ADVANCES IN ANODE AND CATHODE BLOWERS

8th Annual SECA Workshop
San Antonio, TX

Sponsor: Department of Energy

Presented by: Dr. Giri Agrawal (Principal Investigator)
R&D Dynamics Corporation

Date: August 9, 2007

R&D Dynamics Corporation

R&D Dynamics Corporation

OUR BUSINESS

Design, Develop and Production Manufacture Oil-Free, Efficient, and Affordable High-Speed Turbomachinery

R&D Dynamics, Bloomfield, CT

Background

- Started in 1990
- 23,000 sq. ft. space
- 45 employees
- 50% development programs
- 50% production programs
- Quality system approved by FAA
- ISO 9001:2000 / AS9100 to be certified by 09/07

R&D Dynamics Corporation

Experience

- Fuel Cell Blowers
- Motor driven gas compressors
- Turboalternators
- Turboexpanders for air separation plants
- Hydrogen turboexpander
- Refrigerant centrifugal compressors
- High temperature turbochargers

R&D Dynamics Corporation

Fuel Cell Blower Customers

- SECA Members
- General Motors
- UTC Fuel Cells
- Ballard Power Systems
- Global Fuel Cell OEM's

Blower Benchmark Tests Accomplished

- ***Recent testing by fuel cell OEM demonstrated…***

  - ✓ **Hydrodynamic foil bearings to be suitable and robust technology for transportation fuel cell air supply systems**

  - ✓ **Blower passed following tests:**

    1. **Endurance with cycle >2000 hours**
    2. **Start/stop >10,800 cycles**
    3. **Shaker**
    4. **Before and after performance**

R&D Dynamics Corporation

Anode Gas Recycle Blower Advancements

Grant No: DE-FG02-05ER84210

R&D Dynamics Corporation

Summary of Advancements

- Designed AGRB meeting all SECA members requirements.
- High speed motor has been designed and fabricated.
- Parts are manufactured and machine assembled.
- Test plan laid out and all the necessary instrumentation procured.
- Cost reduction worked on in parallel.
- Blower will be tested in 2nd year of funding.

R&D Dynamics Corporation

Specifications

Inlet Gas Temperature	600 to 850 ^{0}C
Inlet Pressure	14.69 psia
Pressure Rise	4 to 10 inches of H_2O
Required Flow	100 SLPM
Overall Efficiency	>40%
Turn Down Ratio	5:2
Design Life	>40,000 hrs
Maintenance Interval	10,000 hours
No. of Thermal Cycles Tolerance	30
Annual Production Volume	50,000

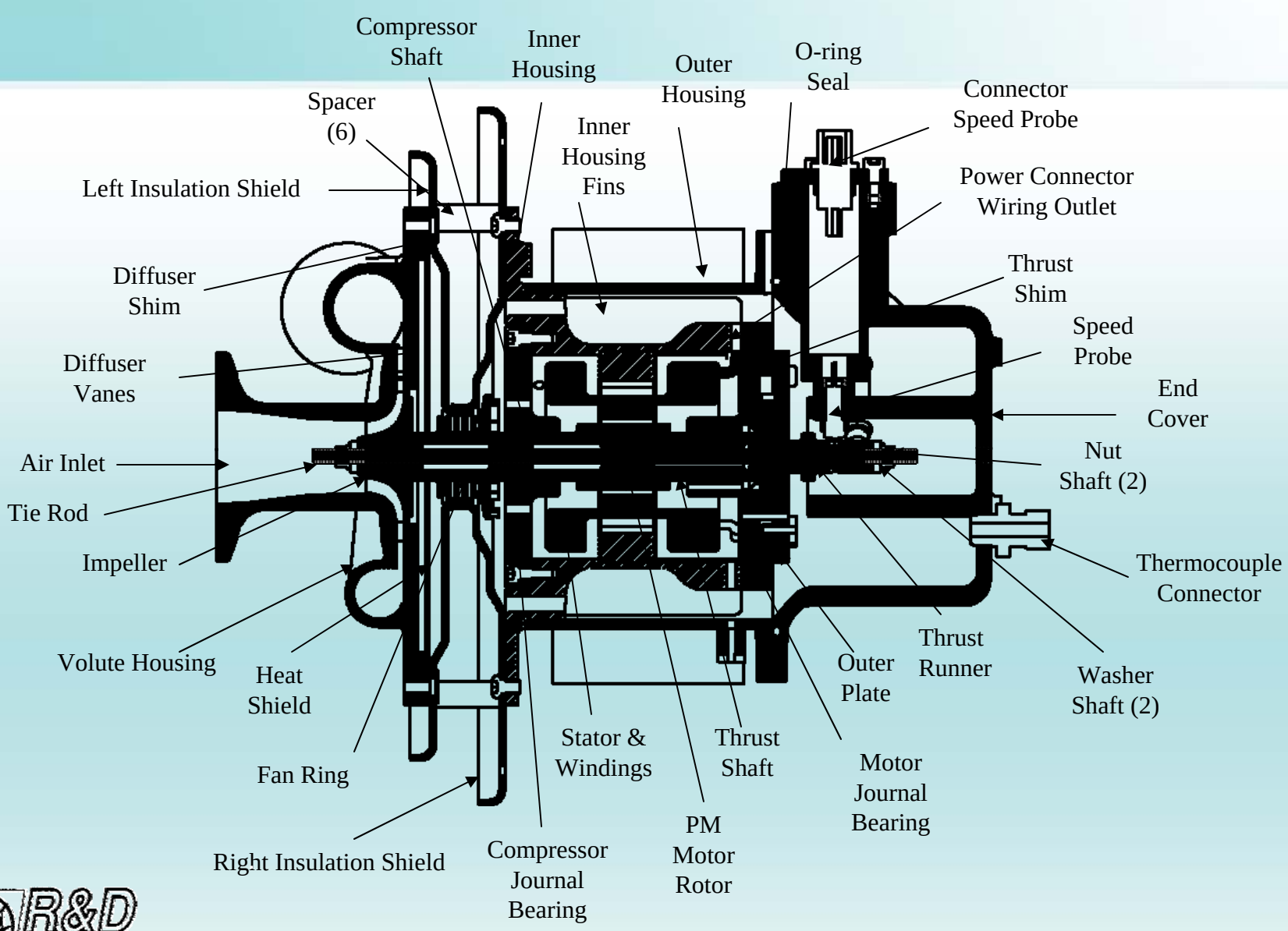
R&D Dynamics Corporation

Technical Requirements

- Low Cost
- High Temperature Capability (~850^{0}C)
- High Efficiency
- High Reliability
- Compact
- Maintenance Free

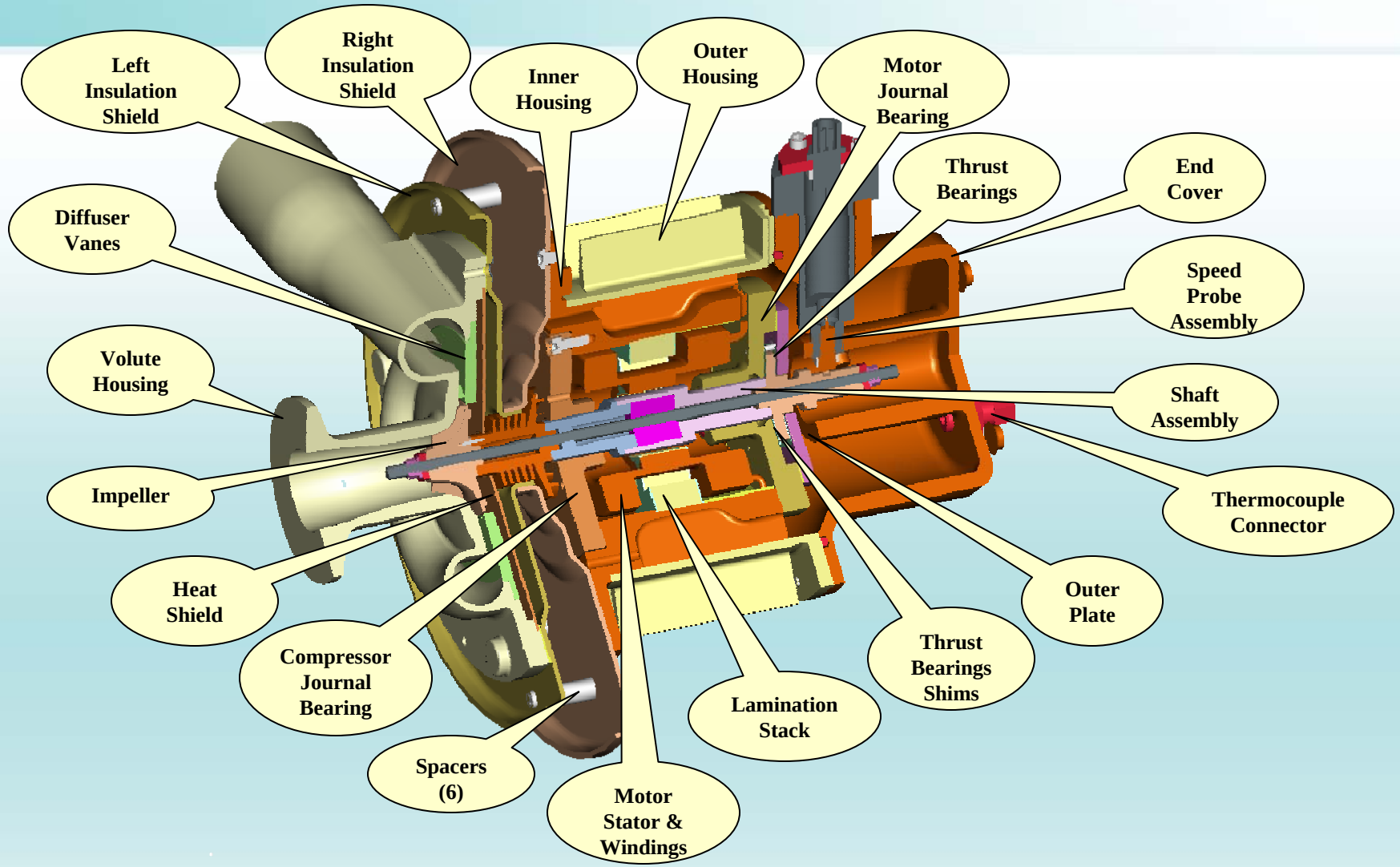
R&D Dynamics Corporation

AGRB Cross-Section Cut Vertically



R&D Dynamics Corporation

AGRB Cut Away View



R&D Dynamics Corporation

Technical Summary

Blower Type	Centrifugal
Mechanical Speed	98,600 rpm
Pressure Ratio	1.025
Weight	4.26 kg (9.38 lbs)
Volume	0.565 liter (34.5 cu. in.)
Bearings	Foil Gas Bearings
Motor Type	Permanent Magnet Motor
Controller	Sensorless
Operating Temperature	850º C (1562º F)
Overall Efficiency	45%

R&D Dynamics Corporation

AGRB Parts

R&D Dynamics Corporation

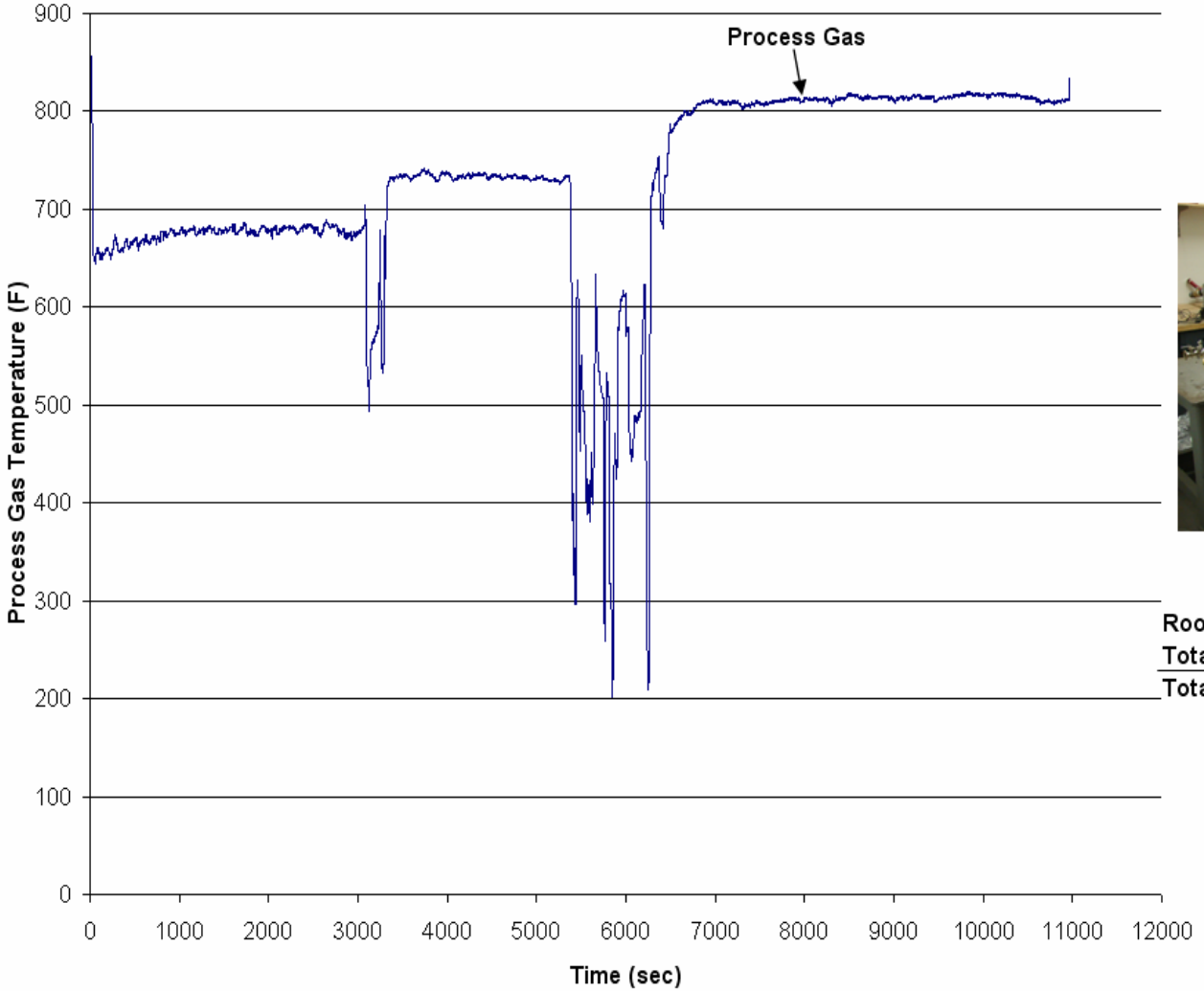
AGRB Assembled

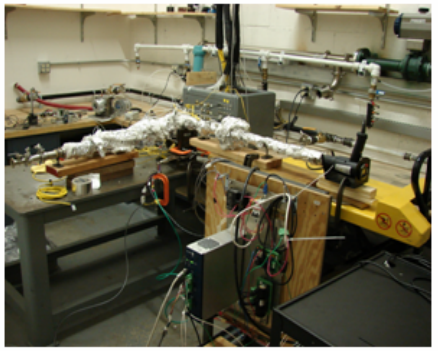
R&D Dynamics Corporation

AGRB Lab Testing

AGRB - Process Gas Temperature @100krpm, High Temperature Testing

R&D Dynamics Corporation





Room Temp. Testing	= 8 hours
Total High Temp. Testing	= 7 hours
Total Testing Time	= 15 hours

Future Plans & Conclusion

- Machine to be tested in 2nd year of funding.
- Cost reduction will be done.
- AGRB will be system tested at SECA member's facility.
- RDD has plans for mass producing the blower.

R&D Dynamics Corporation

Cathode Blower Advancements

Grant No: DE-FG02-06ER84616

R&D Dynamics Corporation

Summary of Advancements

- A low cost high efficiency cathode air blower has been designed.
  - Oil free
  - Highly efficient (>61%)
  - Highly reliable
  - Maintenance free
  - Higher design life (>40,000 hrs)
  - Lower noise (< 70dBa)
  - Easily scalable
  - Variable speed (turn down ratio > 5:1)

- A cost model targeting $100 has been developed.
  - Road map for low cost using DFMA techniques
  - Blower made of only 16 parts
  - Split housing design invented to reduce cost
  - Low Blower cost (<$106)

R&D Dynamics Corporation

Summary of Advancements

- Bread board test conducted to prove structural strength of plastic impeller concept.
  - Plastic impeller manufactured (impeller made of PPS plastic)
  - Impeller tested at high speed (tested up to 155,000 rpm)
- Phase I design and cost met.
  - Ricardo, Inc. supported DFMA effort
  - Blower cost met target
  - Blower efficiency exceeds 60%
  - Blower reliability high
- Feasibility of program achieved.

Specifications

Working Fluid	Air
Pressure Ratio	1.1 to 1.2
Volume Flow	1500 slpm
Turn-Down Ratio	5:1
Overall Efficiency	>60%
Design Life	>40,000 hrs
Maintenance Interval	10,000 hrs
Target Cost	$100 @ 50,000 units/yr
Noise Level	<70 dBa
Contaminants	None, Oil-free

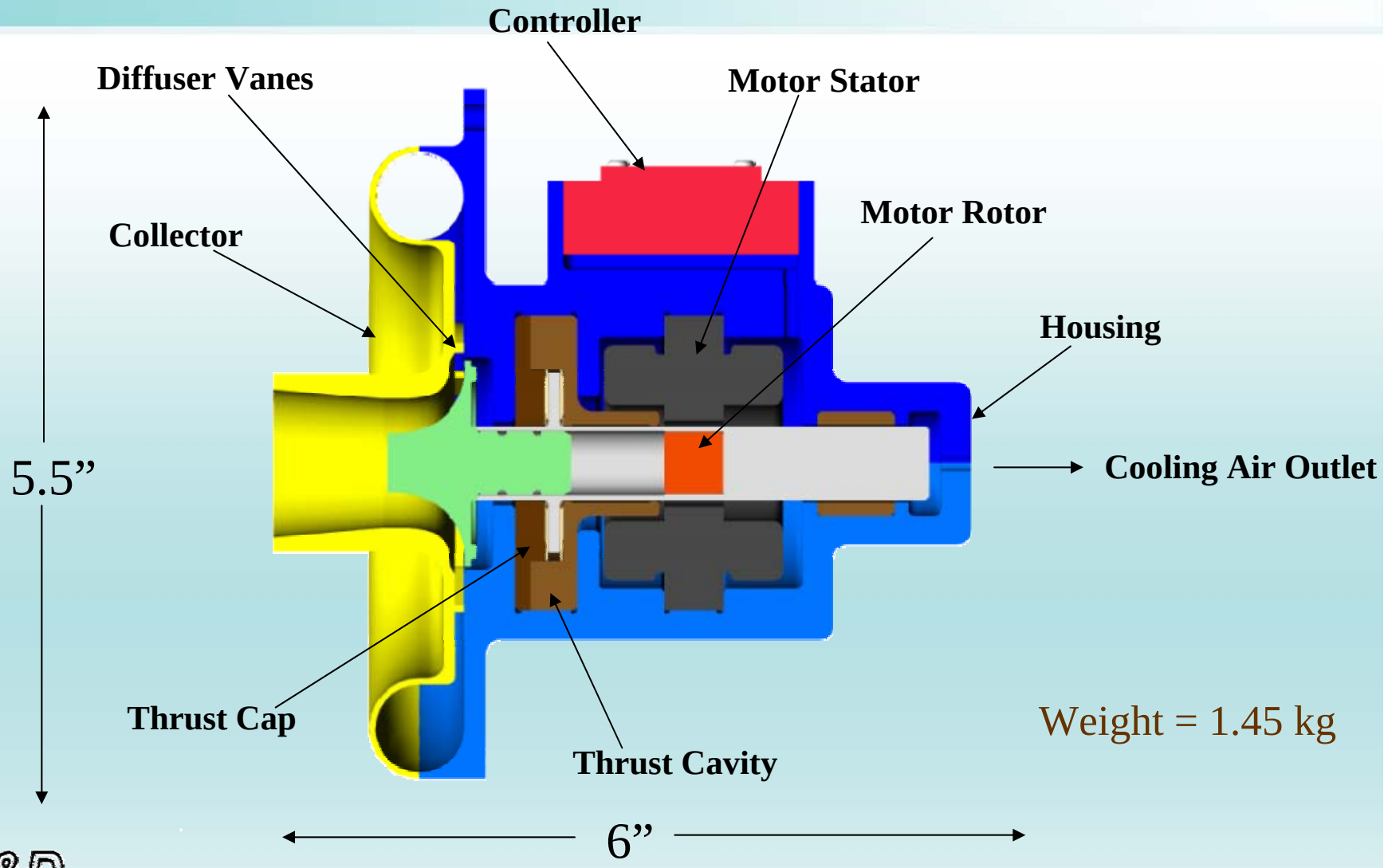
R&D Dynamics Corporation

Key Issues

- Low Cost
- High Efficiency
- High Reliability
- Oil free

R&D Dynamics Corporation

Low Cost Blower Cross-Section
Number of Parts = 16



Weight = 1.45 kg

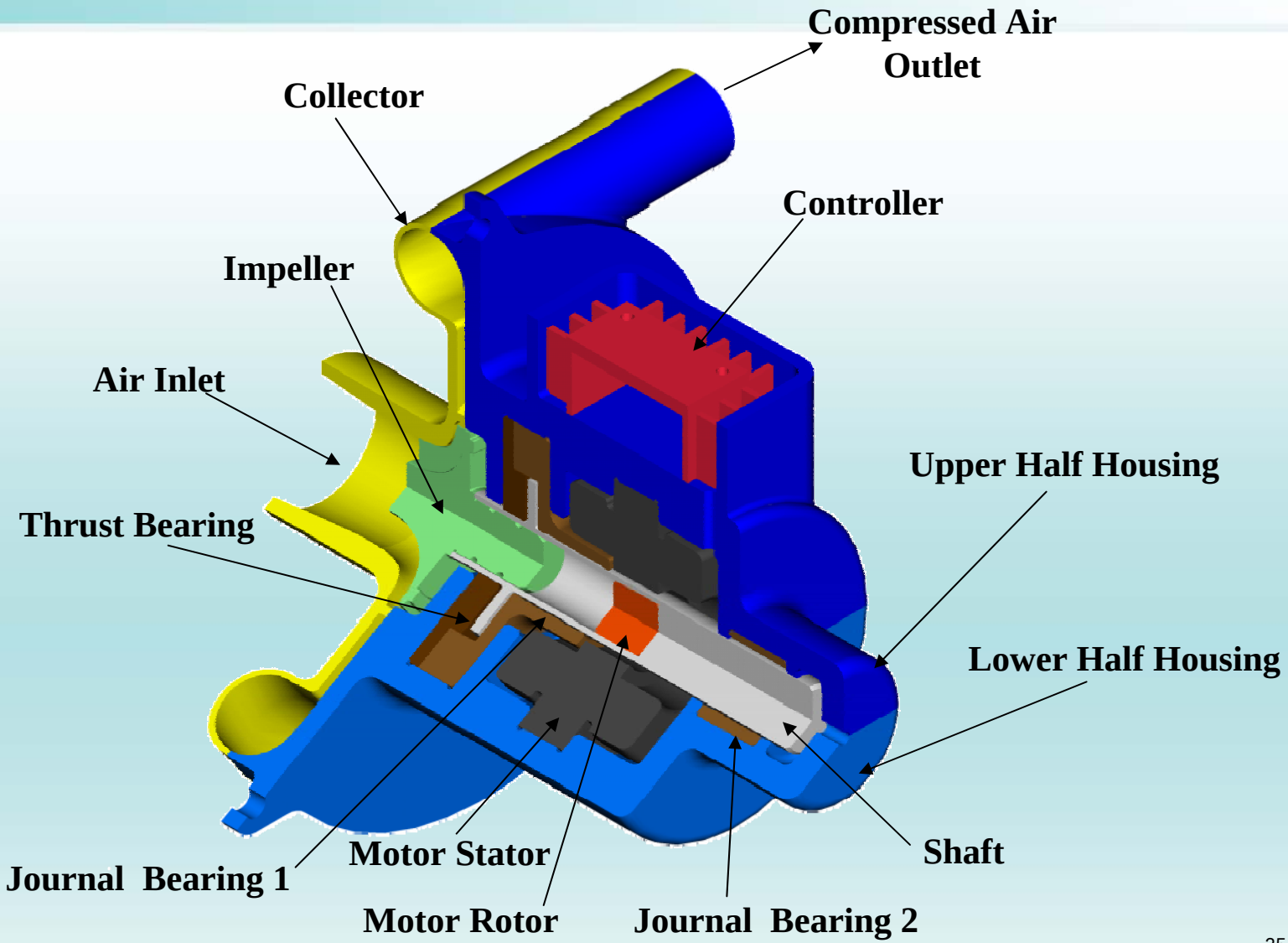
R&D Dynamics Corporation

Technical Summary

Blower Type	Centrifugal
Mechanical Speed	80,500 rpm
Weight	1.45 kg (3.2 lbm)
Bearings	Foil Gas Bearings
Motor Type	Permanent Magnet Motor
Controller Type	Sensorless Controller
Input Electric Power	769 watt
Overall Efficiency	61.6 %
Total Blower Cost	$105.11 [@ 50,000 units/year]
Life	>40,000 hrs

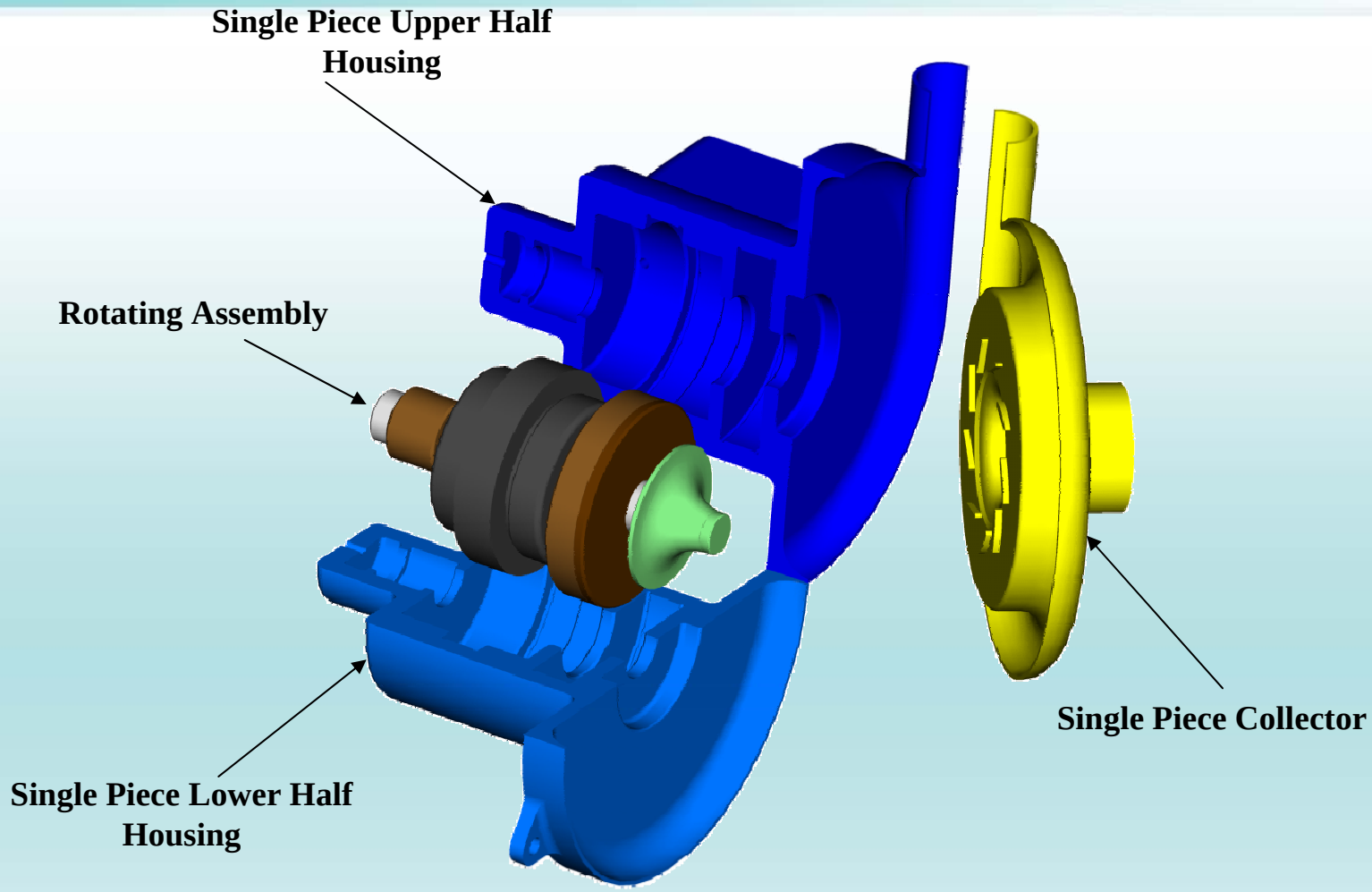
R&D Dynamics Corporation

Blower Cut-Section View



R&D Dynamics Corporation

Innovative Low Cost Split Housing Design



R&D Dynamics Corporation

Cathode Air Blower Cost Model

Low Cost Cathode Air Blower Cost Model			
Component	**Cost**	**Material**	**Manufacturing Processes**
Upper Half Housing	**$4.79**	**Nylon**	**Injection mold**
Lower Half Housing	**$4.79**	**Nylon**	**Injection mold**
Journal Bearing	**$1.24**	**Inconel**	**Stamping**
Thrust Bearing	**$15.32**	**Inconel**	**Stamping, Welding**
Bearing Sleeves	**$2.03**	**Aluminum**	**Rolling**
Shaft	**$3.49**	**Aluminum**	**Machining, Annodizing**
Impeller	**$1.32**	**PPS Plastic**	**Injection mold**
Thrust Cap	**$2.14**	**Aluminum**	**Casting, machining**
Collector	**$1.68**	**Nylon**	**Injection mold**
Shims, fasteners & screws	**$0.00**	**-**	**-**
Total Part Cost	$35.70		
Manufacturing Tooling & Assembly Tool	$3.35		
Labor Cost	$1.54		
Sub Total	$41.59		
Motor	$8.95		
Controller	$54.57		
Cathode Air Blower Total Cost	**$105.11**		

R&D Dynamics Corporation

RICARDO

R&D Dynamics Can Offer SECA Members

- ***Blowers with ……***

  - ✓ **Outstanding Performance**
  - ✓ **Compact Size**
  - ✓ **High Reliability**
  - ✓ **Low Cost**

R&D Dynamics Corporation

R&D Dynamics Plans To Meet SECA Blower Needs

- ✓ **Future Production Blowers Will Meet SECA Cost Targets**
  - **"Design For Manufacturing and Assembly" techniques plus novel designs will be used.**
- ✓ **15 Acres of Land Purchased for Expansion**

R&D Dynamics Corporation

Acknowledgement

R&D Dynamics would like to acknowledge DOE and SECA members for their support of fuel cell blower development

R&D Dynamics Corporation