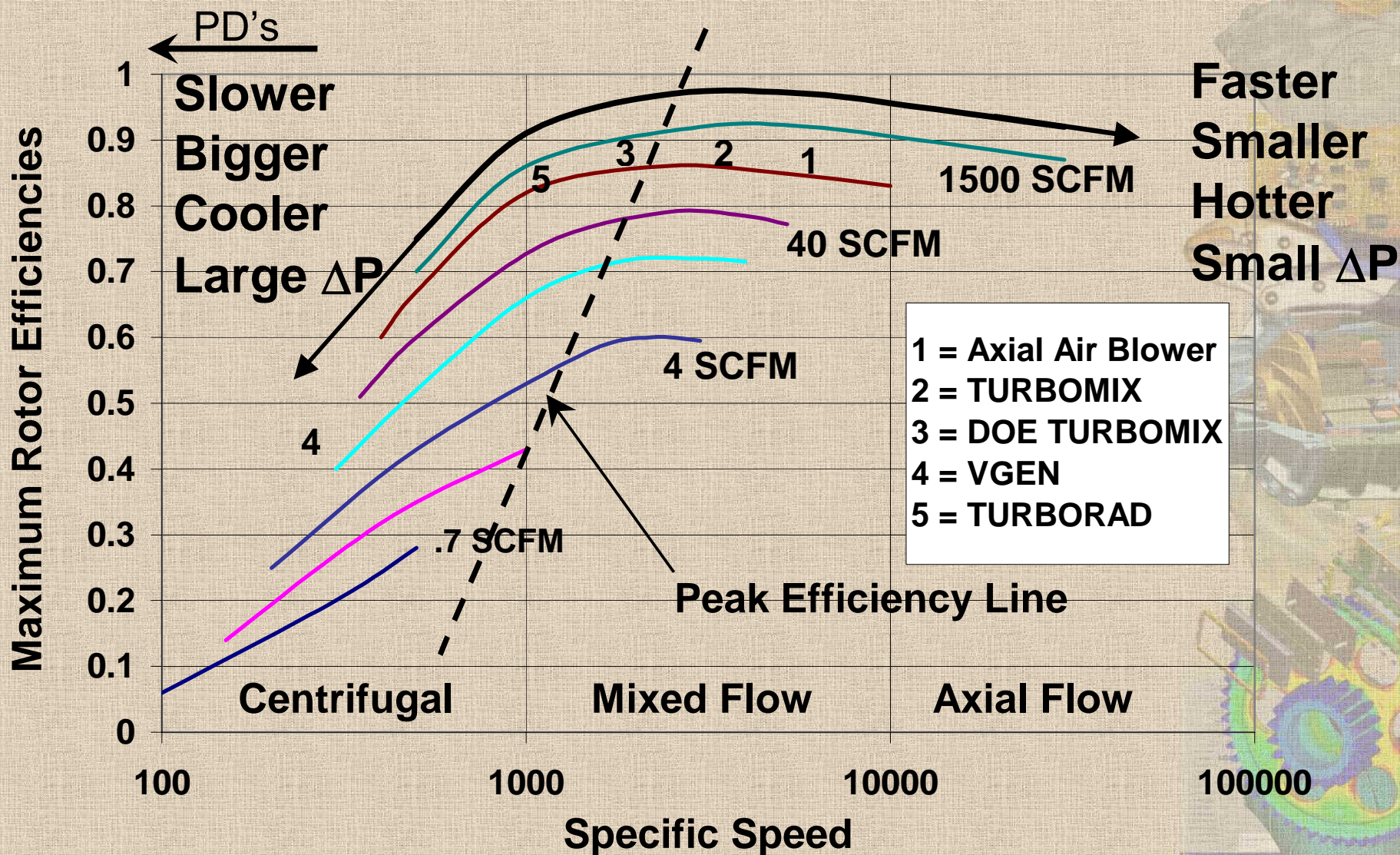
- SOFC Cathode blower for major SECA member
- TURBORAD dev., ~ 60 blowers delivered



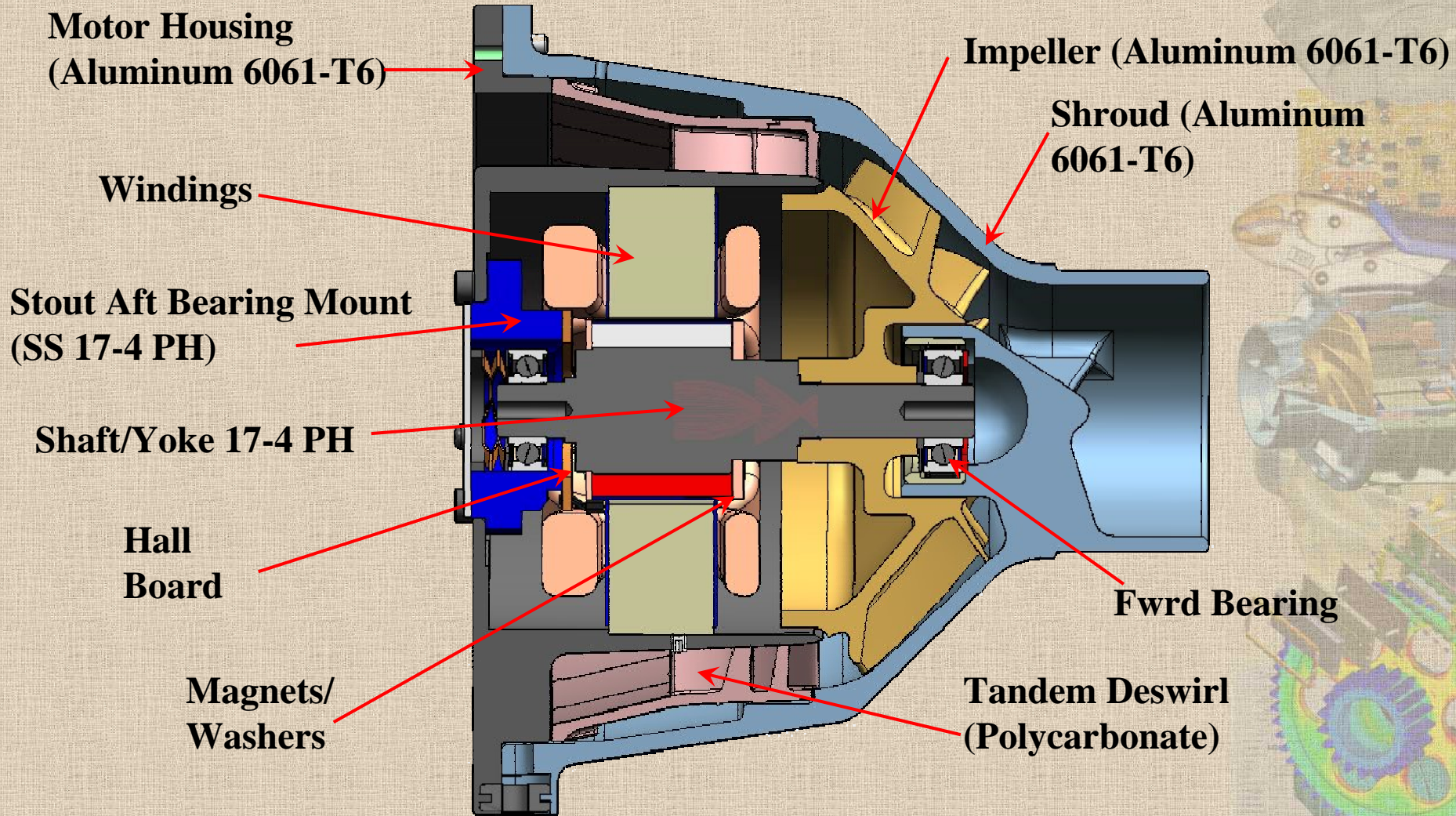
# Blower Design Process



# Specific Speed Describes Turbos



# TURBOMIX Design





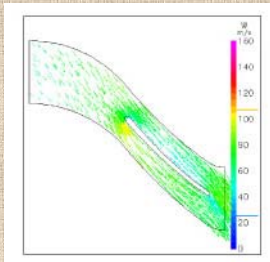
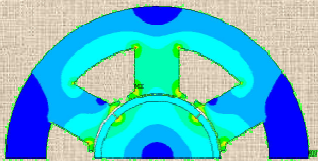
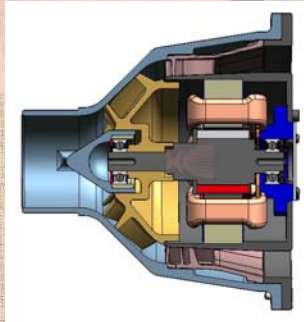
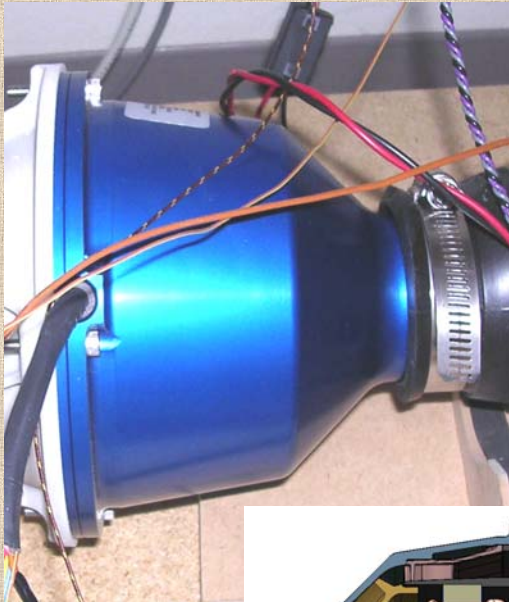
# TURBOMIX Statistics

## Statistics

- Weight 5 lbm, 6" dia x 6" long
- 2000 Watts at max power
- Flow = 280 SCFM @  $\Delta P = 35$  IWC
- Efficiency: 60% (DC in to fluid out)
- Endurance tests (1350 hrs ,1600 hrs)
- ~ 20 units delivered

## Issues

- Bearing life extension underway
- Needs more design validation testing



# VGEN Statistics

## Statistics

- Weigh 5 lbm, 6" dia x 4" long
- Completely sealed with internal motor
- Used in fuel applications
- Flow = 20 SCFM @  $\Delta P = 35$  IWC
- Efficiency: 25% (DC in to fluid out)
- Endurance tests (3000 hrs ,5000 hrs)
- ~ 50 units delivered (including derivatives)

## Issues

- Not capable of high temps
- Lots of issues with internal motor



# TRILOBE Statistics



## Statistics

- Weigh 10 lbm, 6" dia x 6" long
- Roots type w/internal motor and sump
- Used in air pumping applications
- Flow = 25 SCFM @  $\Delta P = 8$  psi
- Efficiency: 55% (DC in to fluid out)
- 2003 Endurance test: 1250 hrs
- ~ 8 units delivered to date



## Issues

- Not capable of high temps
- Not fully sealed – can't pump H<sub>2</sub>

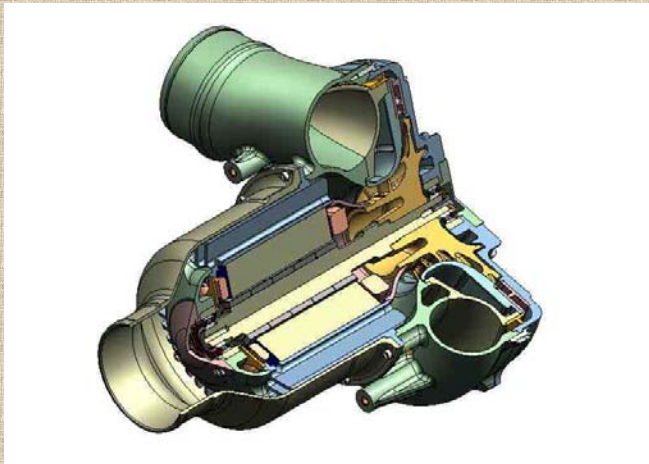
# TURBORAD Statistics

## Statistics

- Weight ~20 lbm, 9" dia x 10" long
- Centrif with radial diffuser and scroll
- Used in air pumping applications
- Flow = 200 SCFM @  $\Delta P = 4.5$  psi
- Efficiency: 64% (DC in to fluid out)
- 2005 Endurance test: 600 hrs
- ~ 2 units delivered to date

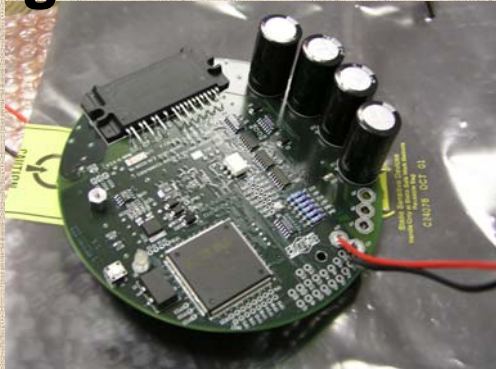
## Issues

- Need more durability testing
- Not fully sealed – can't pump H<sub>2</sub>

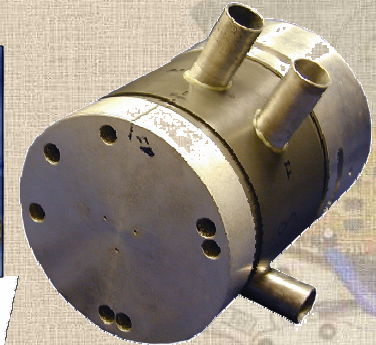
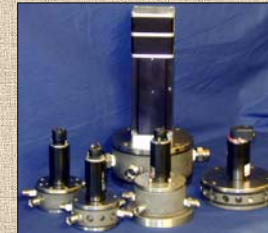


# Other Blower System Work

## Integrated Motor Cont.



## UNIROTOR Comp./Exp.



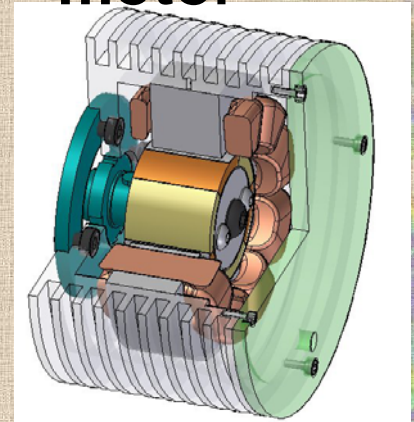
## Modular Motor Controller



## Cathode Blower for SECA Partner



## PADT BLDC motor



# Hot Blower Concept for SOFC (800 C)

- Anode recycle for water recovery and high utilization
- Long life required: 40,000 hr
- Overhung impeller (Regen)
- Internal motor rotor only
- External windings (no passthru)
- NO shaft seals. Process flow completely sealed (like VGEN)
- Thermal choke separates motor/bearing from pumphead
- Close gaps cool rotor
- Thermal mass protects motor from soak back
- External cooling required: Incoming cathode air?
- Bearing Lubrication TBD. Oil? Grease?

