# Filter Element Test Program at NCCC

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# Filter Element Test Program

- Filter Element Testing and Evaluation
- Failsafe Testing and Development
- Material Evaluation and Corrosion Analysis
- Particulate Collection Efficiency
- Particulate Sampling and Characterization
- Online Particulate Monitoring

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# Particulate Control Device (PCD)

- Siemens (Westinghouse) design
- Install up to 91 filter elements
- More than 35 types of filter elements tested
- Metal and ceramic filter elements
- Individual failsafe for each filter element
- Gasification char: ~15 micron MMD
- Particulate loading: 5,000-20,000 ppmw
- Outlet emission: less than 0.1 ppmw
- 150-240 psig pressure, 750°F temperature

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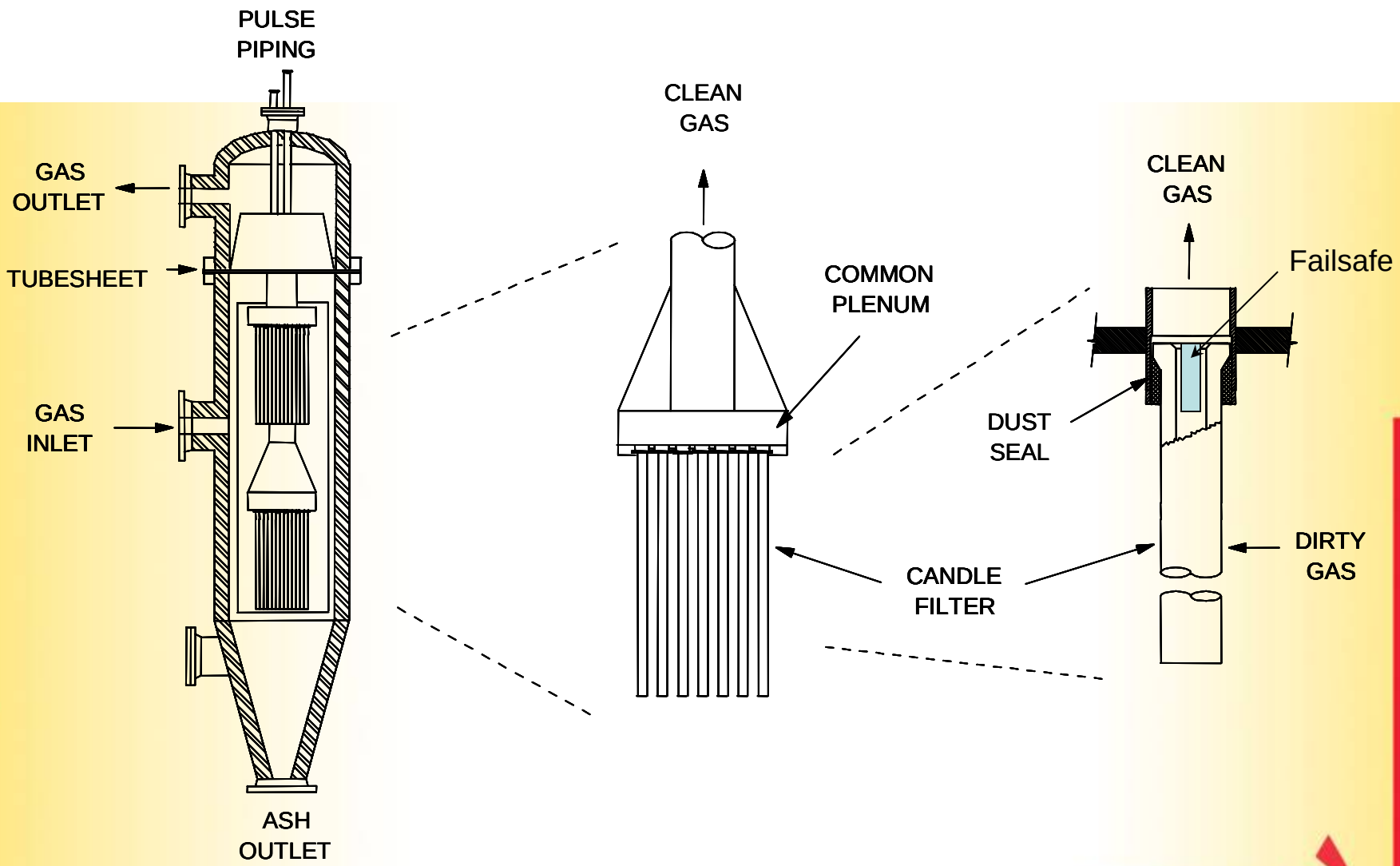
# Particulate Control Device (PCD)

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# Partial List of PCD Group Partners

| Company Name | What was done |
|---|---|
| 3M | Filter element testing and evaluation |
| AlliedSignal Composites (PRD-66) | Filter element testing and evaluation |
| Andersen Instruments | Real-time particulate monitoring/PCME |
| Argonne National Labs | Supplied exposed materials for non-destructive test method development |
| Blasch Precision Ceramics | Filter element testing and evaluation |
| CANMET | Consulting on ash bridging |
| Ceramem | Failsafe testing |
| Clarkson University | Computation Fluid Dynamics of filter system |
| Cleveland State University | Design of high-termperature cyclone manifold system |
| Clyde Pneumatics | Fine ash removal lockhopper performance (high temperature, high pressure seals) |
| Coax Valves | Back-pulse valve improvement |
| Combustion Power Company | Filter system design and installation |
| Coors Ceramics | Filter element testing and evaluation |
| Department of Energy | Filter system performance, design, and CFD modeling |
| Ensto Ceramics | Filter element testing and evaluation |
| Fairey Microfiltrex | Filter element testing and evaluation |
| Foster Wheeler | Technical exchange of information - filter system performance, design |
| Georgia Tech University | Analysis/Consulting on ash bridging |
| Graver technologies | Filter element testing |
| Industrial Filter and Pump | Filter system design, filter element testing & evaluation |
| Jonas, Inc | Real-time particulate monitoring/Jonas Probe |
| Kellogg Brown and Root | Technical exchange of information - filter system performance, design |
| McDermott (Babcock & Wilcox) | Filter element testing and evaluation |
| Mott Corp | Filter element testing and evaluation |
| Oak Ridge National Labs | Technical exchange of information - Iron Aluminide material performance |
| Pall Advanced Separation | Filter element testing and evaluation |
| PCME | Real-time particulate monitor |
| Phoenix Solutions Co. | Coupon test for filter element materials |
| Porvair | Filter element testing |
| Process Metrix | Real-time particulate monitoring/SPC |
| Purolator | Filter element testing |
| RATH | Filter element media testing |
| Sandia National Lab | Real-time particulate monitoring |
| Schumacher (now a subsidiary of Pall) | Filter element testing and evaluation |
| Siemens Westinghouse Power Company | Filter system evaluation, failsafe testing |
| Sierra Pacific Corporation (Pinon Pines) | Technical exchange of information - filter system performance |
| Southern Metal Processing Company | Filter cleaning method development |
| Southern Research Institute | Particulate sampling, filter cake properties, filter element characterization |
| Specific Surface | Filter element testing and evaluation, failsafe testing |
| Techniweave | Filter element testing and evaluation |
| University of Alabama at Birmingham | Corrosion analysis and consulting |
| University of North Dakota EERC | Technical exchange of information - filter system performance |
| US Filter (now a subsidiary of Pall) | Filter element testing and evaluation, failsafe testing |
| Wendell Hull Associates | Char ignition testing |
| West Virginia University | Non-destructive test method development, vibration testing & analysis |
| Bekaert | Filter element testing and evaluation |

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# Filter Elements Tested at PSDF

## Monolithic Ceramic:

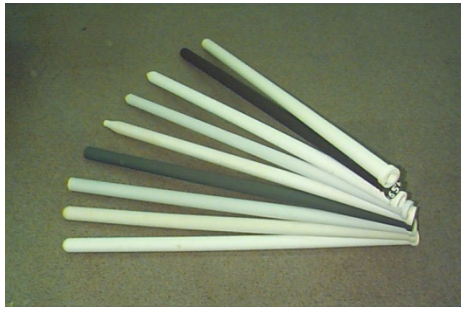
- Pall 181
- Pall 326
- Pall 442T
- Pall/Schumacher F40
- Pall/Schumacher TF20
- Pall/Schumacher T05-20
- Pall/Schumacher T10-20
- Pall/Schumacher N10-20
- Pall/Schumacher 10-20
- IF&P REECER
- Blash precision Ceramics
- Coors Ceramic Company
- Ensto Ceramics
- Specific Surface

## Ceramic Composite:

- 3M 203
- 3M Oxide
- Honeywell PRD-66
- McDermott
- Techniweave

## Metal Powder:

- Pall Iron Aluminide
- Pall 310 SS
- Pall Hastelloy X  Grade H
- Pall Hastelloy X P50
- Pall Hastelloy X P90
- Graver Technologies Titanium
- Mott SR-75



## Metal Fiber:

- Pall HR-160
- Pall Fecralloy
- Pall Haynes 214
- Pall Haynes 230
- Fairey 316L SS
- Fairey Inconel 601
- Fairey Hastelloy HR
- Porvair IC Coated
- Bekaert Alloy

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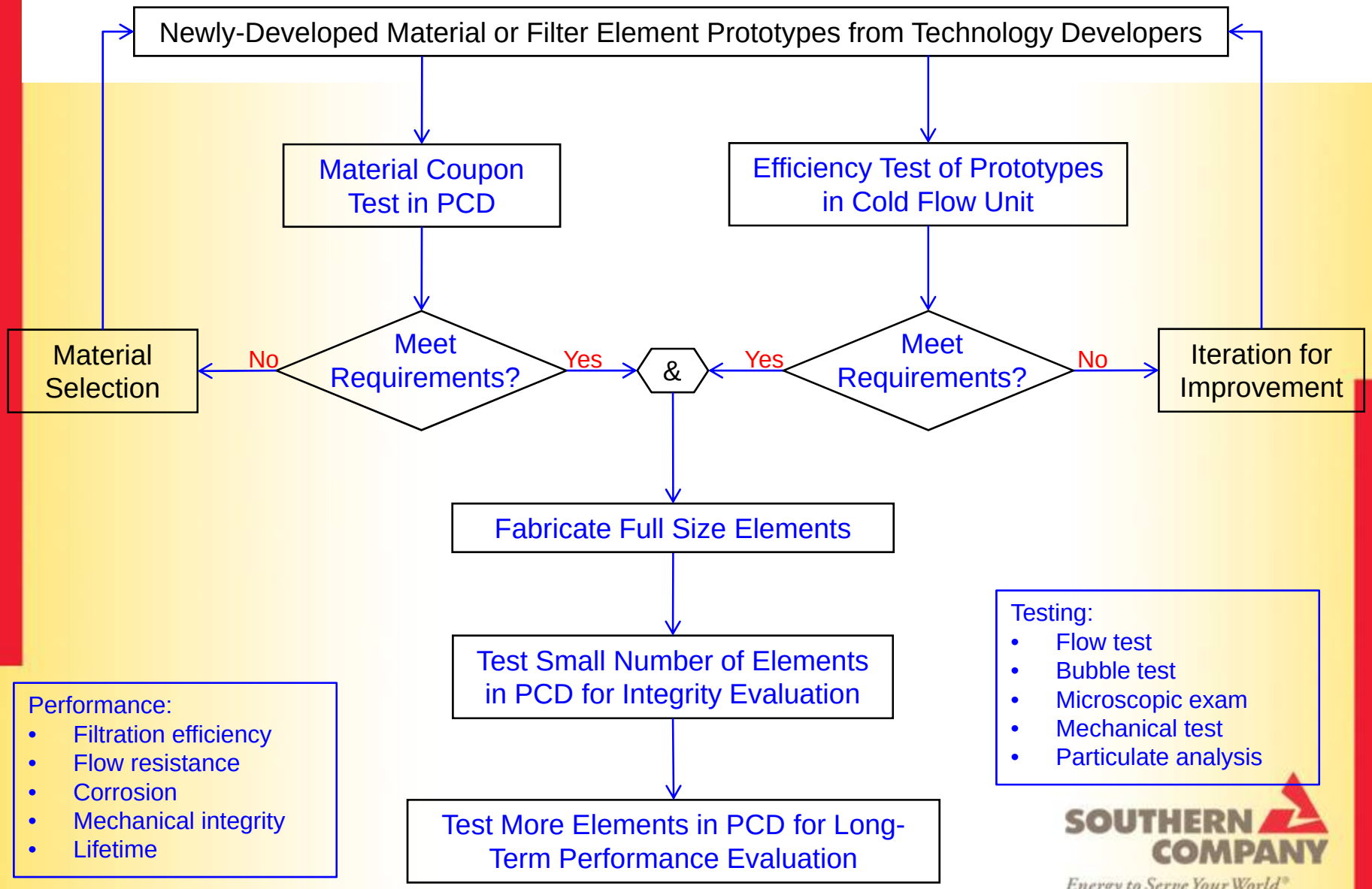
# Filter Element Test Program




Performance:
- Filtration efficiency
- Flow resistance
- Corrosion
- Mechanical integrity
- Lifetime

Testing:
- Flow test
- Bubble test
- Microscopic exam
- Mechanical test
- Particulate analysis

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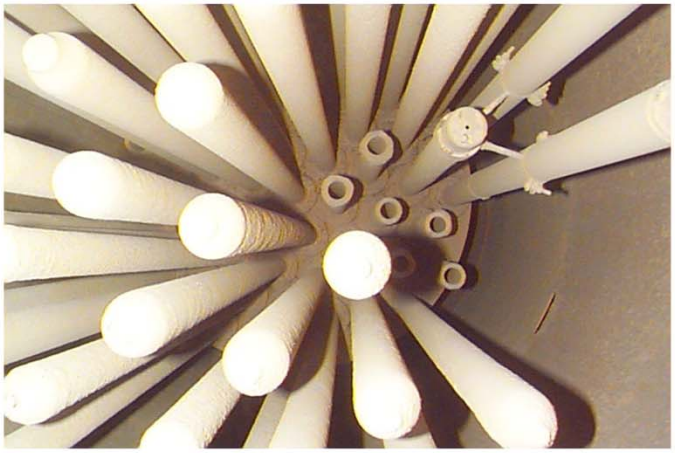
# Filter Element Failures in Early PCD Test



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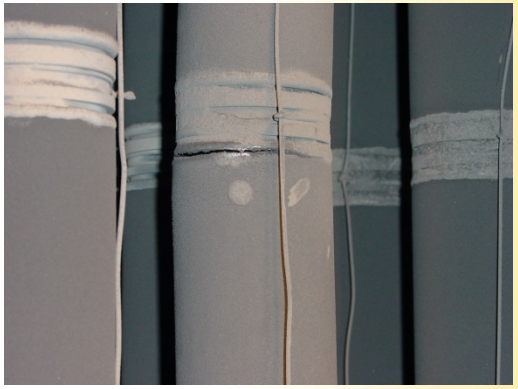
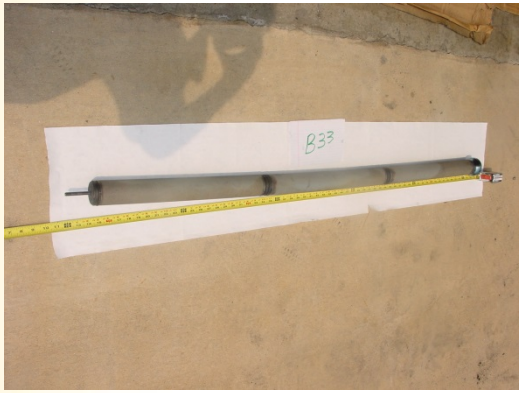
# Failure Analysis of Filter Elements





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# Promising Filter Elements for Commercialization Demonstrated

FEAL:

- High collection efficiency
- Some have accumulated 16,155 hrs
- Corrosion development monitored
- Long-term pressure drop monitored
- Sufficient mechanical integrity

HR-160:

- Some have accumulated 11,023 hrs
- Promising corrosion resistance
- Improvement of efficiency
- Stronger structure

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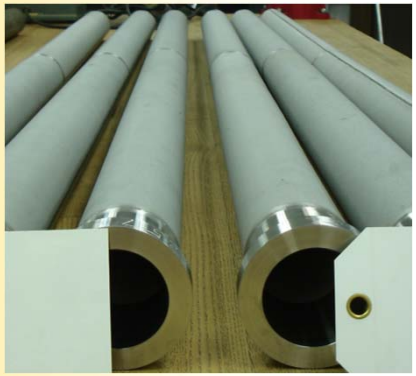
# Testing of Newly-Developed Filter Elements in Recent Years

Porvair IC Coated:

- Alloy fibers coated with inert material
- Some have accumulated 7,978 hrs



Mott SR-75 Sintered Powder:

- High collection efficiency
- Some have accumulated 7,501 hrs

Bekaert Sintered Fiber:

- Newly-introduced
- Some have accumulated 2,960 hrs

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# Testing History of Major and Latest Filter Elements

FEAL:

- Pall product – sintered powder of iron aluminide
- Started testing in combustion mode prior to 1999, and transitioned to test in gasification mode in 1999
- Some with the longest exposure times were retired due to high flow resistance because of corrosion and/or pore plugging

HR-160:

- Developed by US Filter (now subsidiary of Pall) – sintered fiber of HR-160
- Started testing in 2001
- More testing and collaboration with Pall led to an improved media of HR-160 with finer mesh
- The testing for the finer mesh elements started in 2008
- Both coarse and fine media elements are continually tested

Porvair IC Coated:

- Developed by Porvair – alloy fibers coated with inert material
- Started testing non-coated filter elements in 2007
- Started testing inert-coated (IC) filter elements in 2009 (first test was with full set of 72 elements)

Mott Sintered Powder:

- Mott product – sintered powder of high alloy (SR-75)
- Developed with NCCC/PSDF suggestion for media configuration and material selection based on PSDF testing data

Bekaert Sintered Fiber:

- Developed by Bekaert – sintered fiber of alloy
- More testing and collaboration with Bekaert led to an improved media with acceptable efficiency
- Started testing in 2013

All of the above mentioned filter element types have gone through a series of coupon and cold flow testing before they were tested in the PCD following the PSDF filter element test program. The test program and collaboration effort between the NCCC/PSDF and the technology developers resulted in significant improvement to the products in gasification application. The NCCC/PSDF is currently working with technology developers and manufacturers to test new products and support technology development.

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# General Lessons Learned

- Ceramic filter elements have many excellent features such as chemically inert media, high-temperature resistance, and high particulate collection efficiency. However, Their low resistance to thermal shock often results in catastrophic failure in a thermal excursion during operation.
- Many efforts were made in late ‘90 and early ’00 to use composite ceramic structure (ceramic fibers) to improve the thermal shock resistance. However, the majority of the prototypes failed in gasification environment due to incompatible fiber structures and the binders. The technology developers terminated the R&D programs thereafter because of different reasons (budget, market, technical difficulties, etc.).
- Metal filter media have higher thermal shock resistance, stronger mechanical structure, moderate chemical resistance (corrosion), suitable to warm PCD temperature in latest commercial gasification applications, acceptable particulate collection efficiency if designed properly, etc. However, they have higher cost especially for high alloy materials suitable to the gasification environment. More extensive testing is need to improve the performance and reduce the cost with more economic choices for commercial application.
- Sintered powder media have “tight” pore structure (low porosity) and thus have higher collection efficiency. However, this often means higher flow resistance. Further corrosion and particulate plugging can cause unacceptable pressure drop beyond the proper restoration, which is the primary cause for replacement.
- Sintered fiber, on the other hand, have “open” pore structure (high porosity) and thus have lower collection efficiency. The flow resistance is lower accordingly. For some fiber media, a spike of particulate emission can be detected at the PCD outlet during back-pulse due to temporary “opening” of the char cake layer on the fiber media. Properly designed fiber layer configuration can improve the performance.
- Based on the NCCC/PSDF test data, the FEAL filter elements can provide up to two years of continuous operation with certain maintenance. The rest of the tested filter types are showing promising results with more exposure times accumulated. The long-term performance evaluation on these filter elements is continued at the NCCC/PSDF.
- The majority of the filter elements were tested in the PCD in many test runs under different operating conditions. The unique test setup and operating conditions provided a wide range of technology screening and demonstration opportunities.

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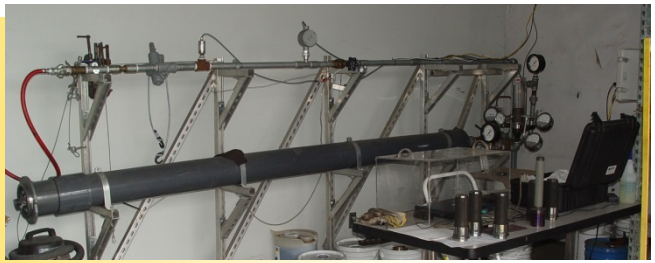
# Filter Element and Failsafe Off-Line Testing

(SCS & SRI)

Flow Test



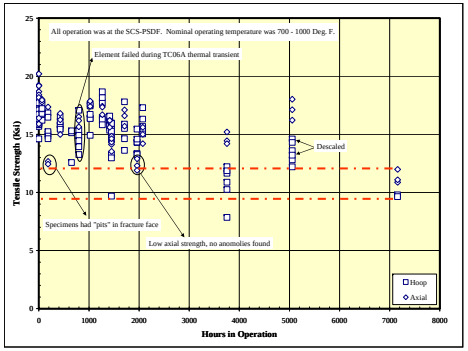
Bubble Point Test

Filter Cleaning

Microscopic Inspection

Efficiency Test

Material property testing

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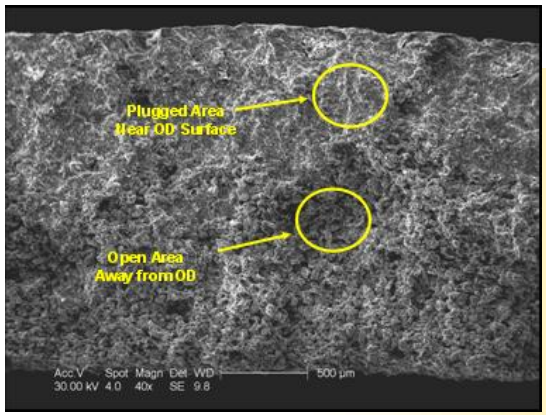
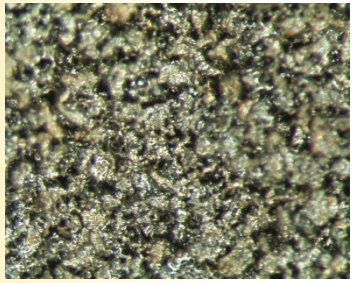
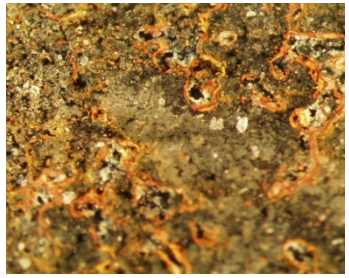
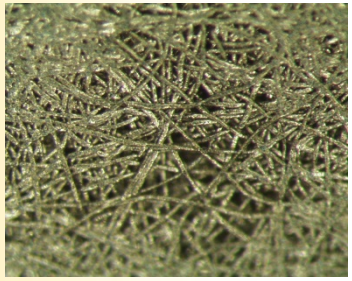
# Corrosion Analysis of Metal Filter Element

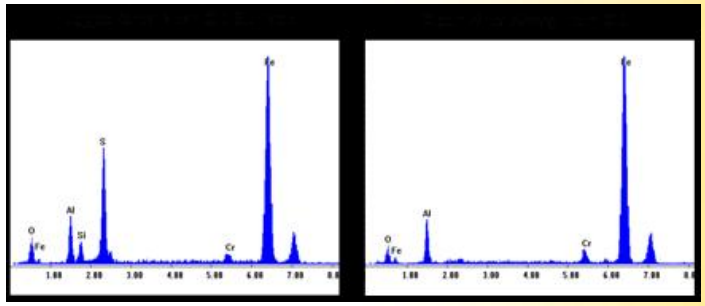
Joint Effort:
-SCS
-SRI
-ORNL
-Pall Corp
-Geogia Tech







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# Particulate Sampling, Monitoring, and Characterization

## (SRI and SCS)

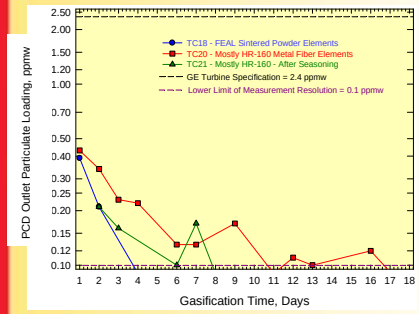
Online Particulate Monitors:

- Jonas Acoustic
- PCME
- PPC (Laser)

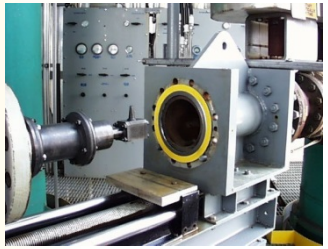
In-situ Outlet Sampling

In-situ Inlet Sampling

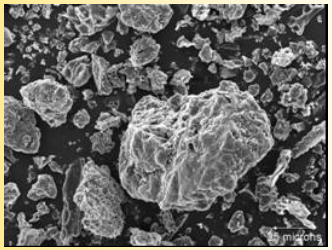
### Particulate Emission



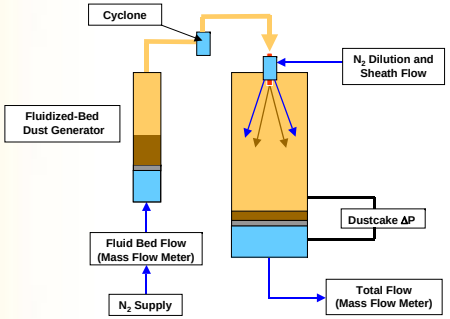

### Sampling System

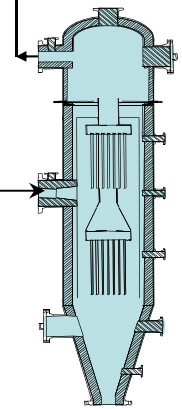


### SEM

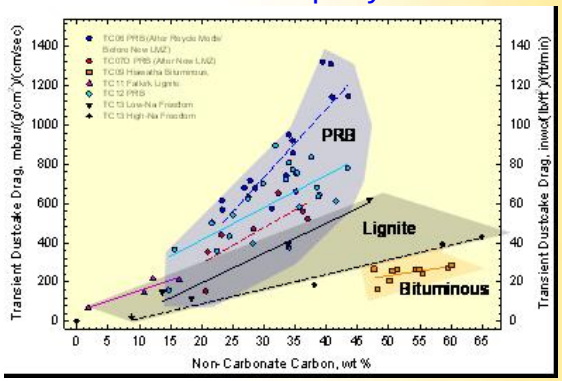


### Drag Measurement



### Cake Property

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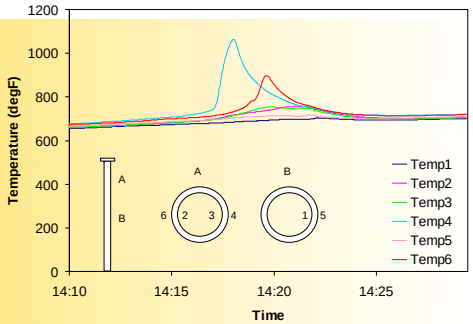
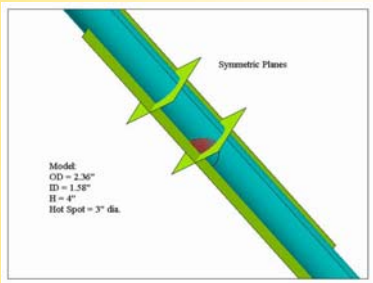
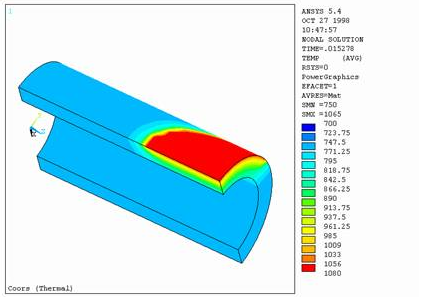
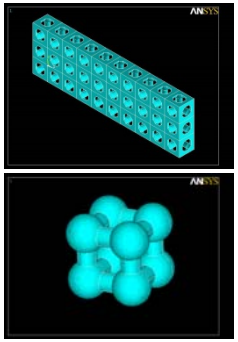
# PCD Process Modeling, Simulation, and Design

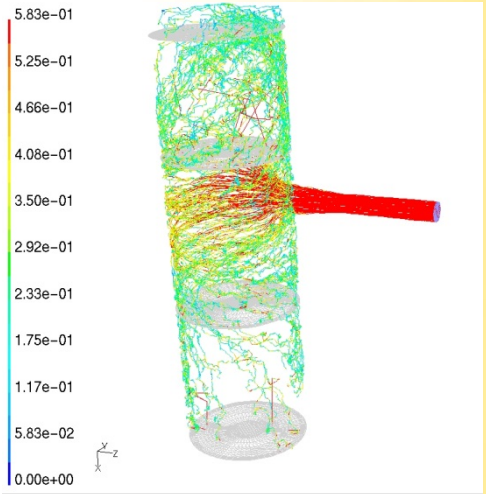
- CFD – SCS & DOE
- FEA – SCS
- Thermal/Mechanical – SCS & SRI
- Process – SCS & SRI
- Material Testing - SRI



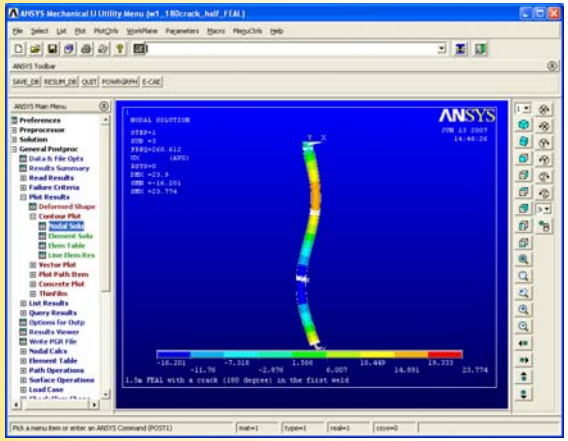



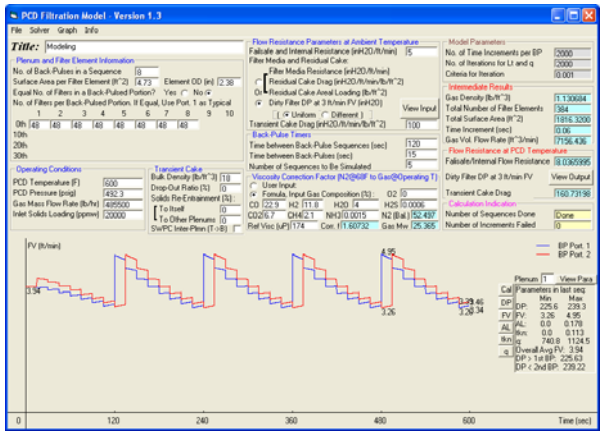




Wilsonville Filter Vessel — Fluent/UNS 4.2 (3d, ke)
Ash Particle Traces Colored by Particle Velocity Magnitude (m/s)
30 micron particle diameter

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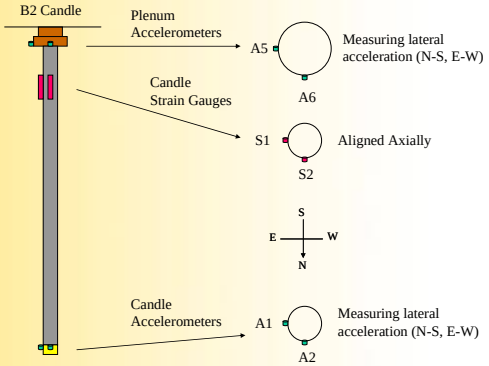
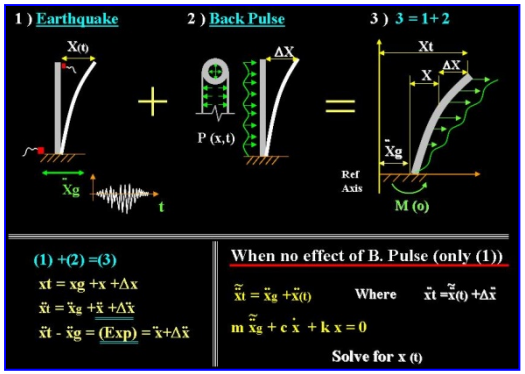
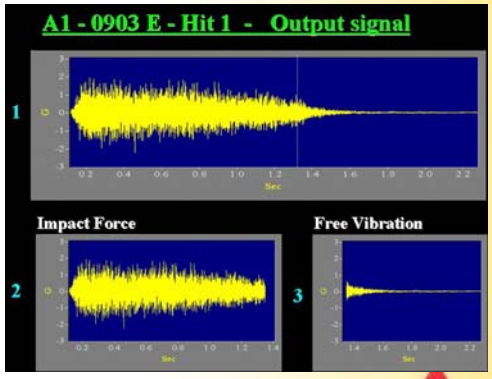
# Vibration Test and Retrofit for Filter Element Support

## (SCS and West Virginia University)

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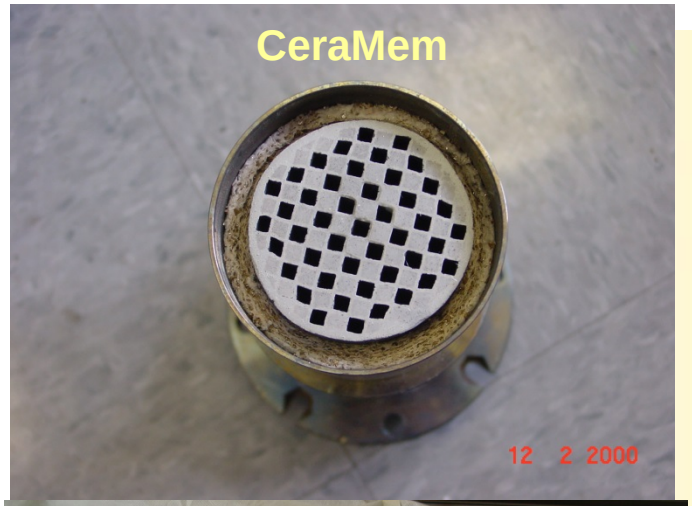
# Failsafe Testing and Development

## (Joint development with manufacturers)



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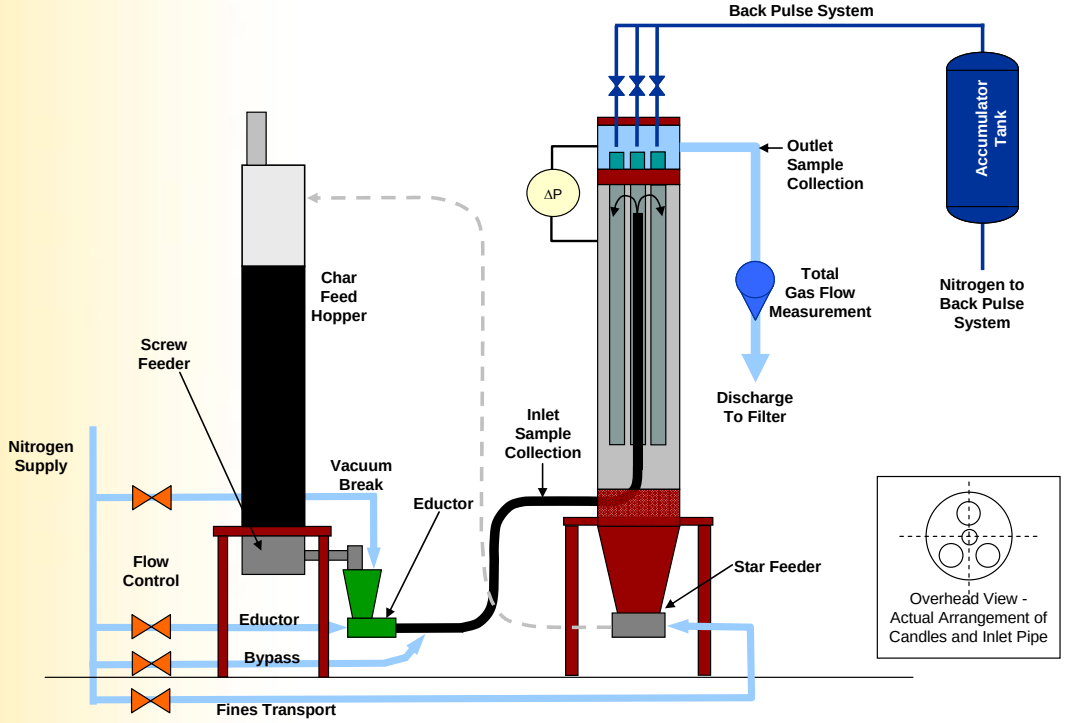
# Cold Flow Test Unit (PPCD)

- Screening test of newly-developed filter elements and failsafes
- Back-pulse parametric testing and pressure measurements
- Collection efficiency testing
- Particulate sampling and monitor testing

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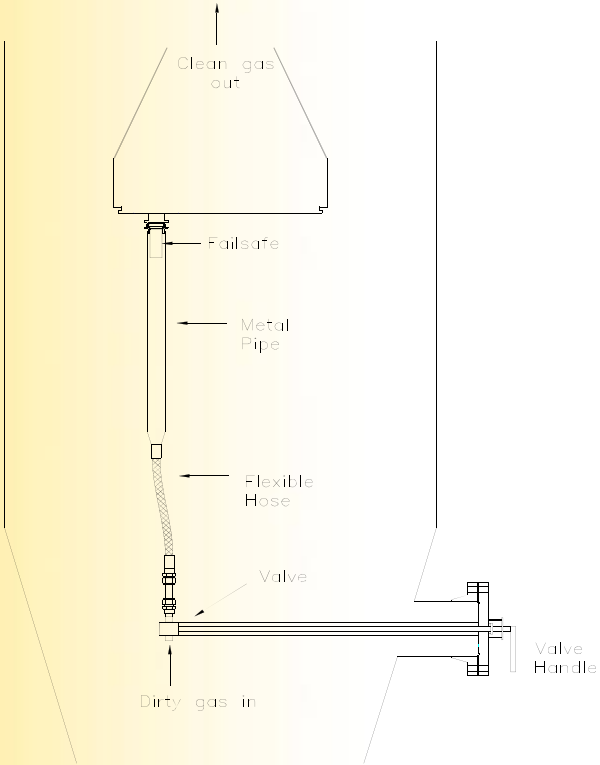
# Failsafe Tester

- Valve-activated mechanism
- Simulate catastrophic filter failure
- Up to 18,000 ppmw particulate loading
- Open/close the valve from outside of the vessel



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# Recent Coupon and Prototype Testing

- Pall Corp new metal fiber media
- Porvair metal fiber media
- Mott Corp various metal powder media
- Graver Technologies titanium media
- Purolator metal fiber media
- RATH ceramic fiber media
- Bekaert metal fiber media

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