

# Worldwide Pollution Control Association

WPCA-Duke Energy  
FF/HAPS Seminar  
October 12-13, 2011

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# Bag Life Optimization Through Testing

**Presented At:**

**2011 WPCA-Duke Energy Fabric Filter /  
HAPS Seminar**

**Duke Energy's Plainfield Office, IN  
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# Introduction

- ◆ Bag Test Methods & Value
- ◆ Causes of Premature Bag Failure
- ◆ Design Considerations and Trade-Offs
- ◆ Importance of Fabric & Bag Specifications
- ◆ Quality Assurance/Quality Control
- ◆ Preventive Maintenance Programs
- ◆ Bag Monitoring Programs
- ◆ Extending Bag Life
- ◆ Review & Recommendations



# Reasons For Fabric Testing

- ◆ Quality Assurance
- ◆ Diagnostic Aid or Troubleshooting
- ◆ Fabric Monitoring
- ◆ Alternative Fabric Selection
- ◆ Research & Development
- ◆ Bag Replacement Timing



# Standard Fabric Tests

## TEST

1. Weight
2. Construction
  - 2A. Yarn Count
  - 2B. Type of Weave
3. Thickness
4. Tensile Strength
5. Mullen Burst
6. Permeability
7. Organic Content (LOI)
8. MIT Flex
9. Filtration Performance
10. Width
11. Water Repellency
12. Surface Resistance
13. Volume Resistance
14. Two-Point Resistance

## METHOD \*

ASTM D3776

ASTM D3775

ASTM D579

ASTM D1777

ASTM D5035

ASTM D3786

ASTM D737

ASTM D578

ASTM D2176

ASTM D6830

ASTM D3774

ASTM D2721

STM 11.11

STM 11.12

STM 11.13

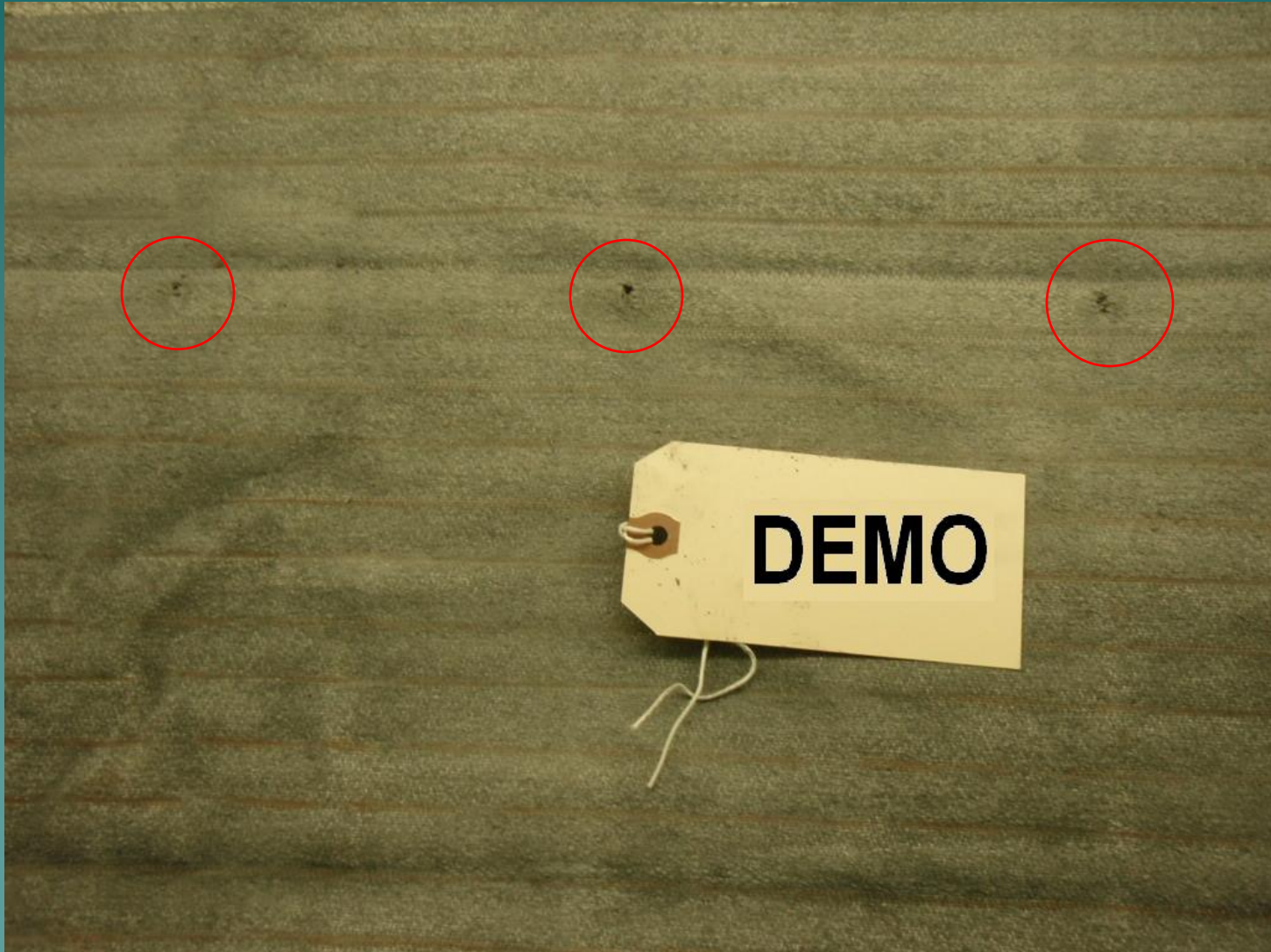
\*NOTE: The ASTM methods are to be interpreted and modified by ETS Test Procedures



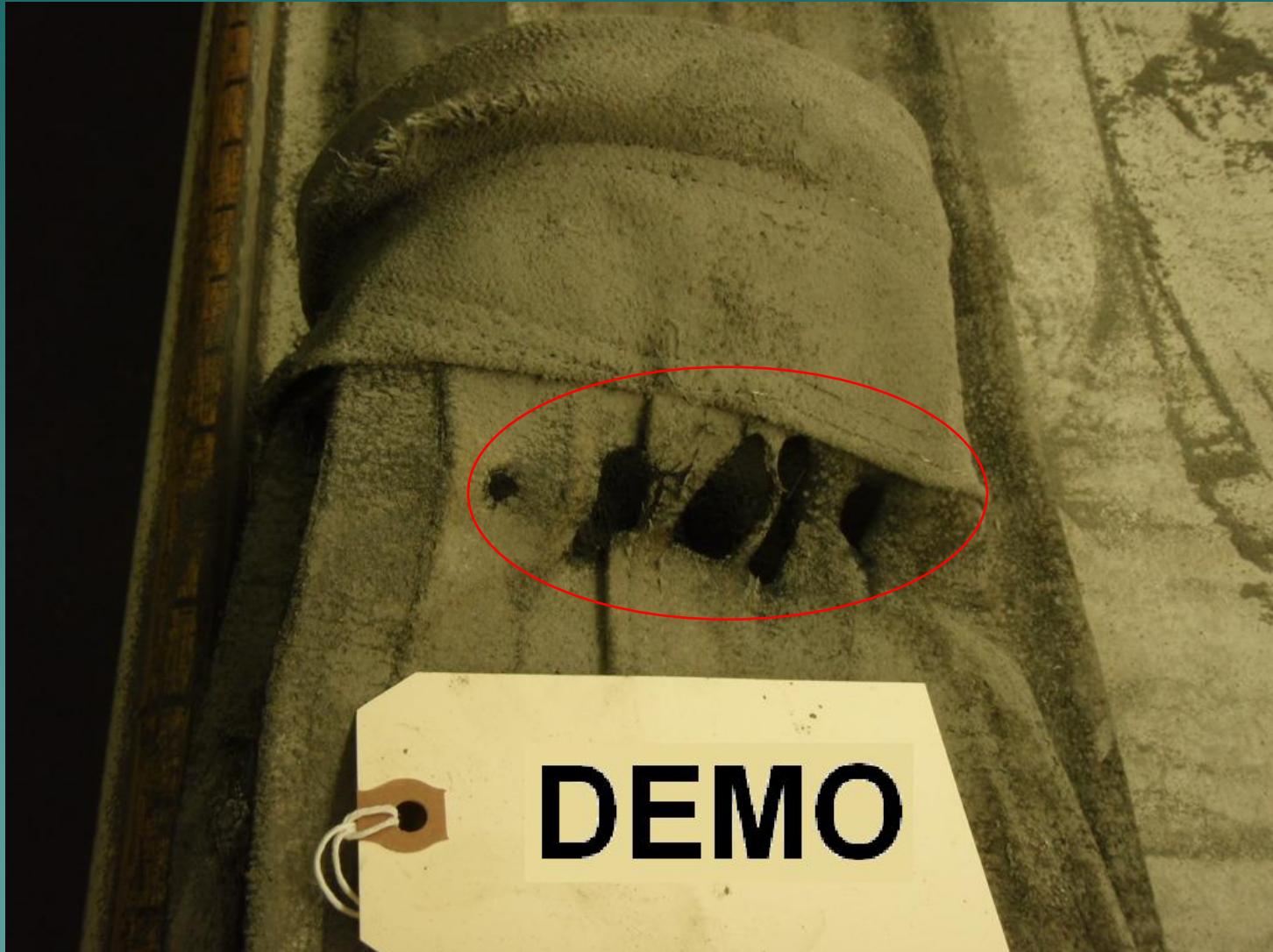
# Visual Inspection



# Pinholes



# Dust Abrasion



# Clean Side Contamination



# Poor Seam Construction



# Permeability Test Method



- ◆ Frazier Permeability apparatus is used to determine air handling capability of filter media.
- ◆ Includes capability to measure air flow over a wide (0-20" w.g.) differential pressure.
- ◆ Ambient to 400 °F temperature range.
- ◆ Non-destructive manner.



# MIT Flex Endurance Test

- ◆ Primarily measures relative value of fabric weaves and finishes to withstand self abrasion from flexing that occurs in the baghouse by measuring the number of flex cycles necessary to break a fabric sample.



# Tensile Test Method

- ◆ Provides stretch, elongation, and tear data for fabrics.
- ◆ Measures relative strength of warp and filling yarns in fabric samples.



# Mullen Burst Test Method



- ◆ Shows the relative total strength of fabrics to withstand severe pulsing or pressure.
- ◆ Fabric strength is measured by determining the difference between the total pressure required to rupture the specimen and the pressure required to inflate an expandable diaphragm.

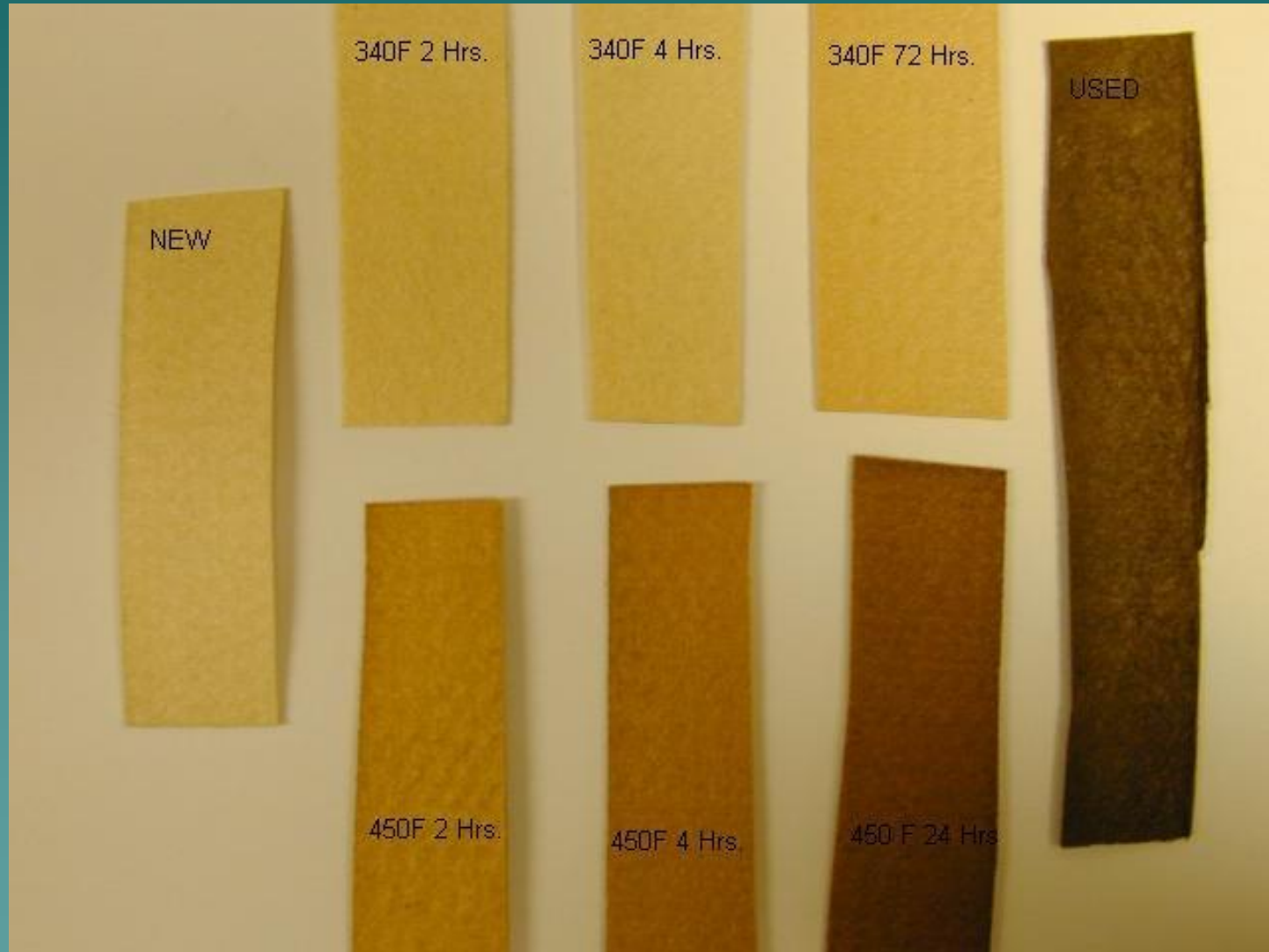


# Microscopic Analysis

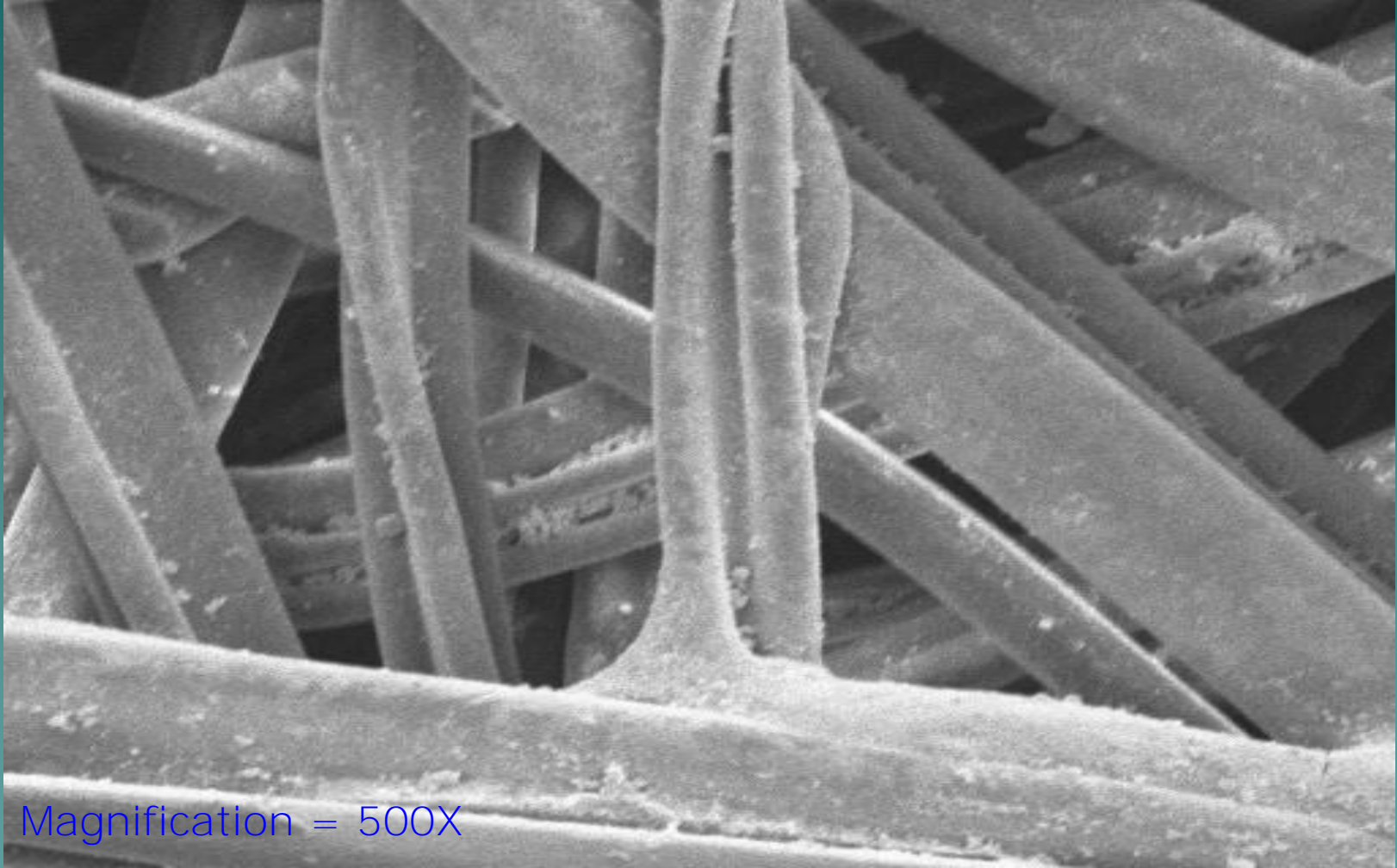
- ◆ Aides in determining causes of bag deterioration and bag blinding.



# PPS Felt at Specific Temperatures



# SEM Photomicrograph



Magnification = 500X

**P-84 Felt Fabric**

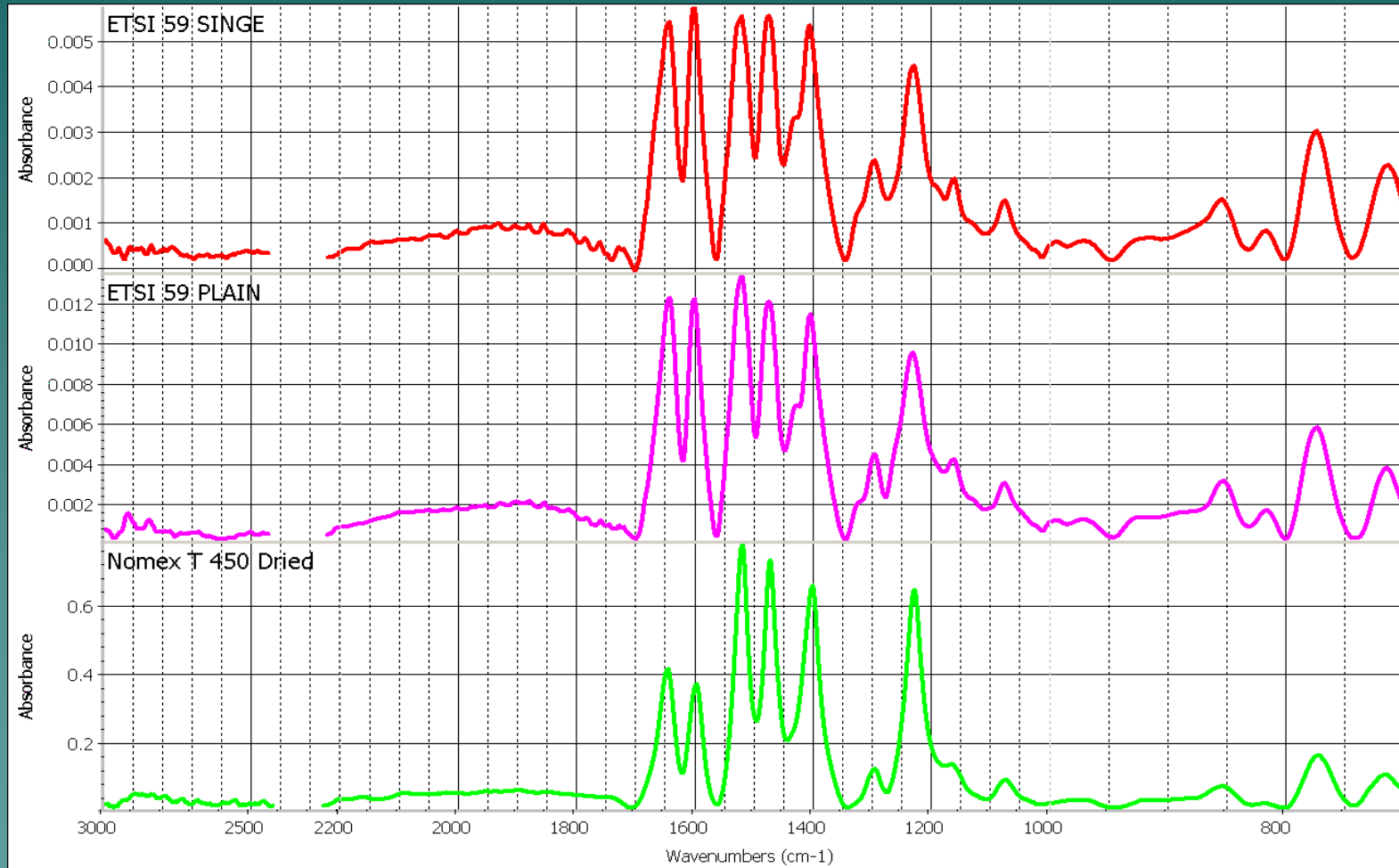


# Chemical Analysis

- ◆ Used either to predict or determine what effect on-stream conditions would have on the performance of a bag.



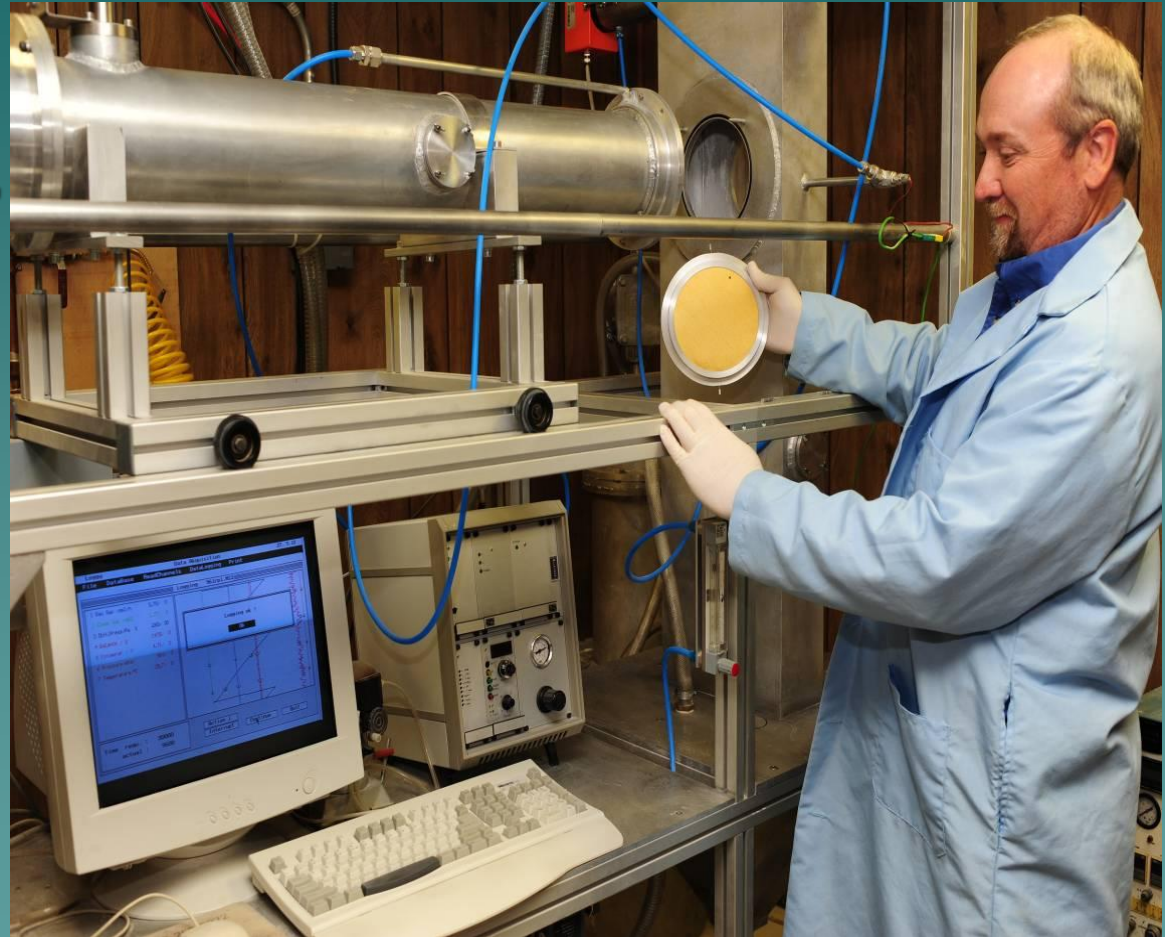
# Fiber Identification by FTIR



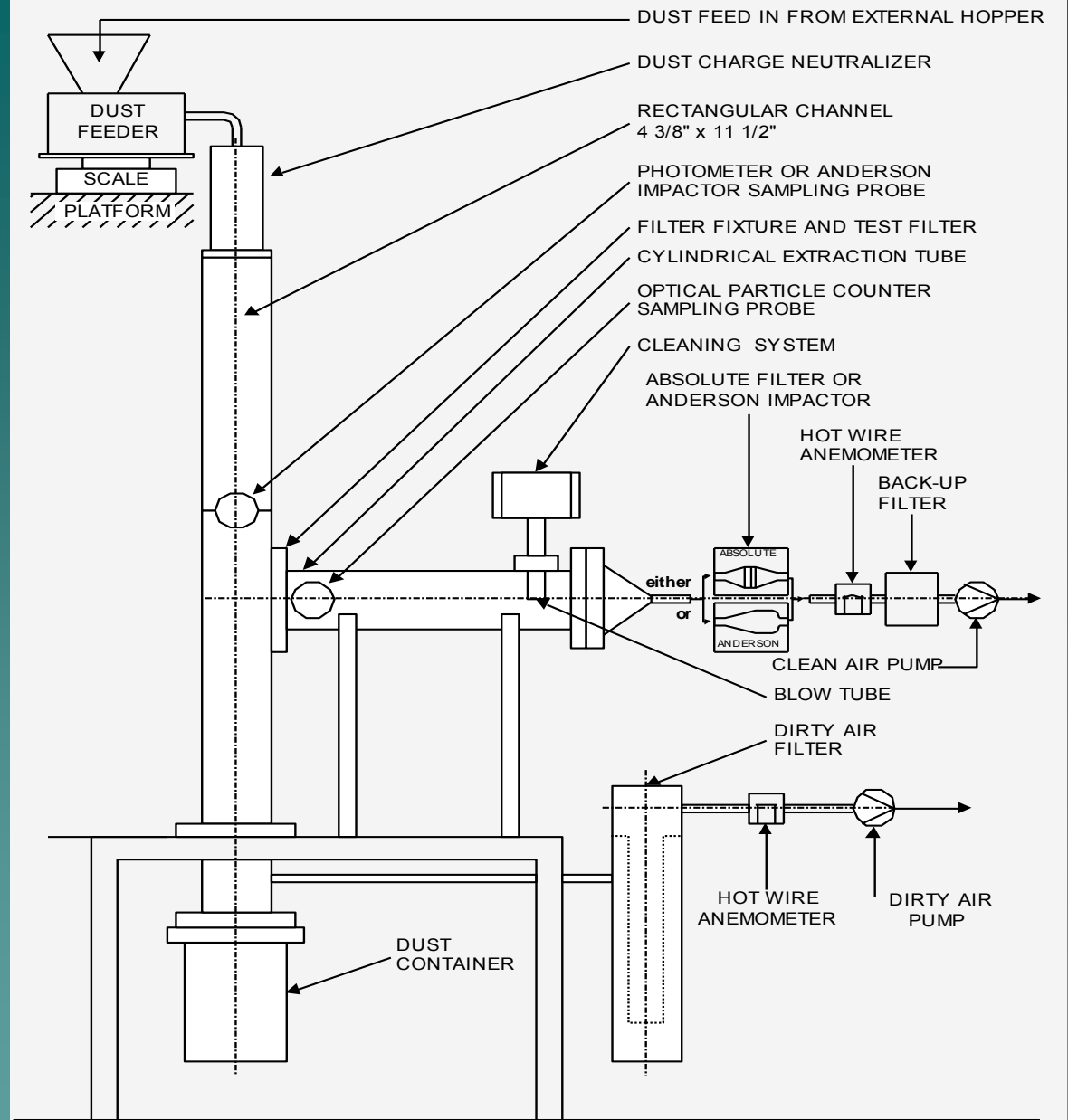
# Filtration Performance Test Apparatus

## ASTM D6830

- ◆ Filtration Effic.
- ◆ Pressure Drop
- ◆ Cleaning Frequency



# ETS-FPTA Schematic



# Bag Monitoring With Stream Time

## Fabric Type A

Bag Status	Tensile (lb/in)		Flex (#cycles)		Burst (lb/psi)	Permeability (FPM)	
	Warp	Fill	Warp	Fill		Dirty	Clean
New	232	226	3100	778	405	68	68
4-wk	117	57	550	68	209	10.9	83

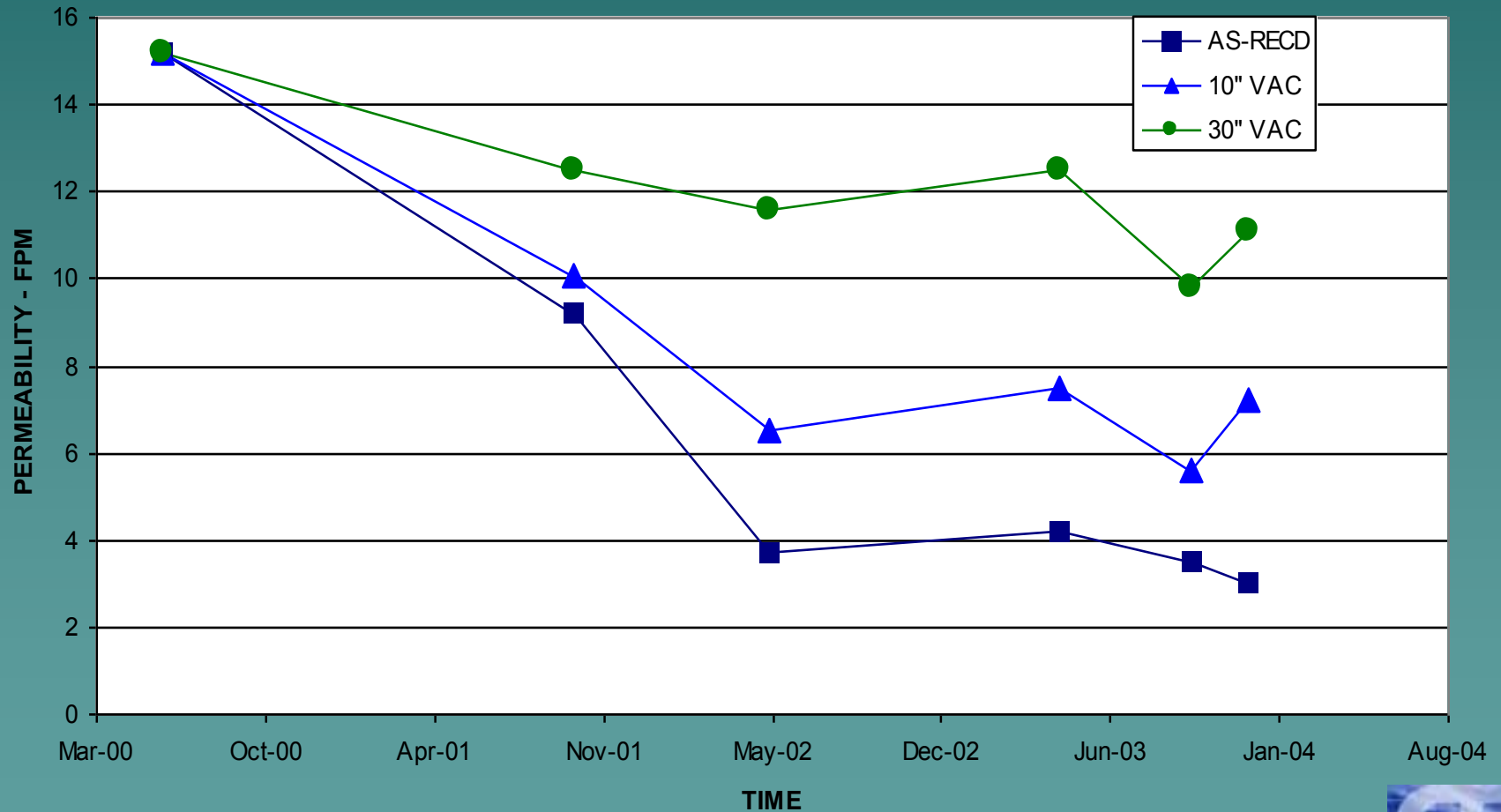
## Fabric Type B

New	123	109	> 50,000	> 50,000	307	37.2	37.2
4-wk	101	81	> 50,000	> 50,000	263	10.8	36.2



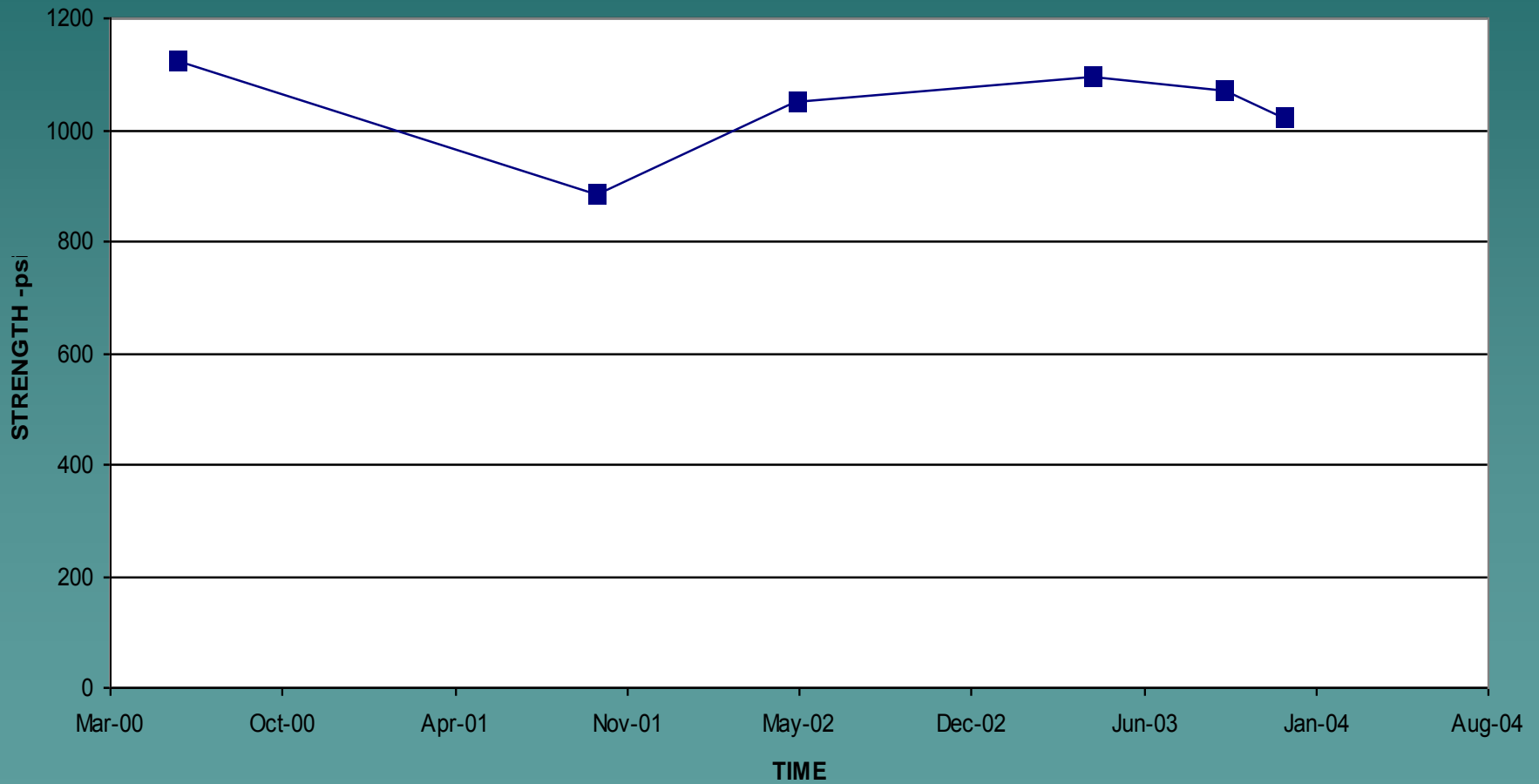
# Bag Monitoring

FIGURE 1  
PERMEABILITY



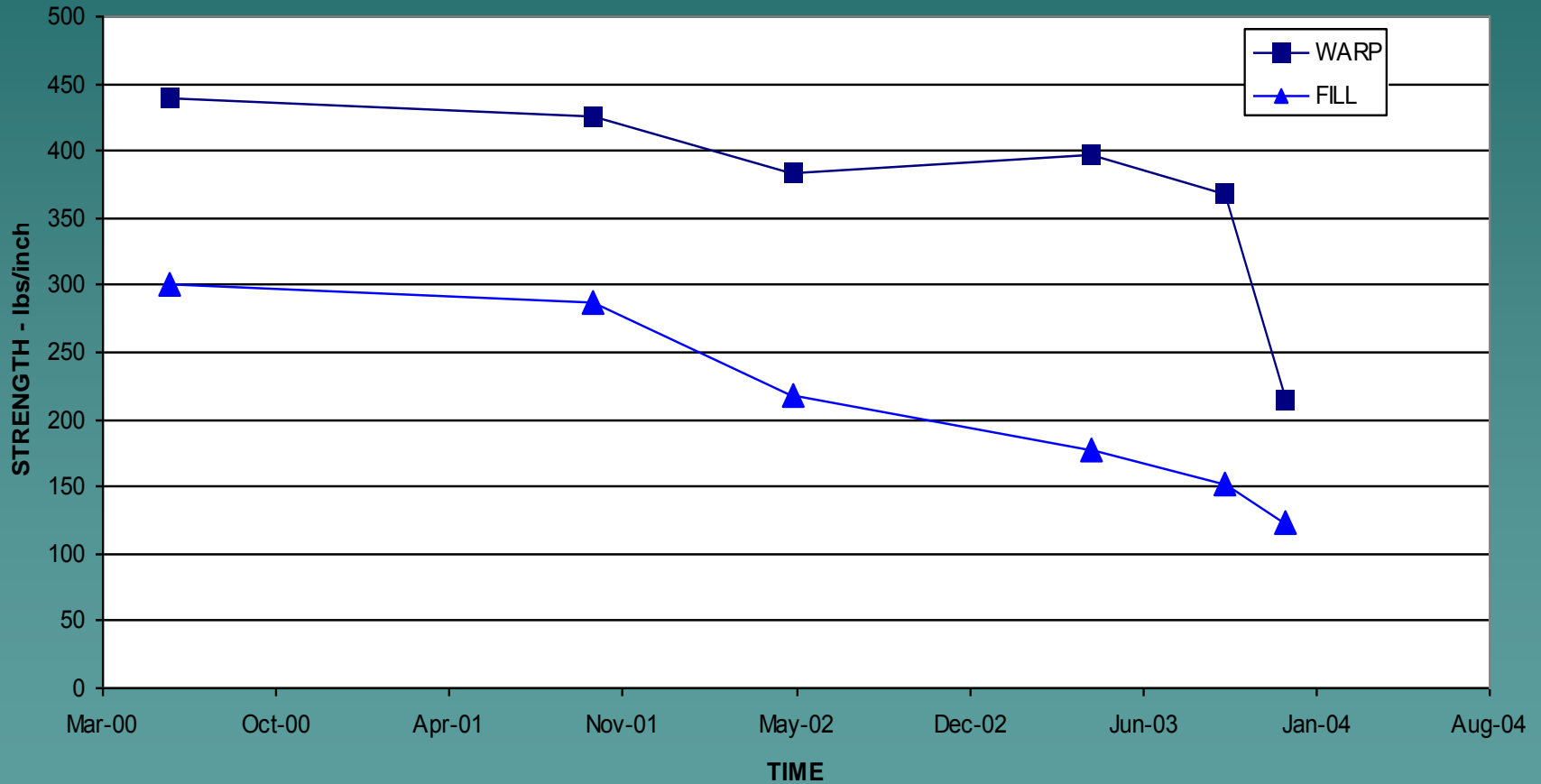
# Bag Monitoring

FIGURE 2  
MULLEN BURST



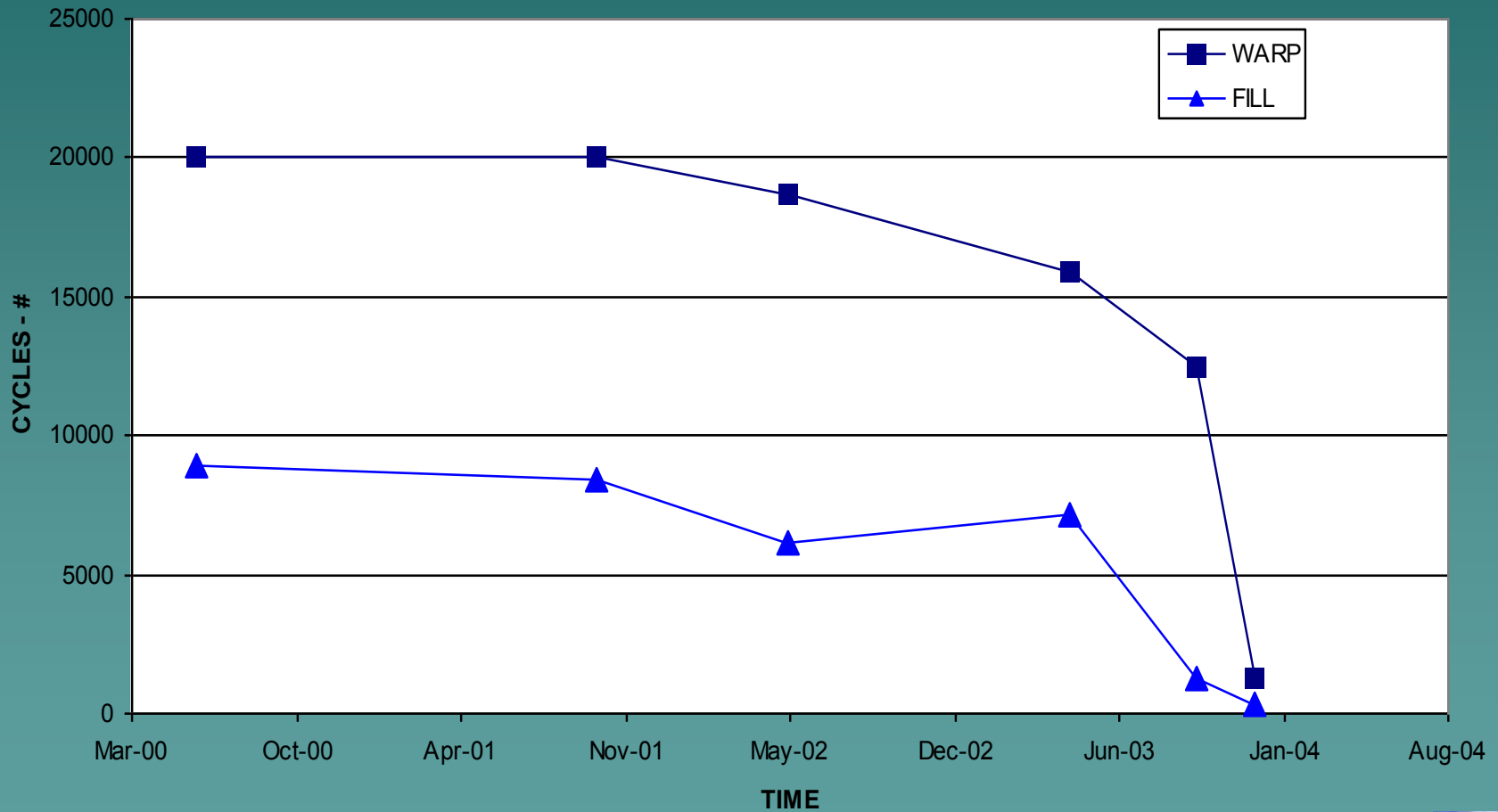
# Bag Monitoring

FIGURE 3  
TENSILE STRENGTH



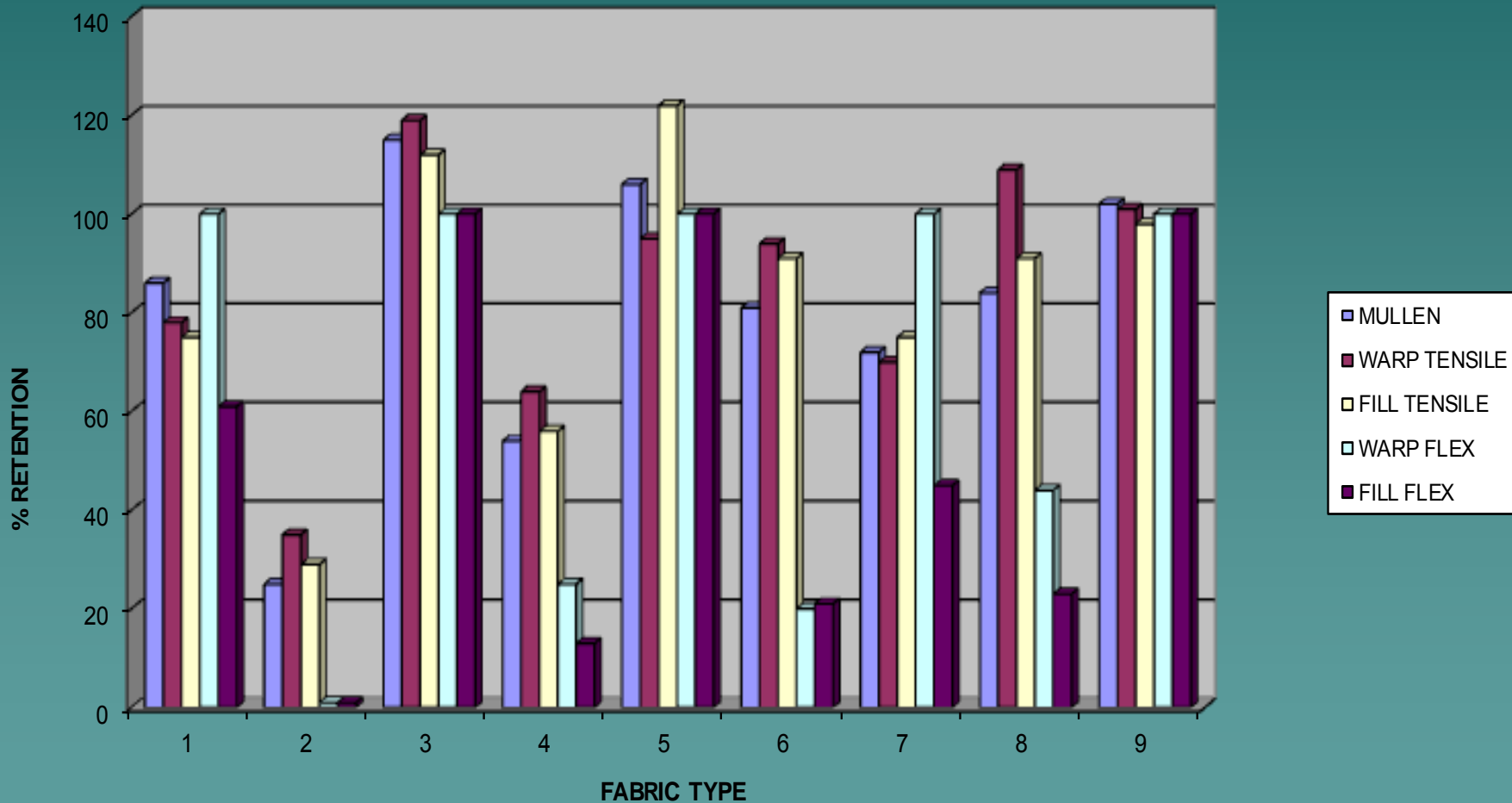
# Bag Monitoring

FIGURE 4  
MIT FLEX ENDURANCE



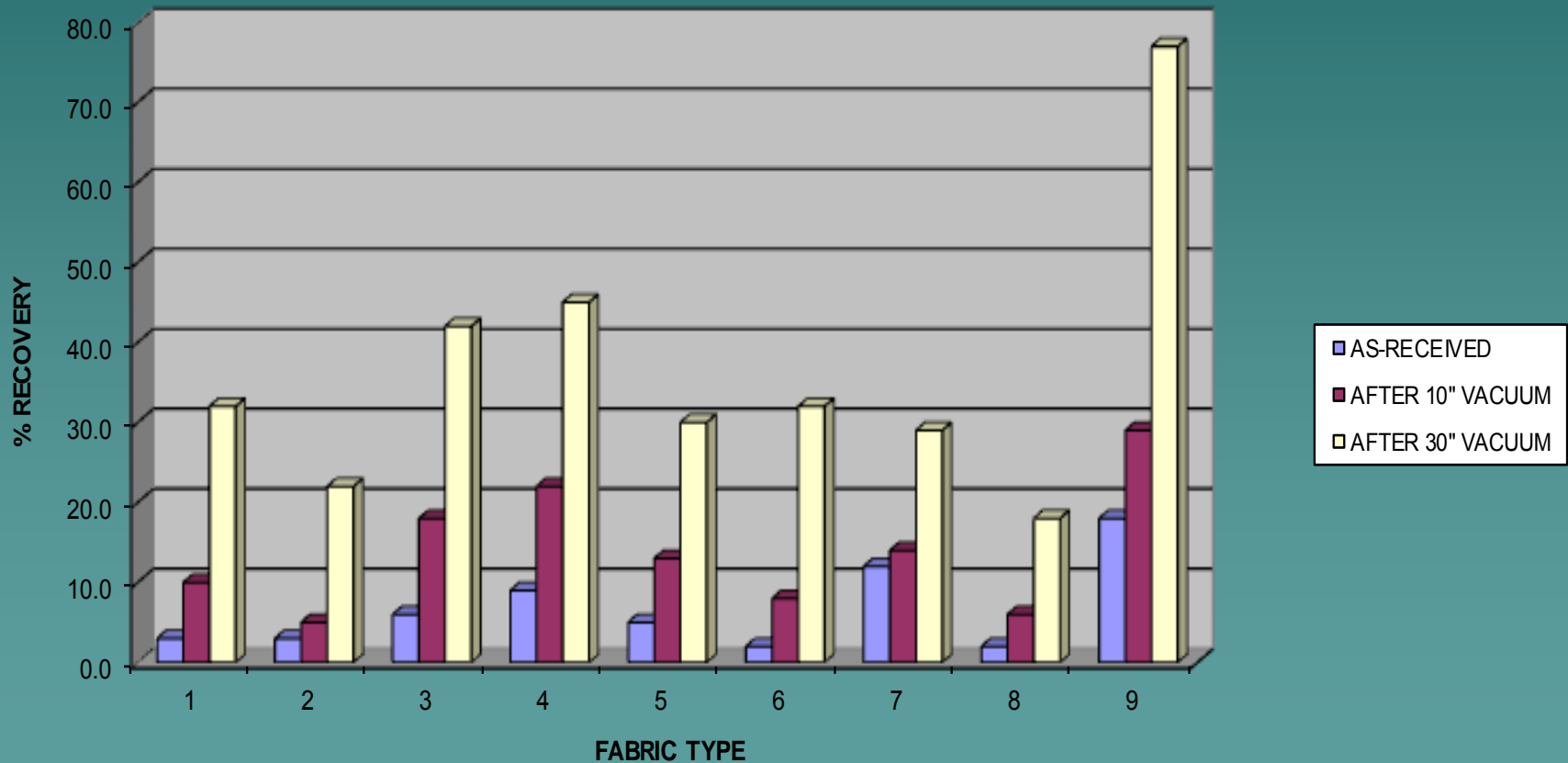
# Alternative Fabric Study

FIGURE 1  
STRENGTH RETENTION  
AFTER 2031 HOURS OF SERVICE



# Alternative Fabric Study

FIGURE 2  
PERMEABILITY RECOVERY  
AFTER 2031 HOURS OF SERVICE



# Premature Bag Failure: Factors Effecting Bag Life (PJ & RA)

- ◆ Design and Manufacturer
- ◆ Installation
- ◆ Gas Flow
- ◆ Gas Temperature
- ◆ Gas Acidity
- ◆ Dust Loading & Particle Size
- ◆ Cleaning Intensity/Frequency/Duration
- ◆ Bag Tension - Bag/Cage Fit
- ◆ Adjacent Bag Life



# Premature Bag Failure: Causes

## ◆ Mechanical

- Dust Abrasion
- Over Cleaning
- Bag Tension
- Adjacent Bag

## ◆ Chemical

- Acids
- Alkalies
- Condensation  
(Organics, Acids,  
Water)

## ◆ Thermal

- Excessive  
Temperature
- Dew Point



# Premature Bag Failure:

## Typical Causes of Pulse Jet Bag Failures

- ◆ Dust on "clean side" - accelerates bag-to-cage wear
- ◆ High velocity dust abrasion - Bottom of bag
- ◆ Chemical attack from flue gas contaminants coupled with acid dew point excursions
- ◆ Bag-to-cage abrasion - Bad fit, poor design, damaged cage
- ◆ Bag-to-bag abrasion - Too close, bent cages, high can velocity
- ◆ Mechanical abrasion in top 1/3 of bag - misaligned Venturi or pulse pipe
- ◆ Process upset conditions - Fabric temperature capability exceeded; particulate is introduced to blind or attack the fabric



# Design Considerations & Trade-Offs

- ◆ Provide Required Filtration
- ◆ Obtain Optimum Bag Life
- ◆ Provide Required Cleaning Capability
- ◆ Distribute Gas & Dust Equally
- ◆ Provide Effective Dust Removal From Collector

N.B.

Lower G/C gives longer bag life & lower  $\Delta P$  (trade-off capital vs. operating cost)

Good design & PM retains design cleaning frequency (low)

Longer Bag Life



# Design: Fabric Filter Categories

- ◆ Capacity
- ◆ Filtering Temperature
- ◆ Operating Duty

Needs  
Dictated By  
Specific  
Application

- ◆ Cleaning Method
- ◆ Filter Media
- ◆ Filtering Gas Flow  
Direction

Options



# Design:

## Fabric Selection Considerations

### Gas Stream

- ◆ Temperature
- ◆ Moisture
- ◆ Chemistry
- ◆ Dust Loading

### Fabric

- ◆ Filtration Performance
- ◆ Temperature Max
- ◆ Release Properties
- ◆ Pressure Drop
- ◆ Life/Durability
- ◆ Costs

### Dust Characterization

- ◆ Abrasiveness
- ◆ Stickiness
- ◆ Explosiveness
- ◆ Flammability

### Other

- ◆ Scrim
- ◆ Coatings/Treatment
- ◆ Hardware
- ◆ Blends



# Design: Key Issues

- ◆ Full process description affecting inlet gas ( $V$ ,  $T$ ,  $P$ , dust loading – high, low & normal)
- ◆ Baghouse specs (G/C, flow distribution)
- ◆ Bag Spec - Devil in the details (e.g. shrinkage)



# Importance of Fabric & Bag Specifications

- ◆ Spec is the basis for the QA/QC
- ◆ The details & comprehensive breadth are critical
- ◆ Without the spec there can be no recourse
- ◆ Drawings & quantitative acceptable tolerances are required



# Filter Bag Specification

## Table of Contents

1.0 Purpose	3.4 Guarantees
2.0 Codes and Standards	3.5 Design Requirements
3.0 Technical Requirements	3.5.1 General Design
3.1 General	3.5.2 Bag Construction
3.2 Glossary of Terms	3.5.3 Cage Specification
3.3 Performance Requirements	3.5.4 Bag Support/Removal
3.3.1 General	3.5.5 Filter Bag QA/QC
3.3.2 Specific Performance	3.5.6 Packing & Shipping

### Appendices

Appendix A – Baghouse Operating Data

Appendix B – Coal Analysis

Appendix C – Pulse Jet Bag And Cage Drawing

Appendix D – Fabric and Thread Specifications



# QA/QC Program: Purpose and Description

- ◆ To insure a new bag set conforms to a material and construction specification
- ◆ Primary focus on specifying and testing of fabric durability & mechanical performance
- ◆ Verification of filtration & pressure drop performance
- ◆ Prevent contamination of “clean side”



# QA/QC Program: Typical Components

- ◆ What should be done in a typical QA/QC program for BFPs?
  - Dimensional and construction inspection of prototype & production of bags to verify product specifications
  - Lab validation of mechanical & physical properties of fabric
  - Filtration performance testing



# Bag Quality Control Program

## ◆ Fabric

- Construction
- Tensile
- Permeability
- Mullen Burst
- MIT Flex Endurance
- Finish
- Filtration Performance
- Fabric Thermal Stability (% Shrinkage)
- Organic Matter (LOI)

## ◆ Thread

- Material
- Strength

## ◆ Hardware

- Caps
- Rings
- Bands

## ◆ Bags

- Inspect for general quality of workmanship
- Length as fabricated
- Length under tension
- Cuff to thimble & cap mate
- Cage Fit



# QA/QC Program: Initial Installation of Bags

- ◆ The bag set is the most important item in the baghouse
- ◆ The entire bag set and associated hardware must be properly installed and is key to successful operation
- ◆ Inspect all system components thoroughly before installation and again prior to initial start-up for compliance to specifications and for correct assembly
- ◆ Retensioning of RA bags very important



# Preventive Maintenance Programs

## Daily PM Checks

- ◆ Opacity
- ◆ Pressure Drop(s)
- ◆ Cleaning System (and Dampers)
- ◆ Temperatures In/Out
- ◆ Dust Removal System
- ◆ Fan Temperature/Vibration



# Preventive Maintenance Programs

## Weekly PM Checks

- ◆ Internal Walkthrough of Clean side
- ◆ Internal Inspection of Hopper(s)
- ◆ Cleaning System
- ◆ Dust Removal System
- ◆ Access Doors Leakage
- ◆ Instrumentation Sensors/Lines/Data
- ◆ Review Daily PM Checks



# Preventive Maintenance Programs

## Compartment Outage Checks

- ◆ Internal Inspection of Bags, et. al.
- ◆ Internal Inspection of Hopper(s)



# Preventive Maintenance Programs

## Annual or Extended Outage Checks

- ◆ Same checks as Prior Slide, Plus:
  - Internal Inspection of Ducting
  - Check Expansion Joints and Turning Vanes
  - Check Dampers



# Preventive Maintenance

◆ Key

“Keep the Clean Side Clean”




# Bag Monitoring Program: Purpose and Description

- ◆ To determine the retention of strength and flow characteristics of a bag set with on-stream time.
- ◆ Used as an aid in determining the useful life and scheduling the replacement of a bag set.
- ◆ Diagnostic tool in assisting the client or his agent in troubleshooting a baghouse.



# Bag Monitoring Program: Example

UNIT 1		
1-13		1-14
1-11		1-12
1-9		1-10
1-7		1-8
1-5		1-6
1-3		1-4
1-1		1-2

6 mo.	Initial Test	3 bags
1 yr.	2 <sup>nd</sup> Test	3 bags
18 mo.	3 <sup>rd</sup> Test	3 bags
2 yr.	4 <sup>th</sup> Test	3 bags
30 mo.	5 <sup>th</sup> Test	2 bags
33 mo.	**	4 bags
36 mo.	**	4 bags

\*\* When fabric deterioration accelerates increase testing frequency to every 3 months with four bags per pull/test

Test Bag location random – never same hole

Each program is custom designed



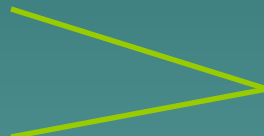
# Short Bag Life

**Physical Failure  
or  
Plugged Fabric**



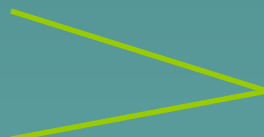
**Inspection  
and  
Maintenance**

**Site Specific  
or  
General Problem**



**Inspection  
and  
Failure Log**

**Mechanical Wear  
or  
Chemical Attack**



**Lab Tests**



# Means of Extending Bag Life

- ◆ Quality Evaluation of New Bags
- ◆ Good Installation
- ◆ Proper Operation (Data Monitoring and Process Control)
- ◆ Regular, Responsive Maintenance
- ◆ Strong Preventive Maintenance Program Implementation
- ◆ Always Remove All Dust From Clean Side As Soon As Obvious



# Review and Recommendations

- ◆ Maximize Bag Life & Minimize  $\Delta P$
- ◆ Proper Design & Detailed Specification (Rec. Low G/C)
- ◆ Sufficient QA/QC Program (Risk/Reward)
- ◆ Installation Inspection & Correction
- ◆ PM & Responsive Maintenance ASAP
- ◆ “Keep Clean Side Clean”
- ◆ Bag Set Monitoring Program and Key Data Collection & Review
- ◆ Operate Within Design Ranges (Especially Bag Cleaning Cycle)



# How Do I Achieve Maximum Bag Life?

- ◆ SELECTION - Select media for the inlet gas constituents & process operation.
- ◆ SPECIFICATION - Specify filter media, thread, bag and hardware.
- ◆ QUALITY ASSURANCE - QA/QC program to insure what is delivered meets the spec.
- ◆ INSTALLATION - Oversee the installation of the bags and perform leak tests.
- ◆ BAG MONITORING - Test periodically. Increase frequency if strength or permeability decline steeply.
- ◆ IDENTIFY & CORRECT - Immediately fix any leaks or high  $\Delta P$ .

Preventing the dust from entering the “clean side” of the baghouse and bags is a must.



# THANK YOU FOR LISTENING

## ◆ ETS CONTACTS

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# Premature Bag Failure: Case Study 1 – Pulse Jet Bag

## Case 1:

1 bag tested, CFB, Fiberglass w/ePTFE membrane

## Results:

Holes on horizontal ring spacers, abrasions on collection side, fill direction flexes low, “clean side” dust present

## Conclusions:

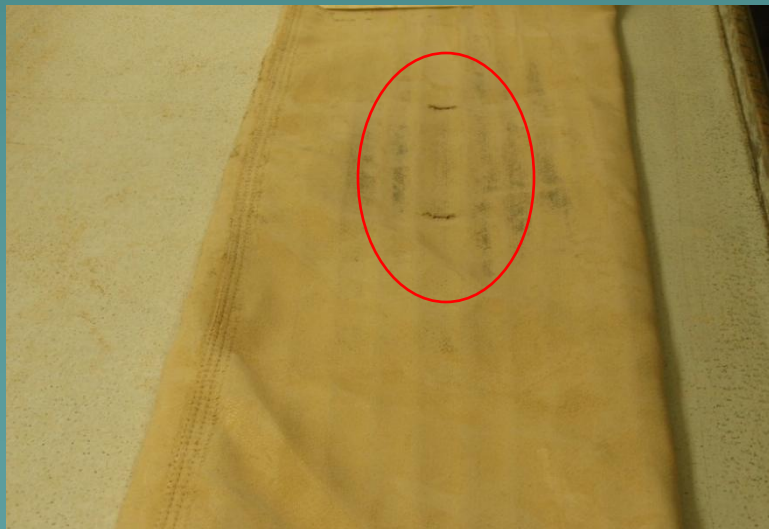
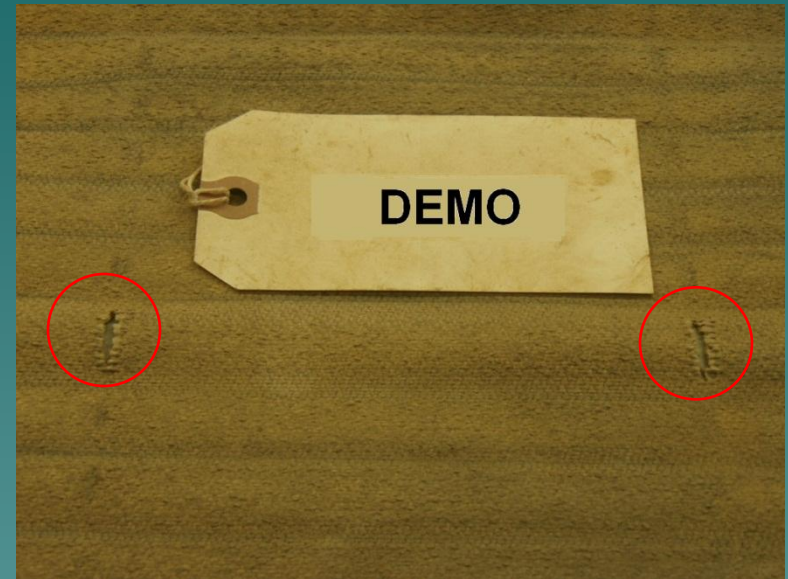
Physical damage consistent with bag-to-cage abrasion

Possible causes - excessive cleaning of bags, dust or rust on cage rings, improper bag-to-cage fit



# Premature Bag Failure: Case 1 Photos – Pulse Jet

Holes at horizontal  
ring spacers in  
middle of bag  
(non-collection side)



View of holes at  
horizontal ring  
spacers from  
collection side



# Premature Bag Failure: Case Study 2 – Pulse Jet Bag

## Case 2:

1 bag tested, CFB, Felt

## Results:

Low perms, pearling of dust, strong cage lines, moderate dust on clean side, holes along or in between vertical stringers

## Conclusions:

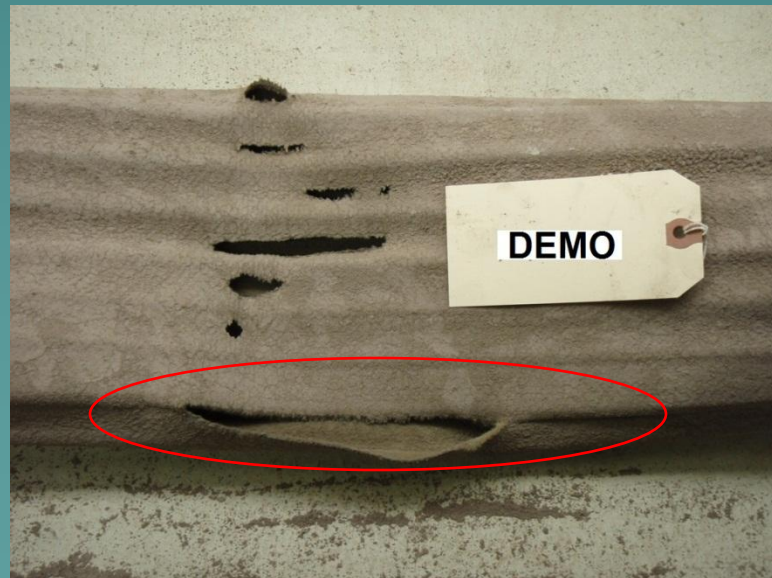
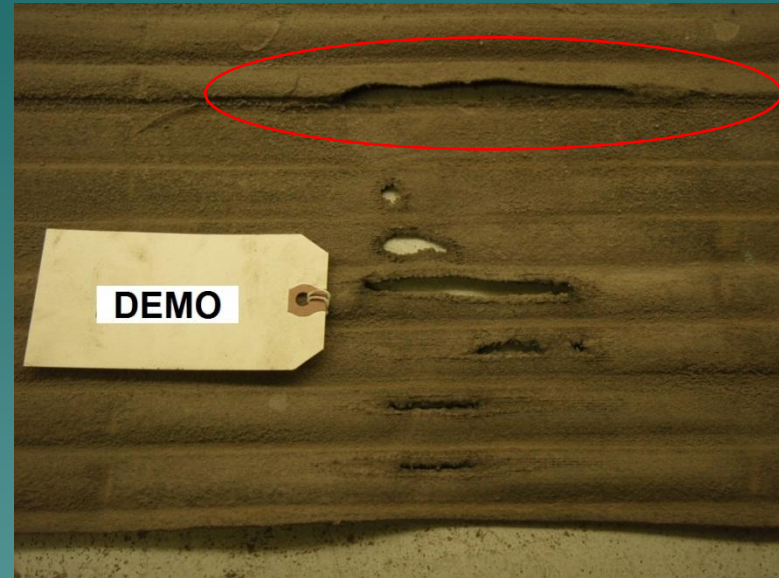
Good strength retention, low perms due to “clean side” contamination, larger hole on a cage line was first to form allowing dust to enter and “sandblast” other holes from inside out. Bag had excess fabric around circumference – bag-to-cage fit issues.



# Premature Bag Failure

## Case 2 Photos – Pulse Jet

Large hole along vertical wire cage line & seven resulting holes (non-collection side)



View of all holes along or in between cage lines from collection side



# Premature Bag Failure: Case Study 3 – Pulse Jet Bag

## Case 3:

1 bag tested, Fly Ash/Coal Dust, Fiberglass w/ePTFE membrane

## Results:

Clean side dust, low perm recovery, failure on vertical cage line, missing membrane in multiple areas

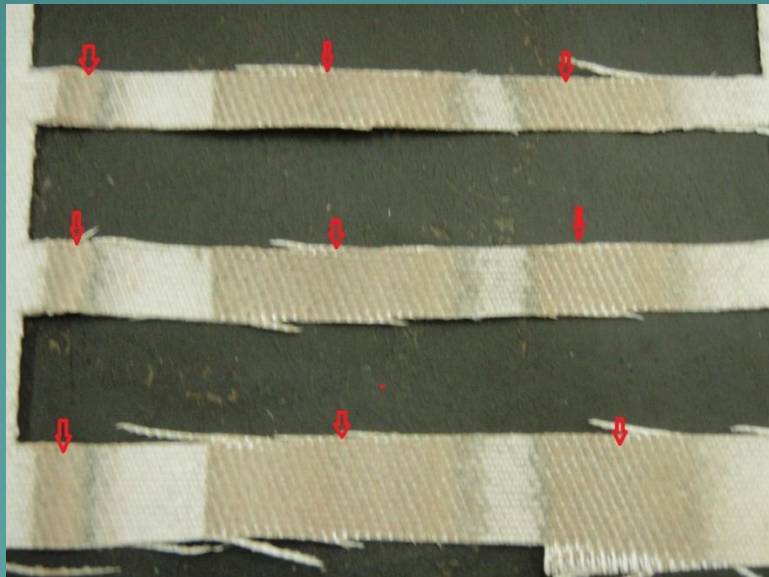
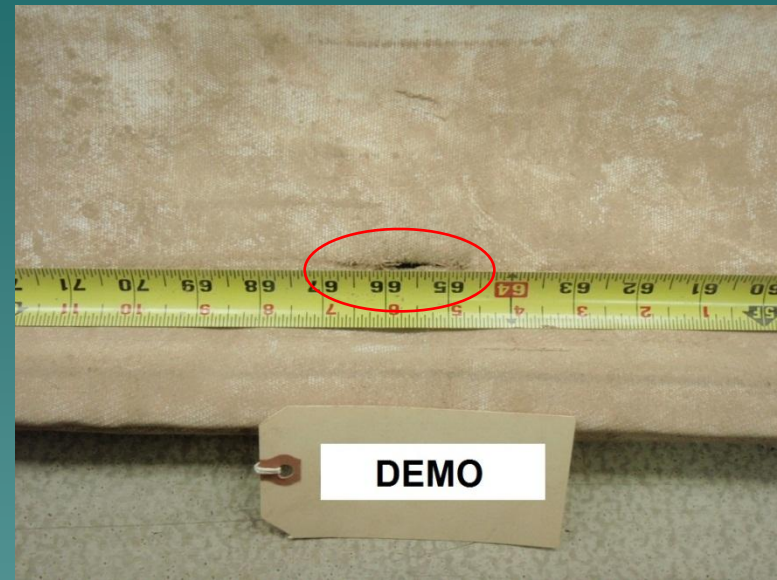
## Conclusions:

Missing membrane possibly due to manufacturing problem – allowed dust penetration and subsequent abrasion at cage line causing holes to form



# Premature Bag Failure Case 3 Photos – Pulse Jet

Bag failure along  
vertical cage line  
(collection side view)



Areas of missing  
membrane on the  
collection side



# Premature Bag Failure:

## Typical Causes of Reverse Air Bag Failures

- ◆ High velocity dust abrasion - Inside bottom of bag
- ◆ Chemical attack from flue gas contaminants coupled with acid dew point excursions
- ◆ Bag-to-bag abrasion - Low tension, too close, stretching, misaligned support racks
- ◆ Bag-to-metal abrasion - Interference with walls or support structure
- ◆ Improper bag to thimble attachment - Results in high velocity leakage path
- ◆ Process upset conditions - Fabric temperature capability is exceeded; particulate is introduced to blind or attack the fabric
- ◆ Accidents - Fires or explosions
- ◆ Improper bag fabrication or incorrect design



# Premature Bag Failure

## Case Study – Reverse Air Bags

### Case 1:

7 bags tested, CFB, Fiberglass w/ePTFE membrane

### Results:

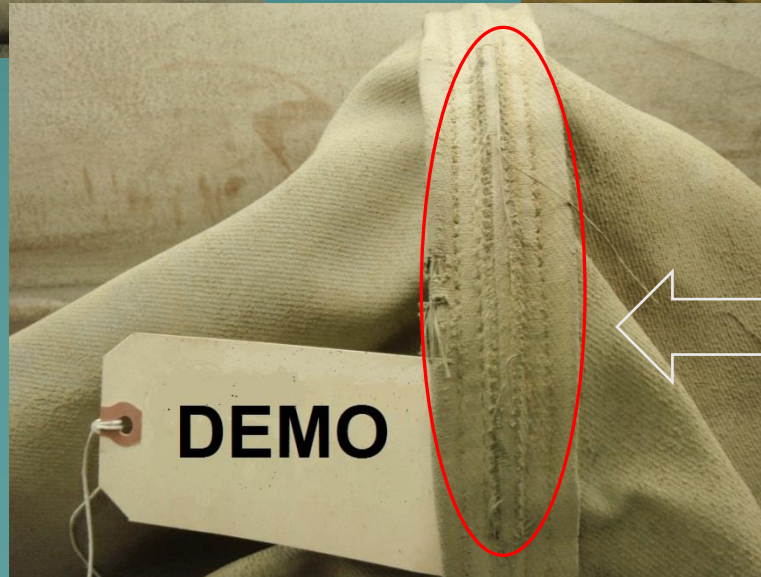
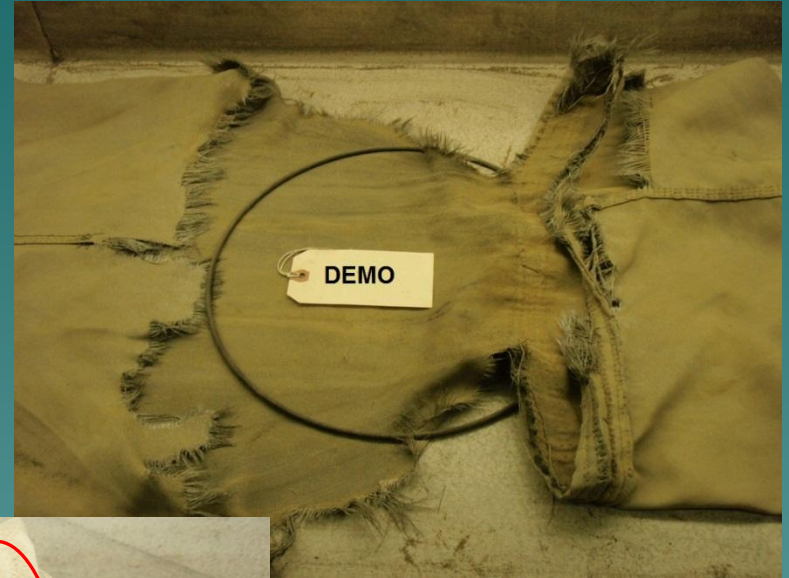
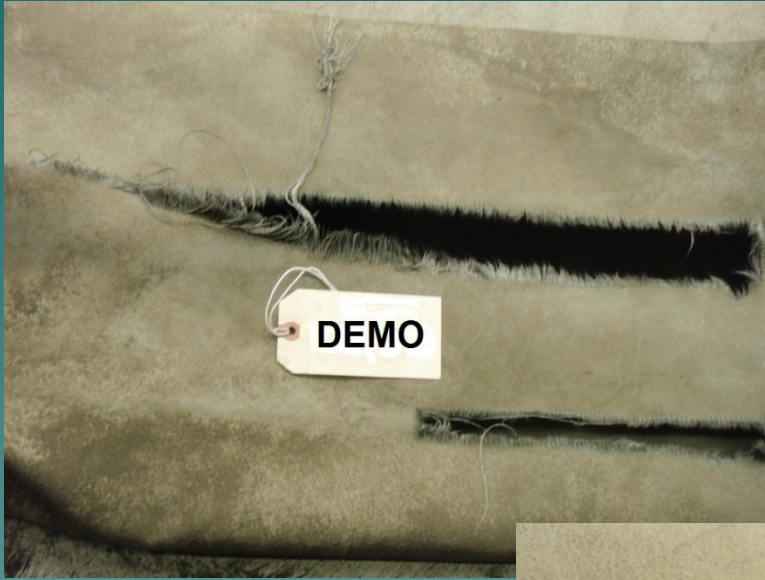
Severe abrasion, holes, perm loss, strength loss, low fill flex (leading indicator of fabric degradation)

### Conclusions:

- ◆ Dust entered clean side via holes – low perms
- ◆ Under tensioning of bags – bag to bag abrasion



# Premature Bag Failure: Case Study - RA Bag Photos



Ring cover  
fabric  
abrasion



# BFP Performance Test

- ◆ Each verification test consists of three test runs.
- ◆ Each test run consists of:
  - 10,000 rapid pulse cycles
  - 30 normal cycles
  - 6-hour performance test



# BFP Test Conditions

<b>Raw gas volumetric flow rate</b>	<b>5.8 m<sup>3</sup>/hr (3.4 cfm)</b>
<b>Filtration velocity</b>	<b>120 m/hr (6.6 fpm)</b>
<b>Test dust</b>	<b>aluminum oxide - Pural NF</b>
<b>Dust feed rate</b>	<b>100 g/hr</b>
<b>Gas temperature</b>	<b>25 °C (77 °F)</b>
<b>Pressure drop trigger for cleaning</b>	<b>1000 Pa (4 in wg)</b>
<b>Pulse cleaning pressure</b>	<b>0.5 MPa (75 psi)</b>
<b>Rapid pulse frequency</b>	<b>3 s</b>



# Test Procedure

- ◆ Performance testing occurs for a 6-hour period immediately following the recovery period (a cumulative total of 10,030 filtration cycles).
- ◆ During the performance test period, normal filtration cycles are maintained and subjected to continuous dust loading.
- ◆ Outlet mass and PM<sub>2.5</sub> dust concentrations are measured using an inertial impactor.



# BFP Verification Outputs

- ◆ Outlet fine particle concentration, PM 2.5
- ◆ Outlet total particle concentration, total mass
- ◆ Residual pressure drop increase
- ◆ Average residual pressure drop
- ◆ Average filtration cycle time
- ◆ Mass weight gain of sample

