Challenges in Fuel Cell Technology: India's Perspective

for presentation at the National Seminar

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Challenges in Fuel Cell Technology – India's perspective

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Hydrogen Energy & Fuel Cells

- Production of Hydrogen
- Storage of H_2
- Means to deliver H_2
- Utilization of H_2 for Transport application
- Utilization of H_2 for Power Generation

Power Generation *using H_2* -

- ***Using Internal Combustion Engines*** *- both Spark ignition (petrol) & Compression ignition (diesel) engines may be adapted for use with H_2.*

- ***Using Fuel Cells -*** *All types of fuel cells, operating at low, medium & high temperatures (AFC, PAFC, PEMFC, MCFC & SOFC) can be used for power generation. When used in Combined Heat & Power (CHP) mode, very high overall conversion efficiencies (80 - 85%) can be achieved.*

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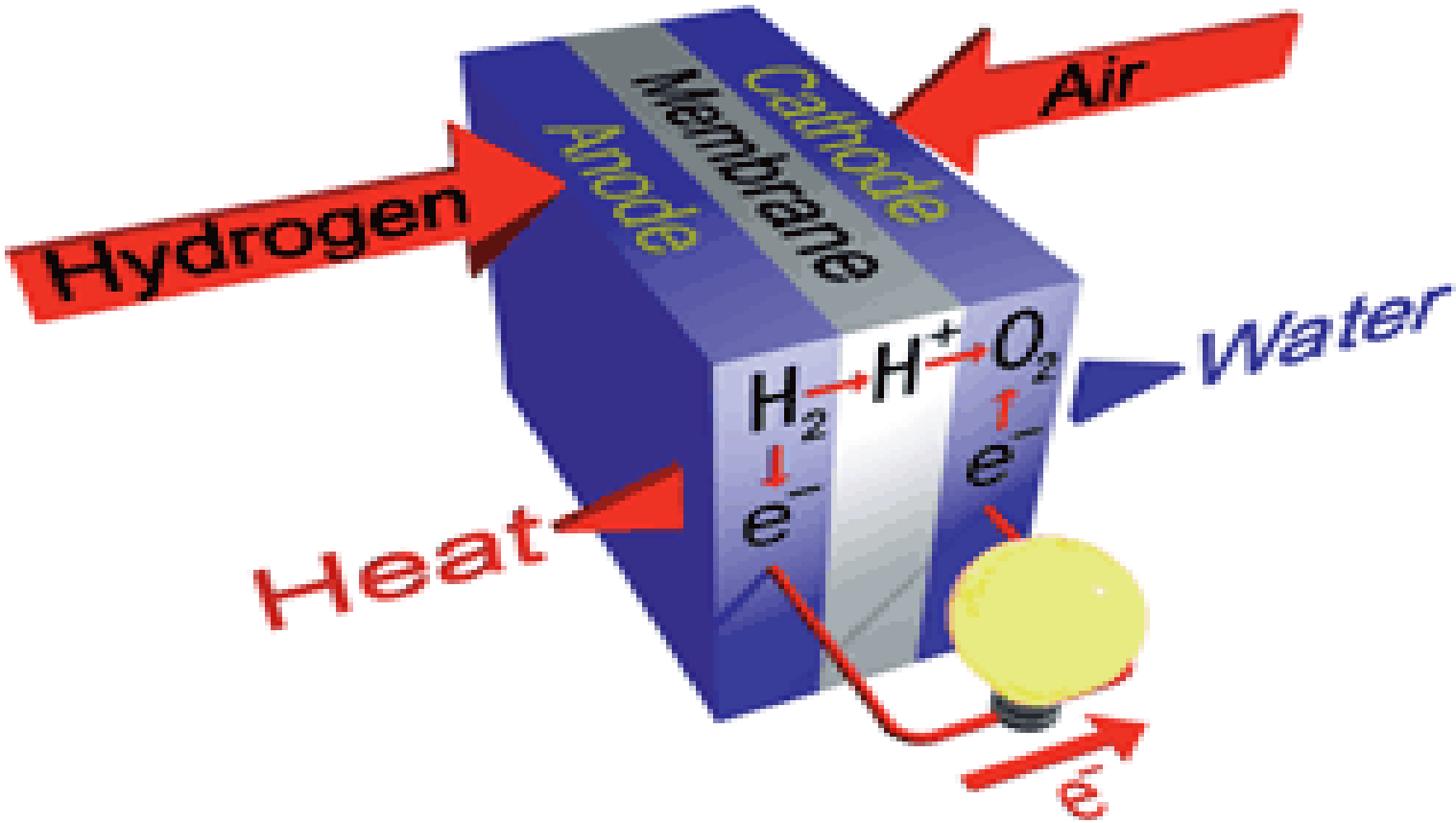
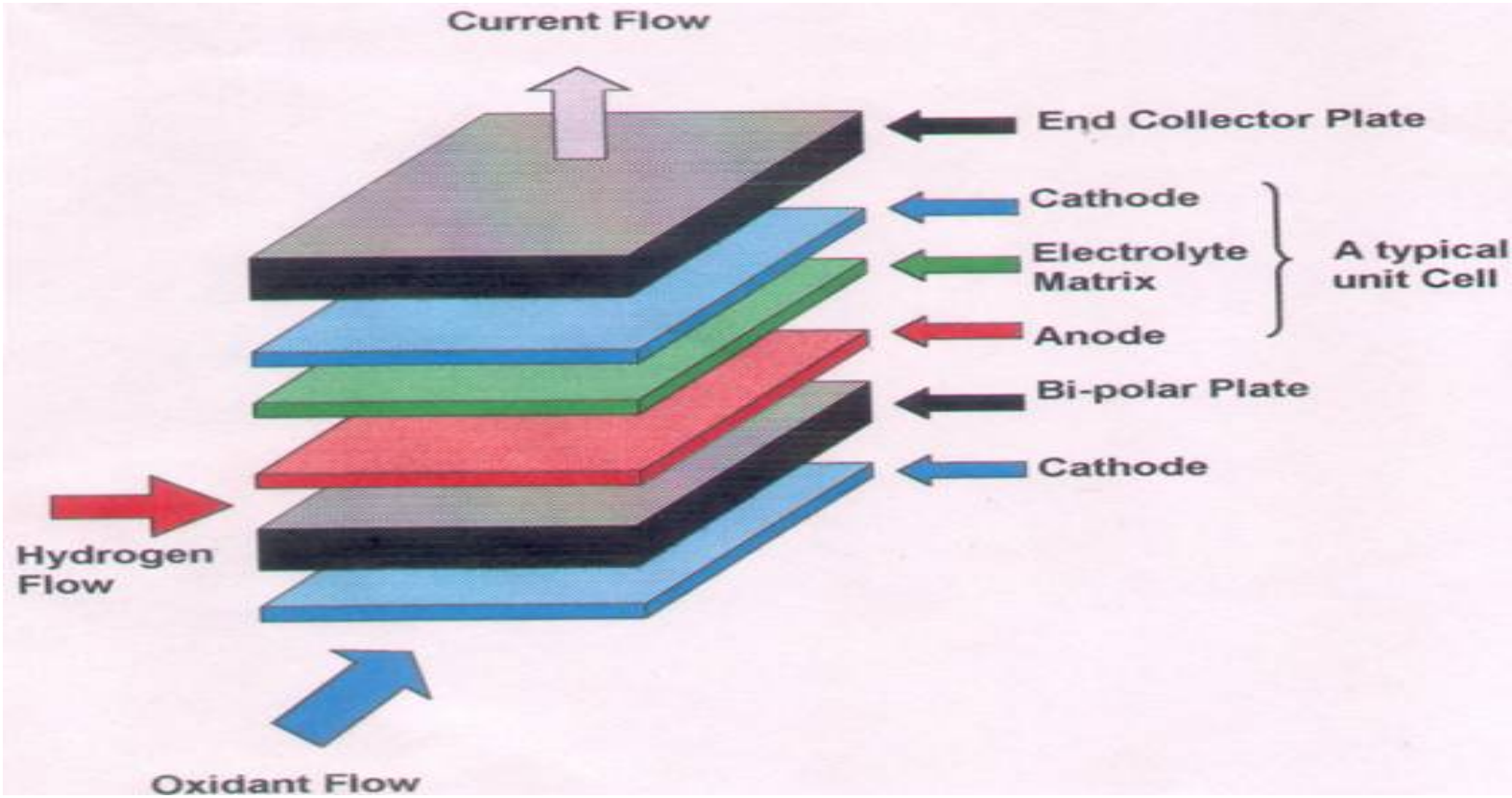
Principle of Operation - Schematic for PEMFC / PAFC



Repeating Elements used in a typical cell stack



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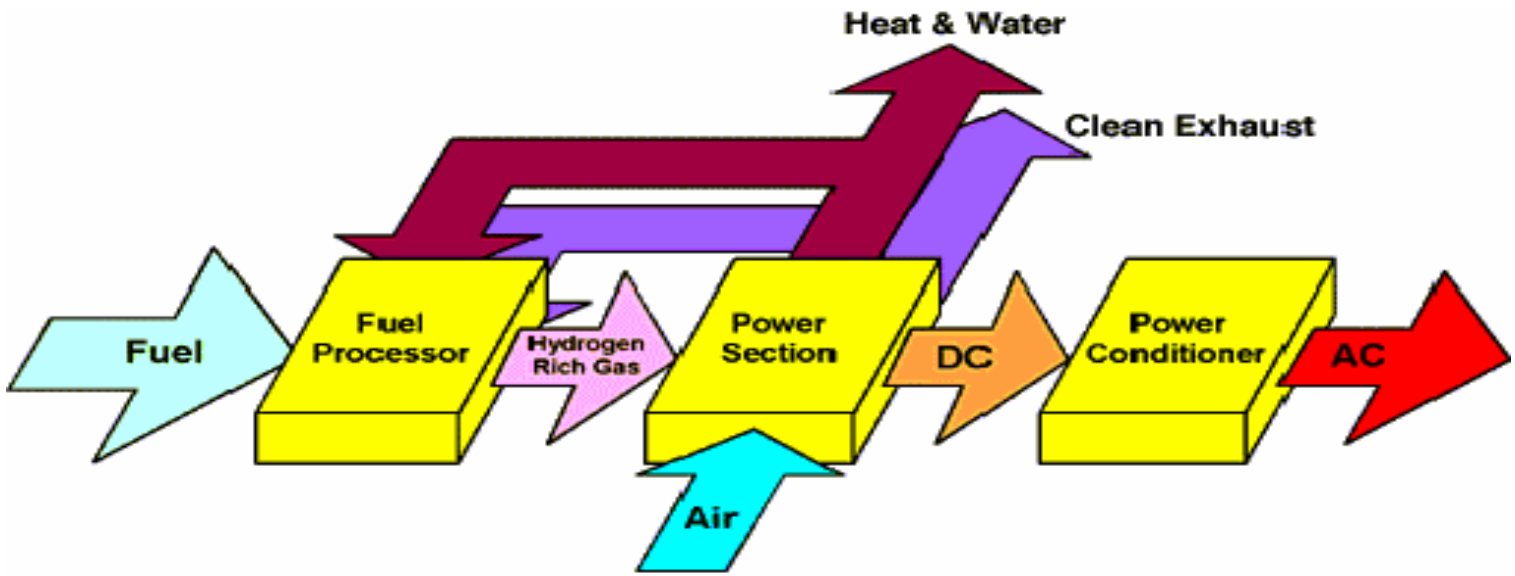
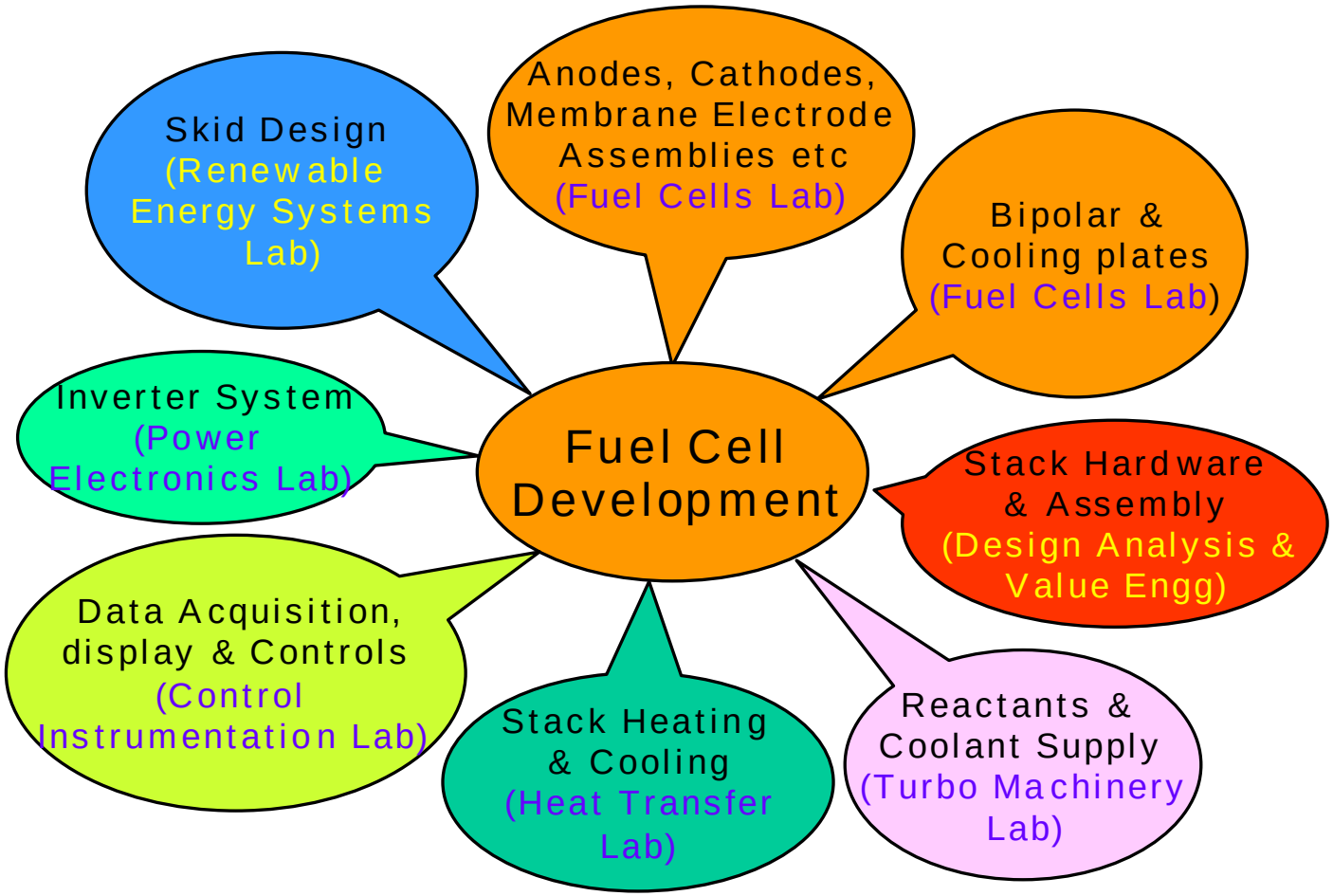
Major sub-systems in a typical Fuel Cell Power Plant



In addition to the above, a number of other sub-systems (viz.: Fuel storage & delivery system, Air supply system, Thermal Management system, C&I systems etc) are also needed

A glimpse of Fuel Cell Developments @ BHEL

(Inter-disciplinary approach followed for Fuel Cells Development)



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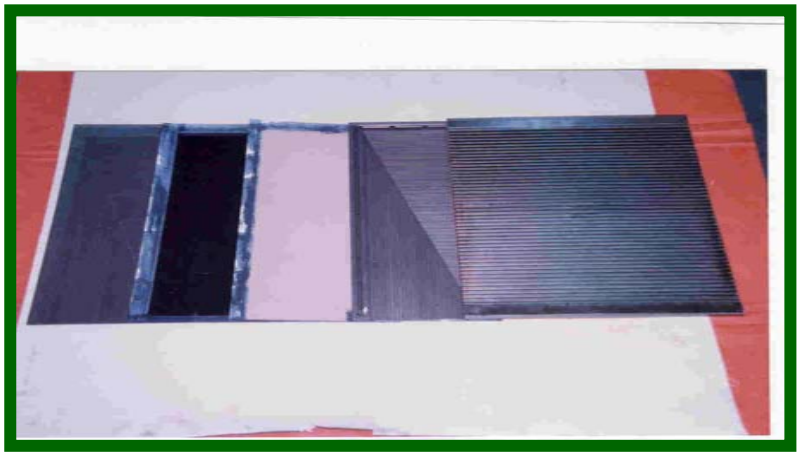
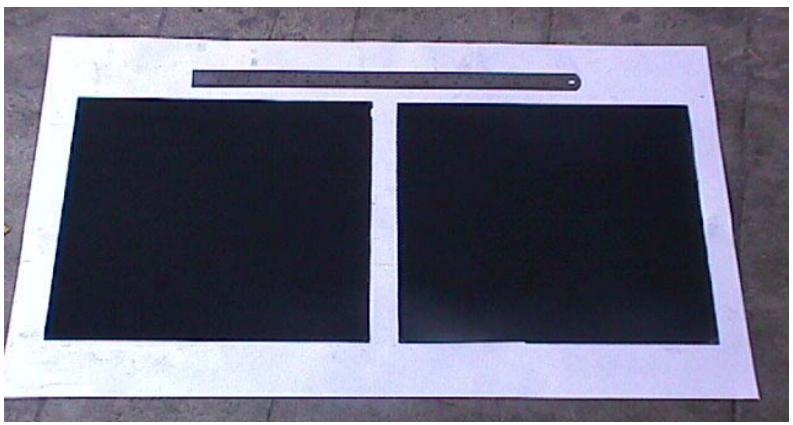
Fuel Cells - Major Challenges / Disadvantages

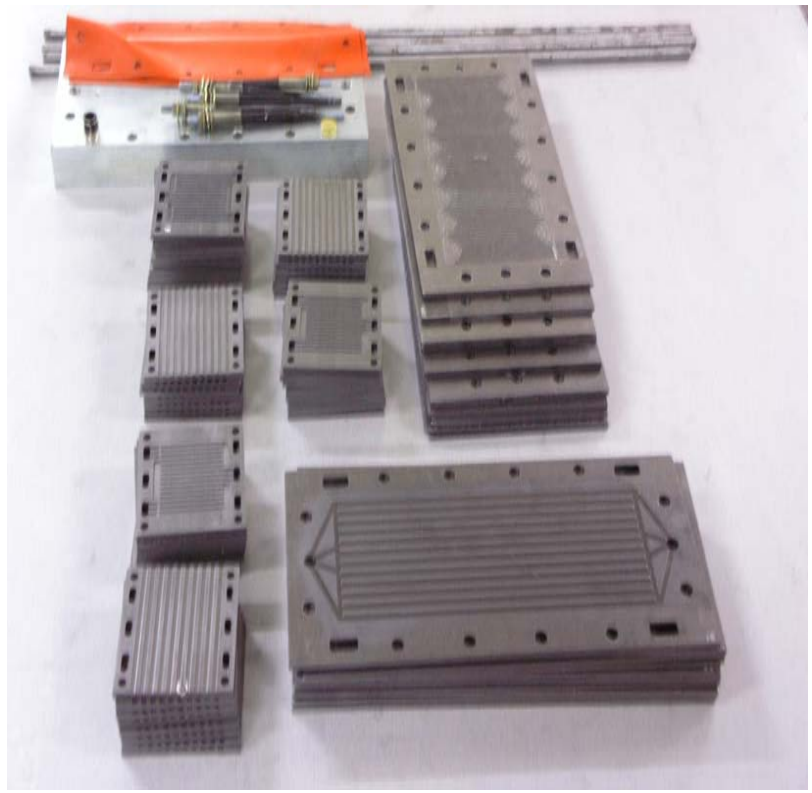
- Performance loss with time (few mV / 1000 hrs)
- Short life span (~ 5000 hrs to 40,000 hours)
- High Capital costs (~ $ 3000 to $ 10,000 / kW)
- Few technology developers / providers
- Limited commercial availability
- Limited fuel infrastructure

A glimpse of Fuel Cell Developments @ BHEL

(PAFC & PEMFC components - Electrodes, bi-polar plates etc, 1998 - 2005)

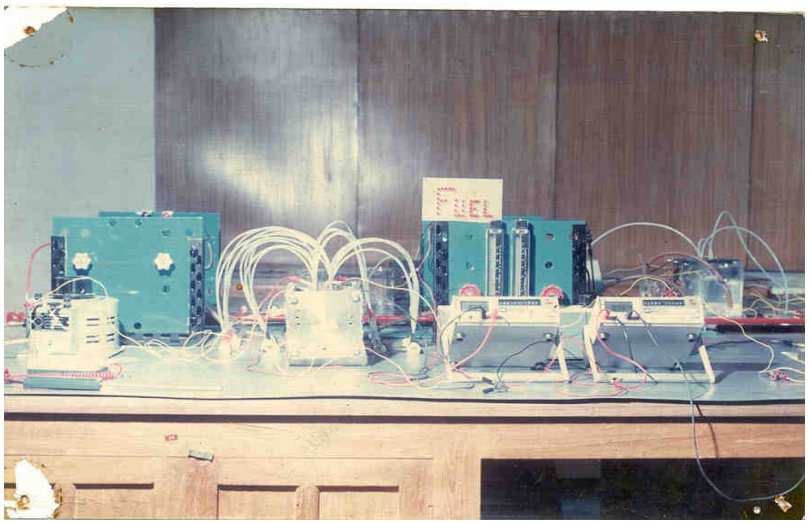




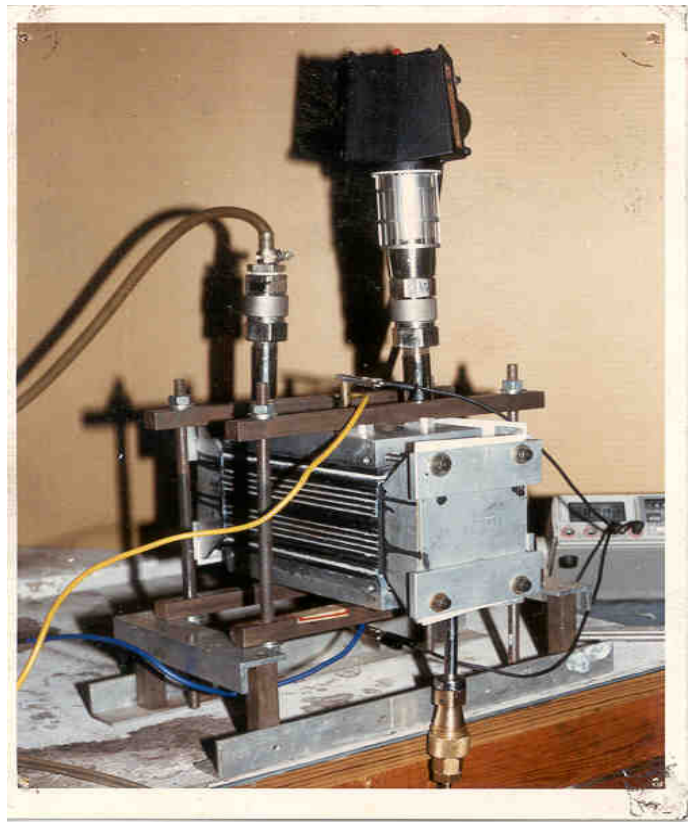


A glimpse of Fuel Cell Developments @ BHEL

Multiple Cells - connected in series
(PAFC, 60x60 mm, 1989)

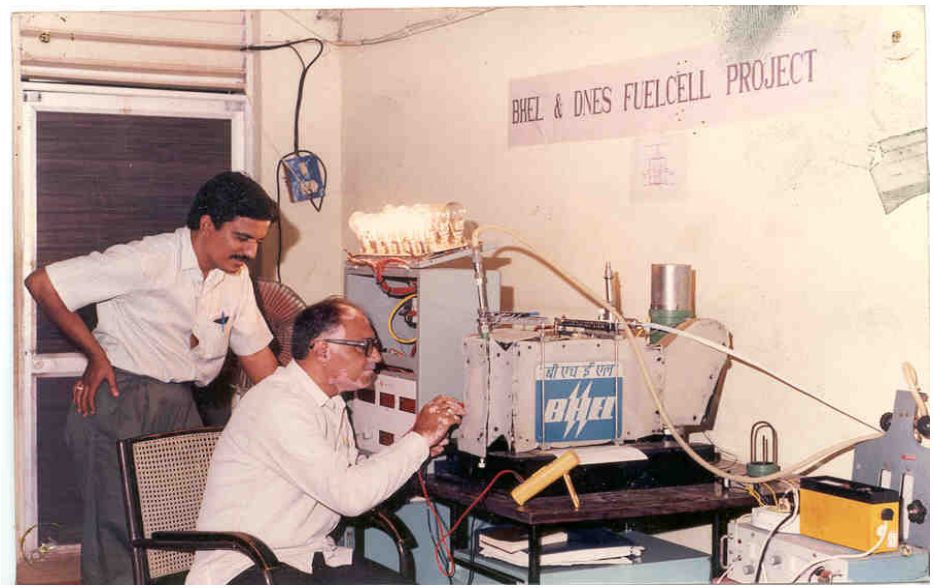


8 Cells PAFC stack, 100 x 200 mm;
(1990)

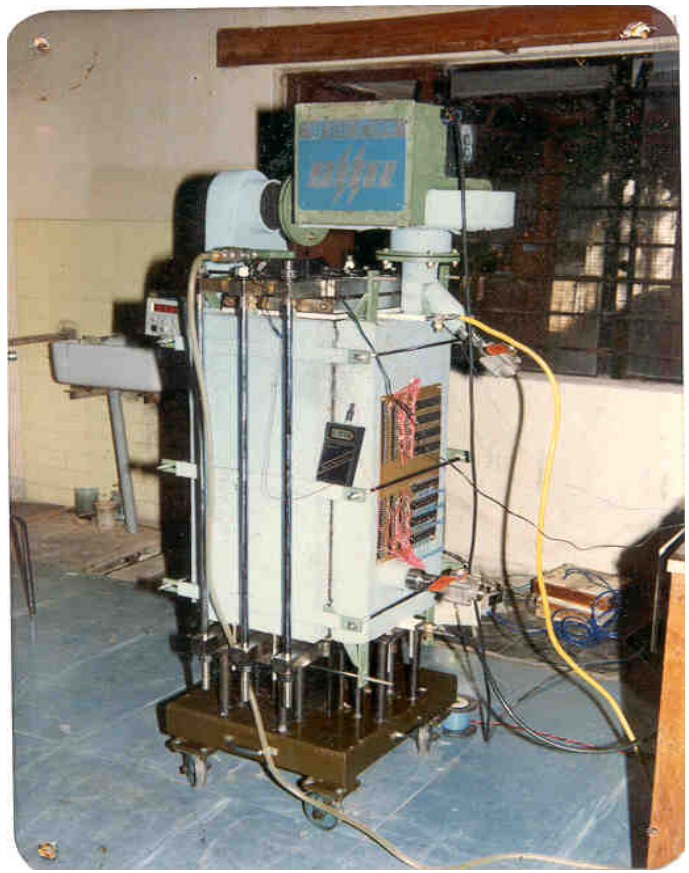


A glimpse of Fuel Cell Developments @ BHEL

India's first kW rated Fuel Cell Stack
(PAFC, 120x360 mm, 40 Cells, 1 kW)
(1991)

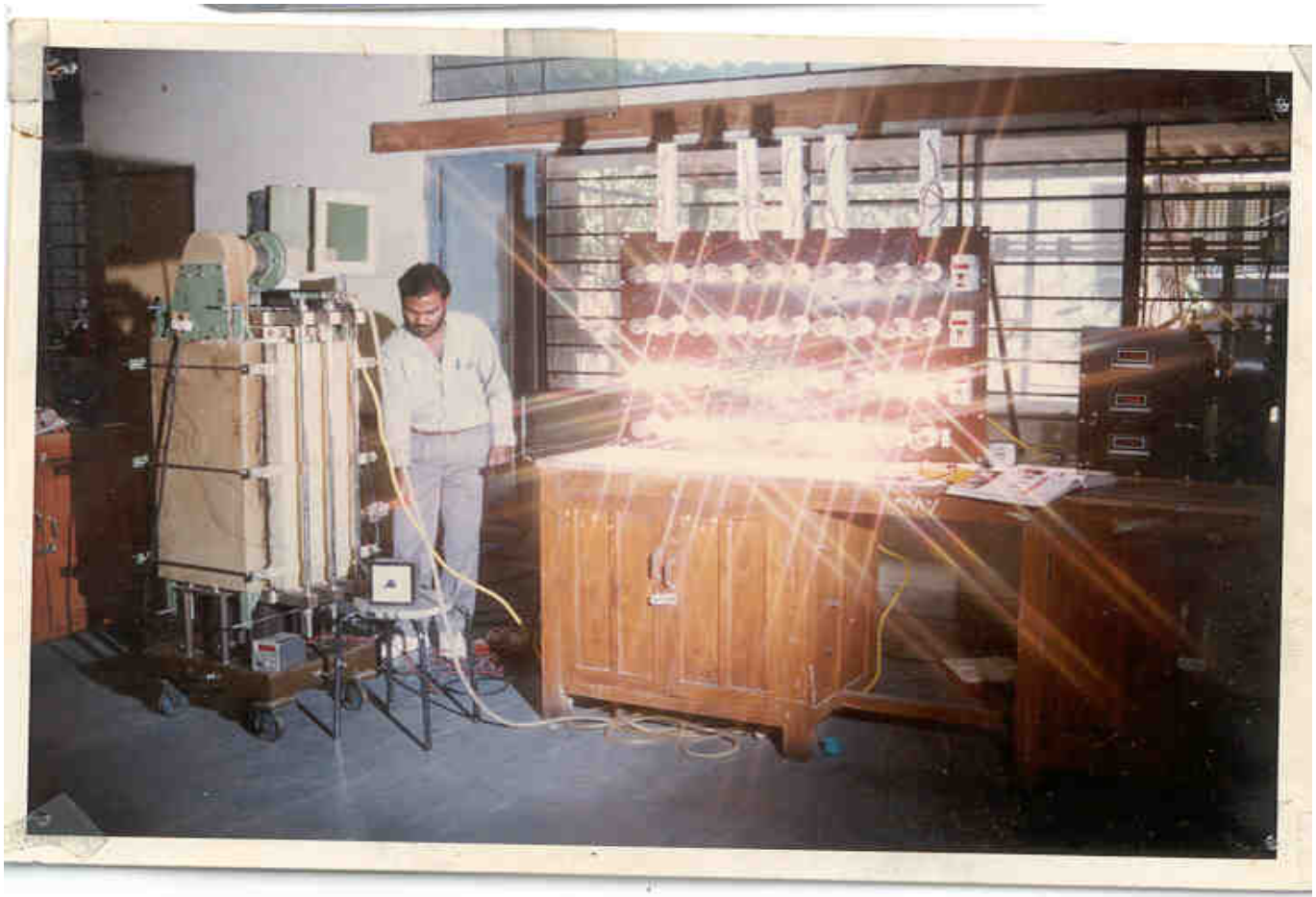


India's first Multi kW Fuel Cell Stack
(PAFC, 300x400 mm, 80 Cells, 5 kW)
(1995)



A glimpse of Fuel Cell Developments @ BHEL

(5 kW PAFC stack under testing, Active Area 865 cm^2, 1995)



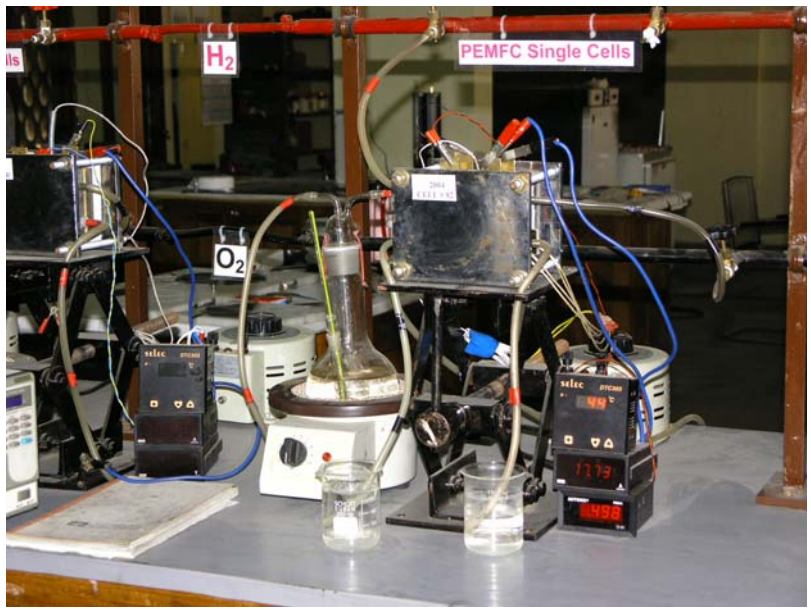
A glimpse of Fuel Cell Developments @ BHEL

2x25 kW PAFC stacks, 400x500 mm (2000 - 2001)

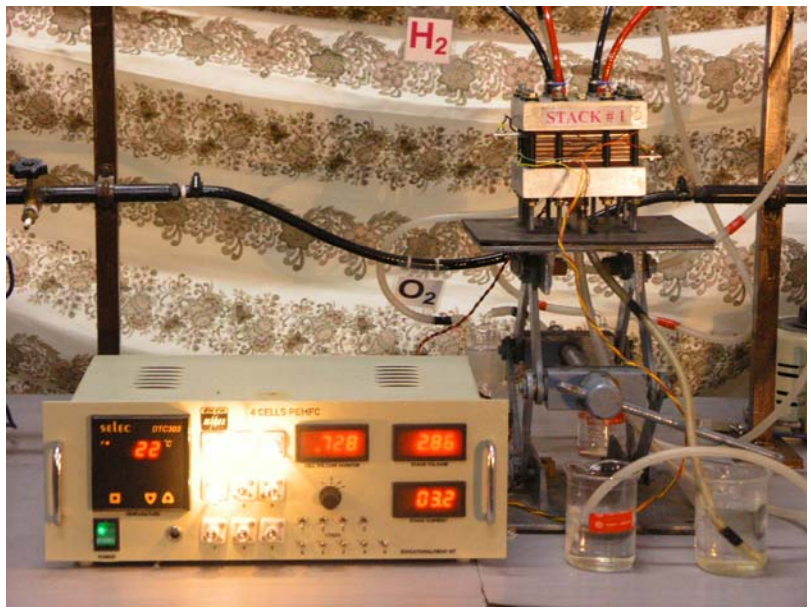
200 kW, Performance Evaluation of PAFC based Power Plant (PC25C-IFC/Toshiba) (1997 - 2000)

A glimpse of Fuel Cell Developments @ BHEL

(PEMFC single cell test set up, 60x60 mm) (2003 - 2006)



(4 Cells PEMFC education-cum-demo stack, 100 x 90 mm; 2004 - 2005)

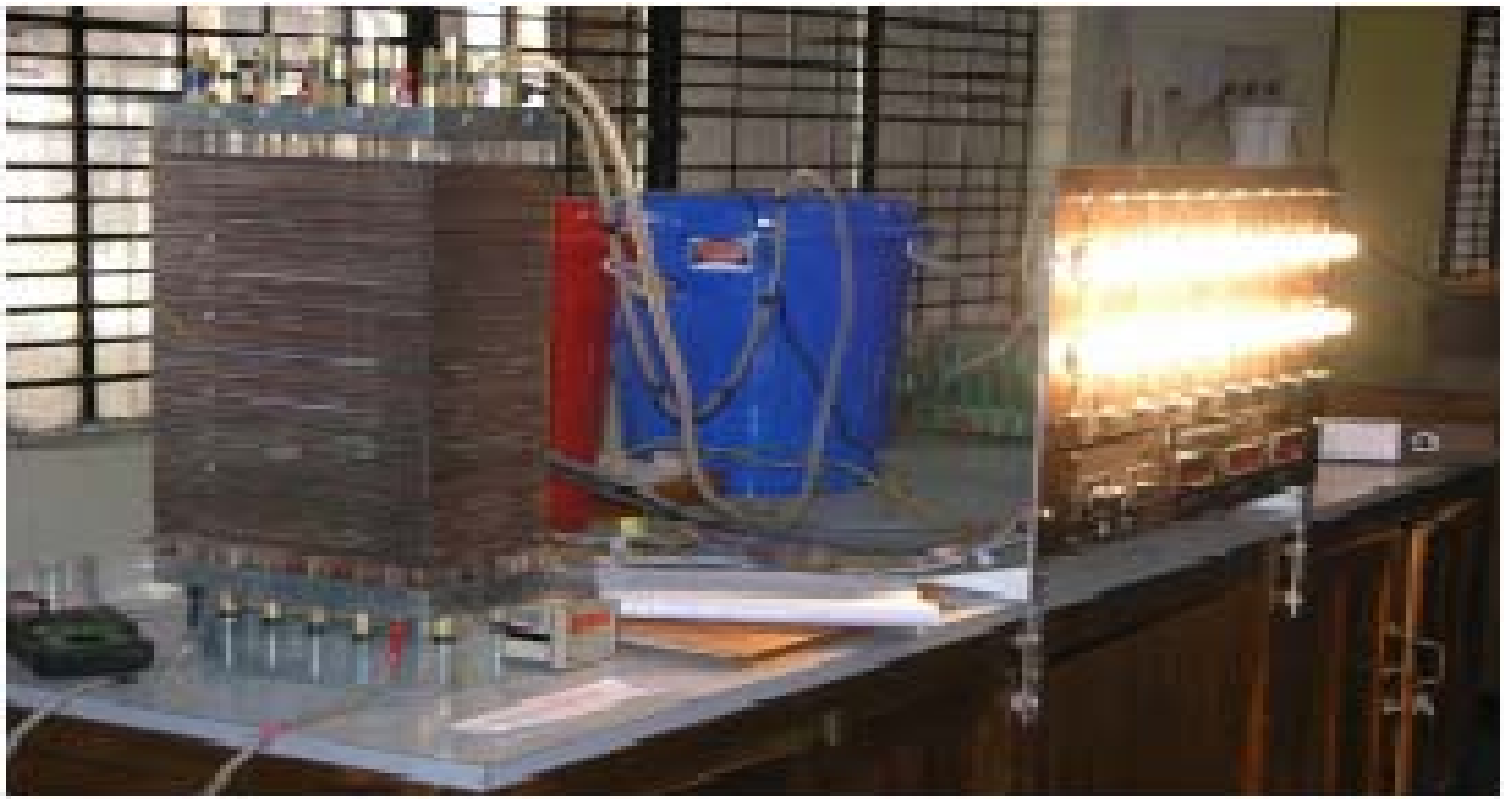


A glimpse of Fuel Cell Developments @ BHEL

(PEMFC, 20 cells' stack under testing - Nov 2005)

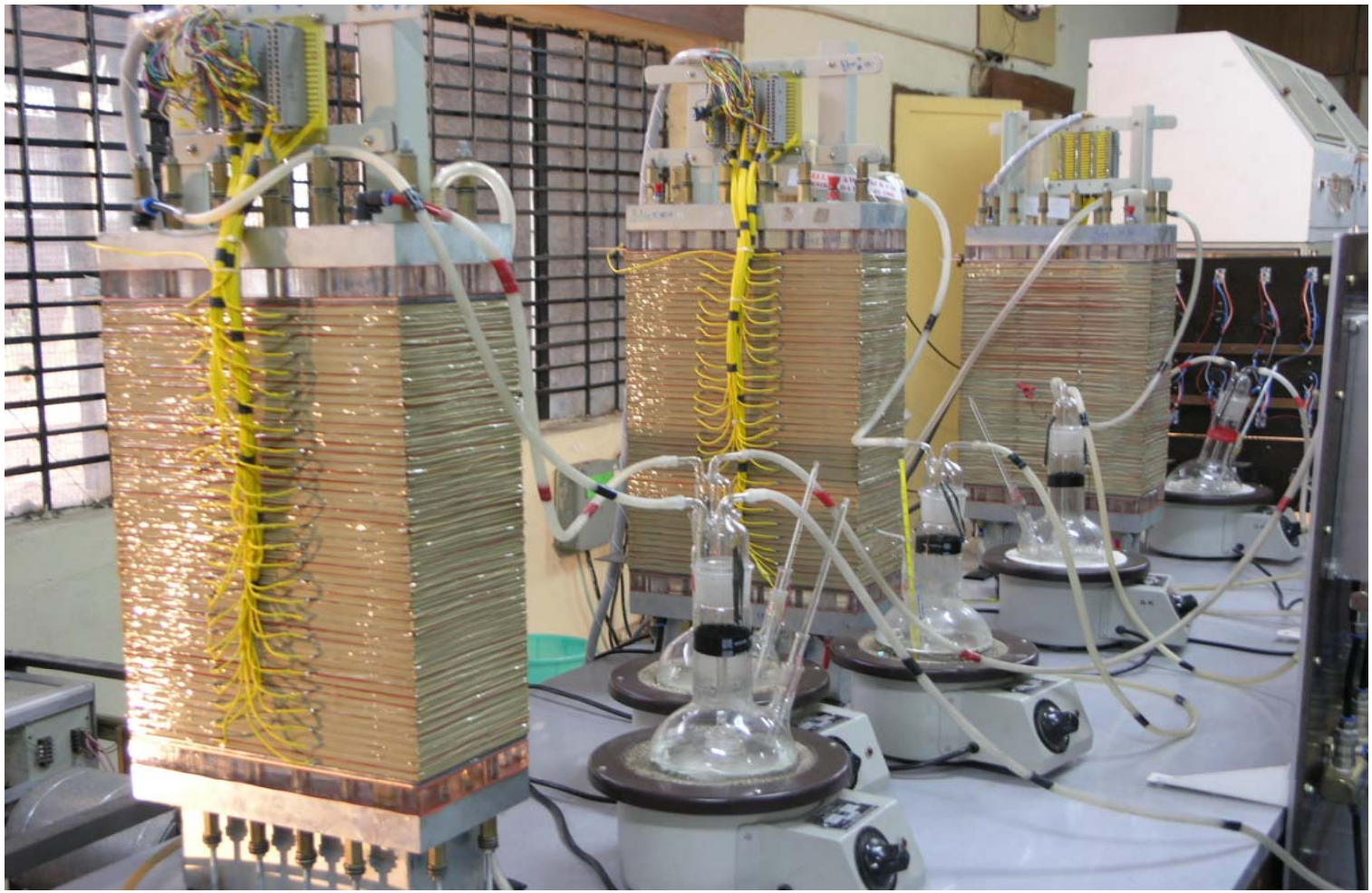
A glimpse of Fuel Cell Developments @ BHEL

50 Cells, 150x300 mm, PEMFC 1 kW modular stack
(under testing - January 2006)



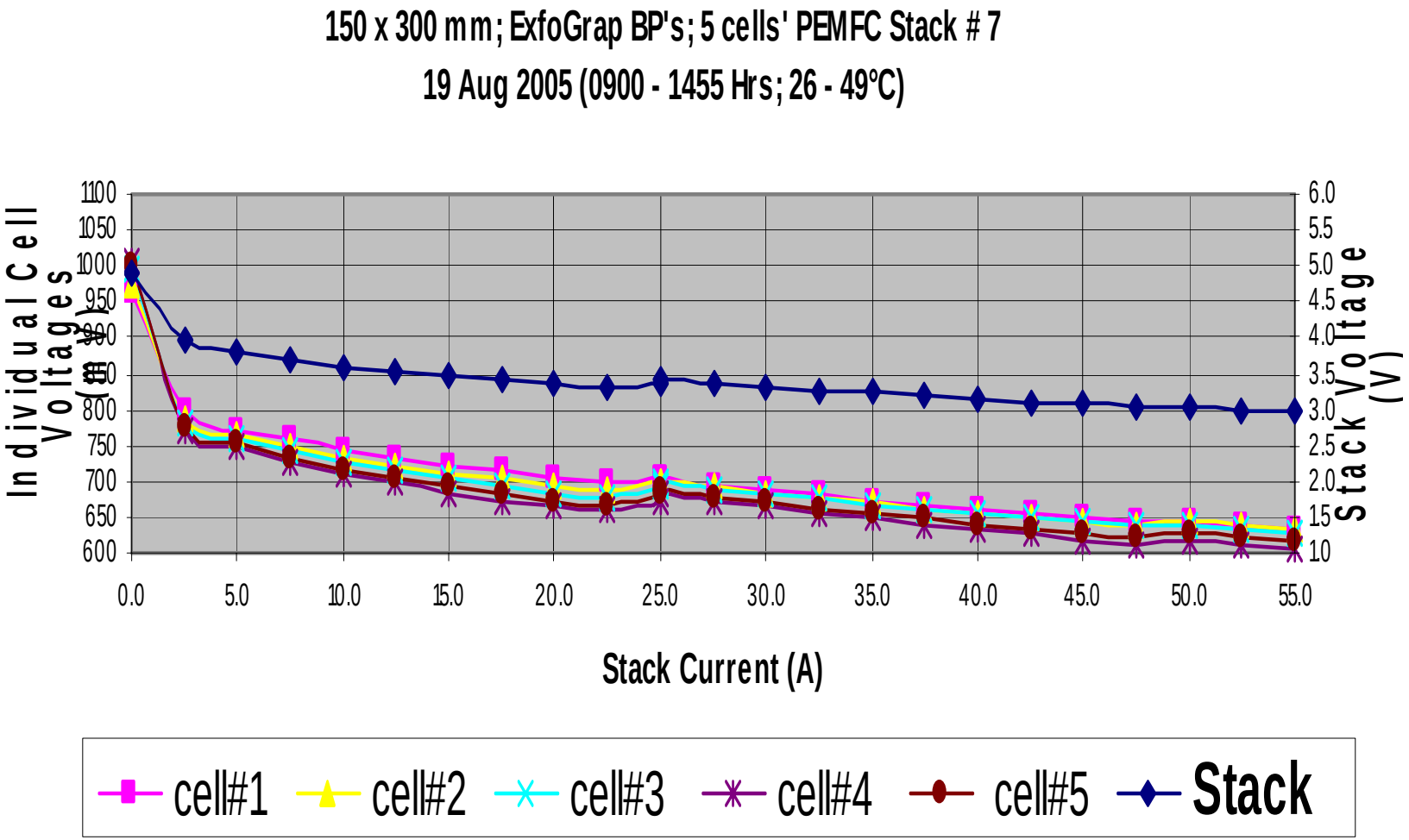
A glimpse of Fuel Cell Developments @ BHEL

50 Cells, 150x300 mm, PEMFC 1 kW modular stacks



A glimpse of Fuel Cell Developments @ BHEL

(V - I characteristics of a typical PEMFC stack)

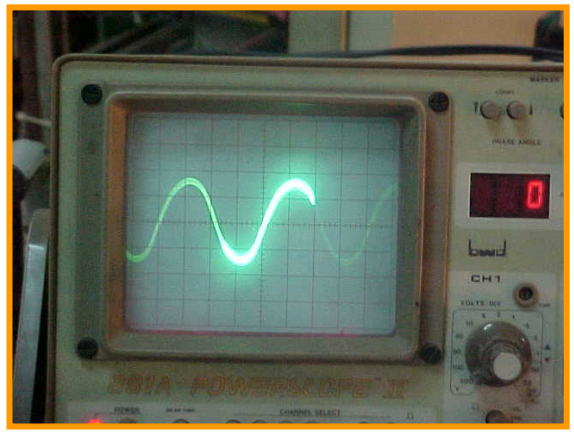


A glimpse of Fuel Cell Developments @ BHEL

C&I system - developed under NMITLI program

A glimpse of Fuel Cell Developments @ BHEL

Power Conditioner Under testing



Power Generation - using Fuel Cells

(Likely markets for different ratings of Fuel Cell Power Packs)

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Few identified technology gaps for PEMFCs

- Development of Indigenous Cathode Catalyst Powders
- Development of Porous C / Graphite paper for use as substrates
- Development of cost-effective Bi-polar plates

4. Development of electrode edge sealing materials (PTFE tapes etc)
5. Development of proton conducting membranes

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Few identified technology gaps (contd)

1. Development of robust dc-dc converters & dc-ac Inverters
2. Development of compact Reformers & Heat Exchangers
3. Development of a C&I to impart 'stand-alone' capability
4. Developing tools & fixtures for ensuring alignment while assembling large stacks

Robust dc-dc converters & dc-ac Inverters

- Usual 'battery' based inverters face ~ 10 - 20% variation in the input dc voltage.
- In contrast, inverters for fuel cells have to face very large fluctuation – of the order of 40 - 50%. Most of this drop, however, is limited to the initial 'no load' – 'load' transition. Use of 'dummy' resistor or fan load etc have been tried.
- With the use of dc-dc boosters (~ 600 V for 3 phase, ~ 300 V for single phase) very high inverter efficiency can be achieved (>90%).

Compact Reformers & Heat Exchangers

- Before we think of commercializing fuel cell based power packs, infrastructure for the most appropriate Fuel needs to be established. Different fuels can be identified for different areas / applications. Ethanol, LPG, NG etc
- Suitable reformers for different fuels are needed. Some expertise already available (Methanol reformers - NMRL & IICT; LPG – NCL)
- Development of compact heat exchangers needed to tap 'excess' or 'waste' heat as hot water or low-grade steam for use at customer end. – with low power pumps/fans

C&I package for 'stand-alone' capability

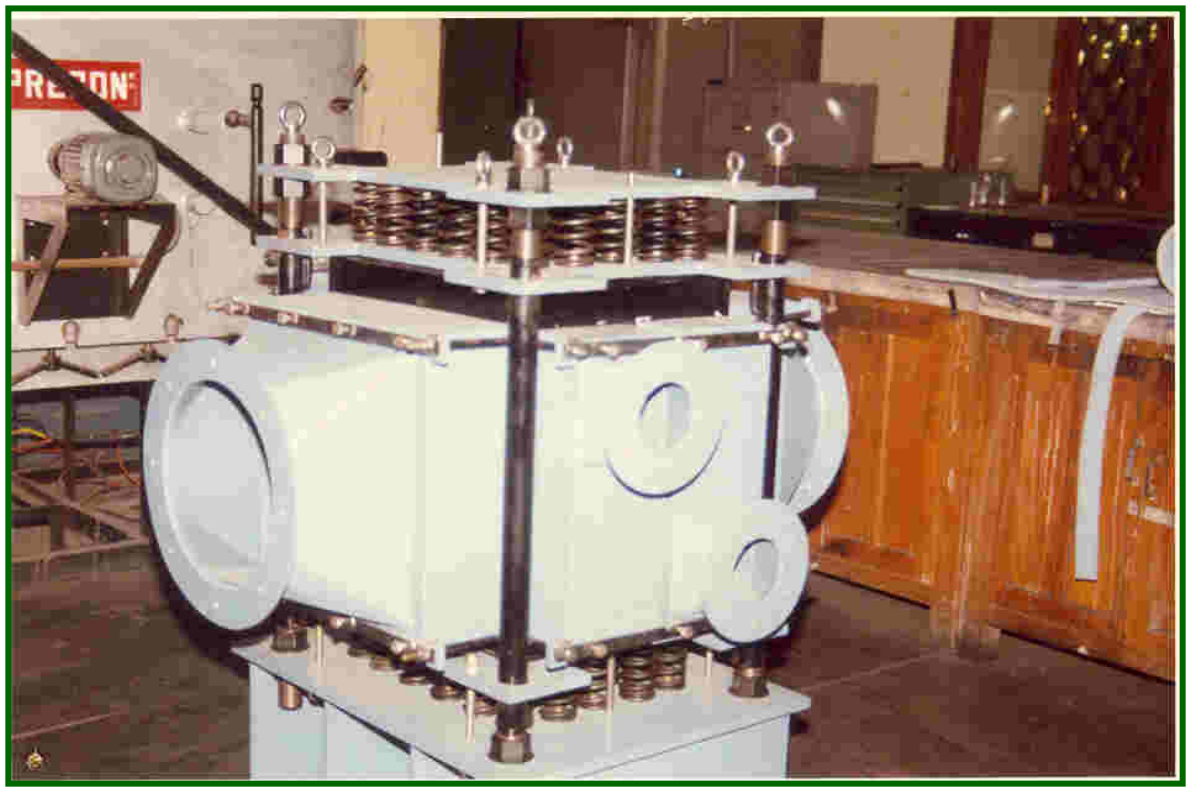
- All FCPPs thus far have been operated by experts only. OK for developmental phase. Robust, cost effective C&I system to ensure auto start-up, safe operation & auto-stop. Should also log & store critical data for experts to analyze initially,& for self diagnostics, later-on.

Ensuring alignment during stack assembly

- Ensuring alignment of components (cells, bi-polar, cooling, dummy & pressure plates etc) poses many problems, especially in larger stacks. Special tools & fixtures were designed for the 25 kW PAFC stack (160 cells, >2 m high)

Stack Compression

- Apply & retain required compressive load over the entire useful life of the stack – a mechanism using active loading components (springs), is shown below



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Thank You