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Moving Bed, Granular Bed Filter Development Program
Option 1: Component Test Facility
Task 3: Test Plan

Topical Report

J. C. Haas
J. W. Purdhomme
K. B. Wilson

April 1994

Work Performed Under Contract No.: DE-AC21-90MC27423

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Combustion Power Company
Menlo Park
Oakland, California

DISCLAIMER

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1.0 INTRODUCTION

In the base contract, Combustion Power Co. developed commercial designs for a moving granular-bed filter (GBF). The proposed filter is similar to previous designs in terms of its shape and method of filtration. The commercial designs have scaled the filter from a 5 ft diameter to as large as a 20 ft diameter filter. In Task 2 of the Moving Bed-Granular Filter Development Program, all technical concerns related to the further development of the filter are identified. These issues are discussed in a Topical Report which has been issued as part of Task 2. Nineteen issues are identified in this report. Along with a discussion of these issues are the planned approaches for resolving each of these issues. These issues will be resolved in either a cold flow component test facility or in pilot scale testing at DOE's Power System Development Facility (PSDF) located at Southern Company Services' Wilsonville facility. Task 3 presents a test plan for resolving those issues which can be addressed in component test facilities.

The issues identified in Task 2 which will be addressed in the component test facilities are:

- GBF scale-up
- Effect of filter cone angle and sidewall materials on medium flow and ash segregation
- Maximum gas filtration rate
- Lift pipe wear
- GBF media issues
- Mechanical design of the gas inlet duct
- Filter pressure drop

This document describes a test program to address these issues, with testing to be performed at Combustion Power Company's facility in Belmont, California.

2.0 PROGRAM OBJECTIVES

The objective is to resolve GBF technical issues which can be addressed in a component test facility. In the process, the testing will validate, as much as possible, the design of the GBF proposed commercially. Specific objectives are:

- Determine the filter cone and inlet pipe geometry required to allow plug flow conditions with 6 mm alumina silicate media with the intention of reducing the overall filter height.
- Determine the filter pressure drop and minimum filter spouting velocity as a function of bed height, media rate and ash rate and filter geometry. Extrapolate this data to high temperature and high pressure operation.
- Determine the gas distribution pattern at the top surface of the filter bed as a function of bed depth and gas flow.
- Determine the minimum fluidization velocity of 6 mm media under ideal conditions compared to minimum filter spouting velocity.
- Evaluate the effect of filter vessel surface roughness on the flow characteristics of 6 mm media.
- Determine if scale up of selected filter geometry produces similar media and air flow characteristics.
- Evaluate attrition resistance of candidate materials to be used as liner for the lift pipe and seal legs.
- Determine the stress and deflection of the cantilevered filter gas inlet pipe due to uneven gas and media forces.
- Measure and compare the attrition characteristics of the 6 mm media and that of the 3 mm used in previous testing.

3.0 COLD FLOW TEST EQUIPMENT

3.1 Split Filter - 3.5 Ft Diameter with Transparent Cross Section

Initial tests are planned with a 3.5 ft diameter, 180 degree split filter, having a transparent cover to allow visual examination of media flow characteristics at the filter cross section. This examination will lead to confirmation of filter cone and inlet pipe geometry for desired media plug flow in the filtration area. Testing will include the effects of filter air flow and fly ash concentration on media flow. Refer to Figure 1 for equipment arrangement. Media will be loaded at the top of the filter with a fork lift and drained into 55 gallon barrels below. The ash collected in the filter will drain out of the filter with the media into a closed barrel having a filter breather to keep fugitive dust contained.

Four filter cone arrangements are considered for testing: 70 degree angle from horizontal(similar to arrangement tested at New York University), 60 degree angle(shallowest angle allowable), a compound cone with a 60 degree cone at the top followed by a 70 degree cone below with an enlarged cylindrical discharge, and lastly, if necessary, a 70 degree cone with an enlarged cylindrical discharge. Refer to Figure 2. The cones will be coated with either sandpaper or glued sand particles to simulate conditions with a refractory lined surface. From the test results, an arrangement will be selected for the remaining test program.

Two inlet pipe configurations are planned as shown in Figure 3. The first inlet pipe design has the same geometry as with the filter tested at New York University except the size is reduced proportionally to the filter diameter reduction. The second design is derived from computational fluid dynamic modeling using a lower exit velocity in order to reduce overall filter pressure drop.

To more clearly observe the media flow profile, layers of colored media may be added along the cross section which will flow with the media through the filter showing changes in relative velocity.

3.2 Full Circumference Filter - 3.5 Ft Diameter

After the basic GBF geometry is established, additional cold flow testing will be performed using a full circumference, 3.5 ft diameter filter with refractory brick lining to more closely simulate the commercial arrangement. The GBF cold flow filter equipment will include, filter assembly, media circulation system, air supply blowers, dust collection baghouse, piping and instrumentation. Refer to Figures 4, 5, and 6 for an approximation of the equipment general arrangement and piping and instrument diagram.

The equipment operates by passing air from the blowers through the filter media to ambient. The filter media is continuously drained from the filter and pneumatically transported to above the filter where, if present, fines separate from the media and the

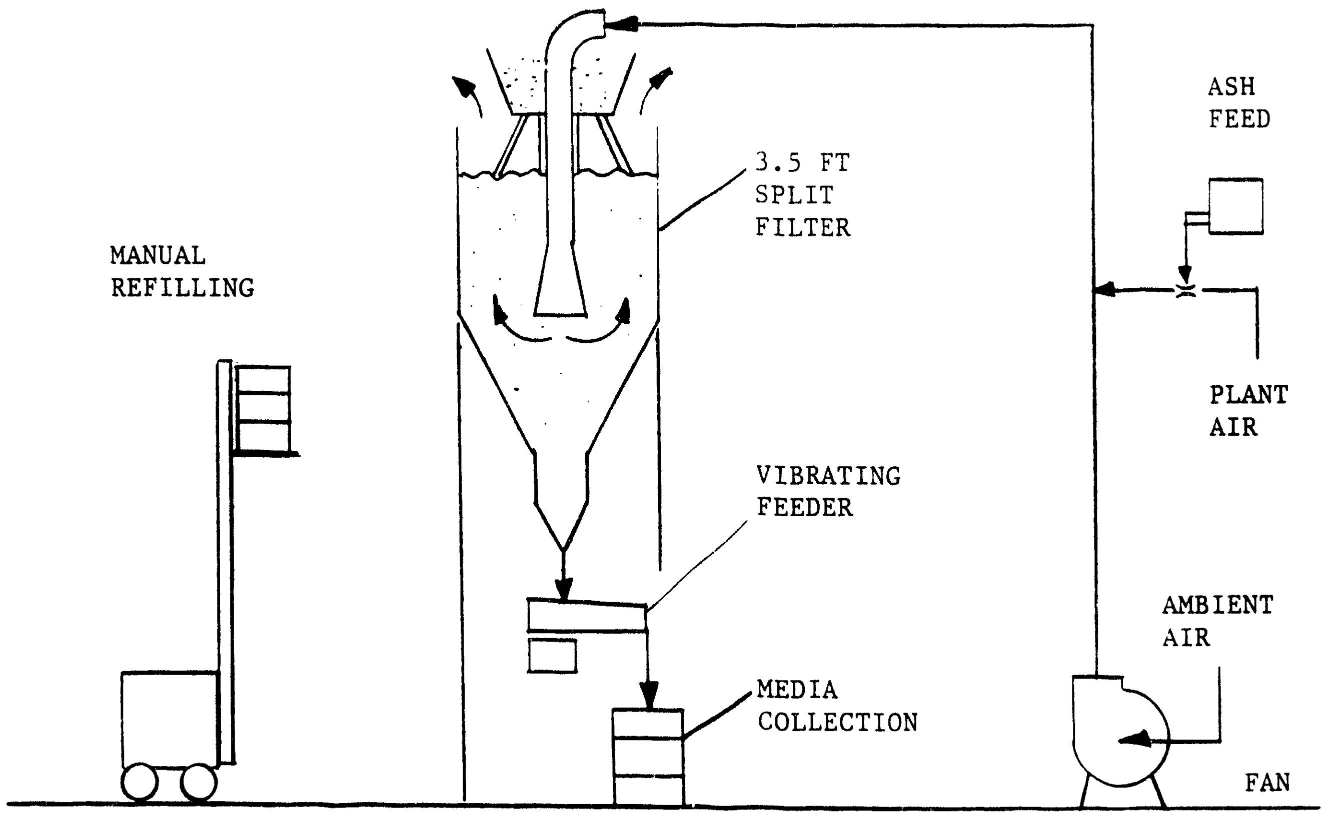

Figure 1 Split Filter - 3.5 Ft. Diameter

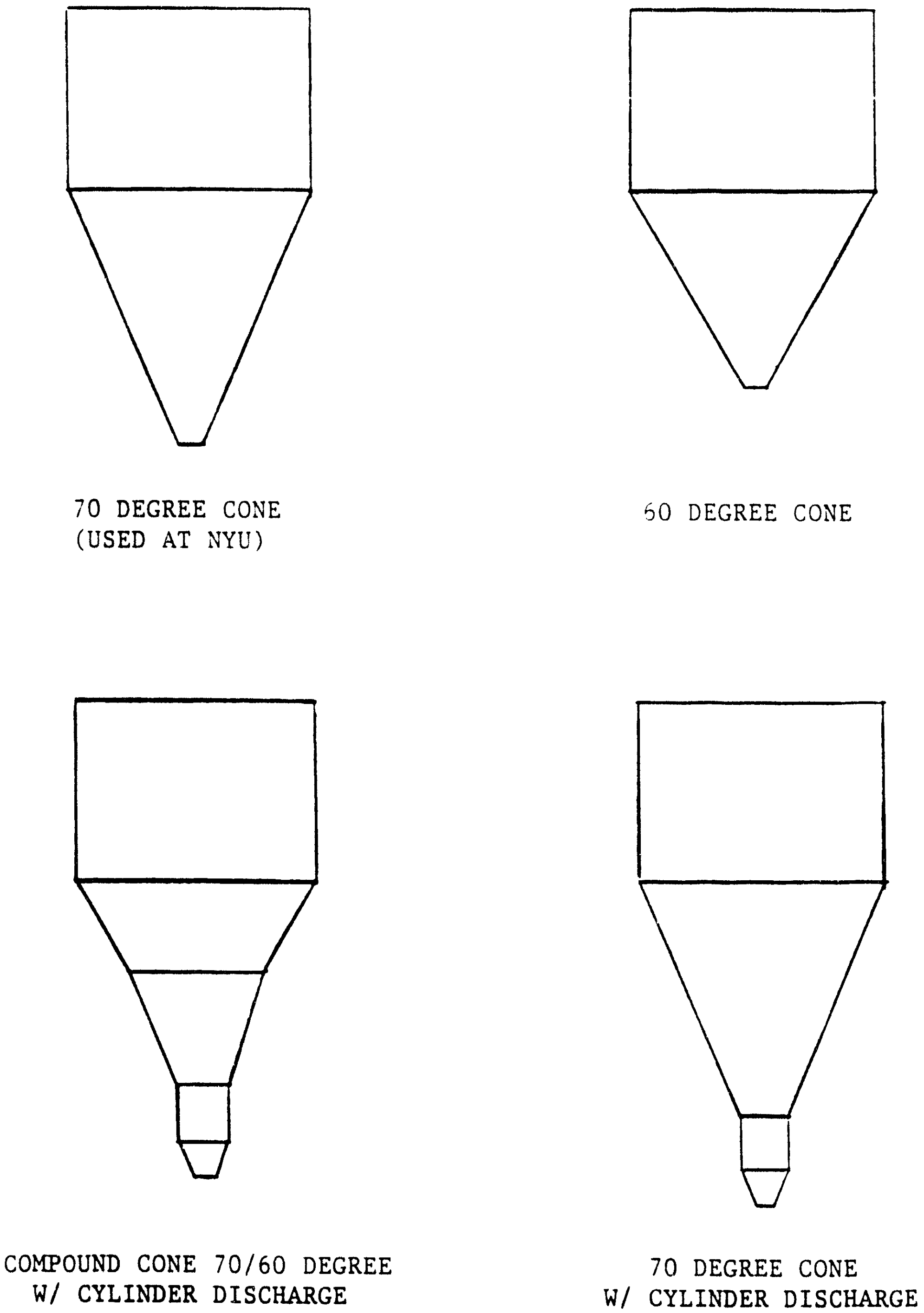

Figure 2 3.5 Ft. Diameter Split Filter Cone Arrangement

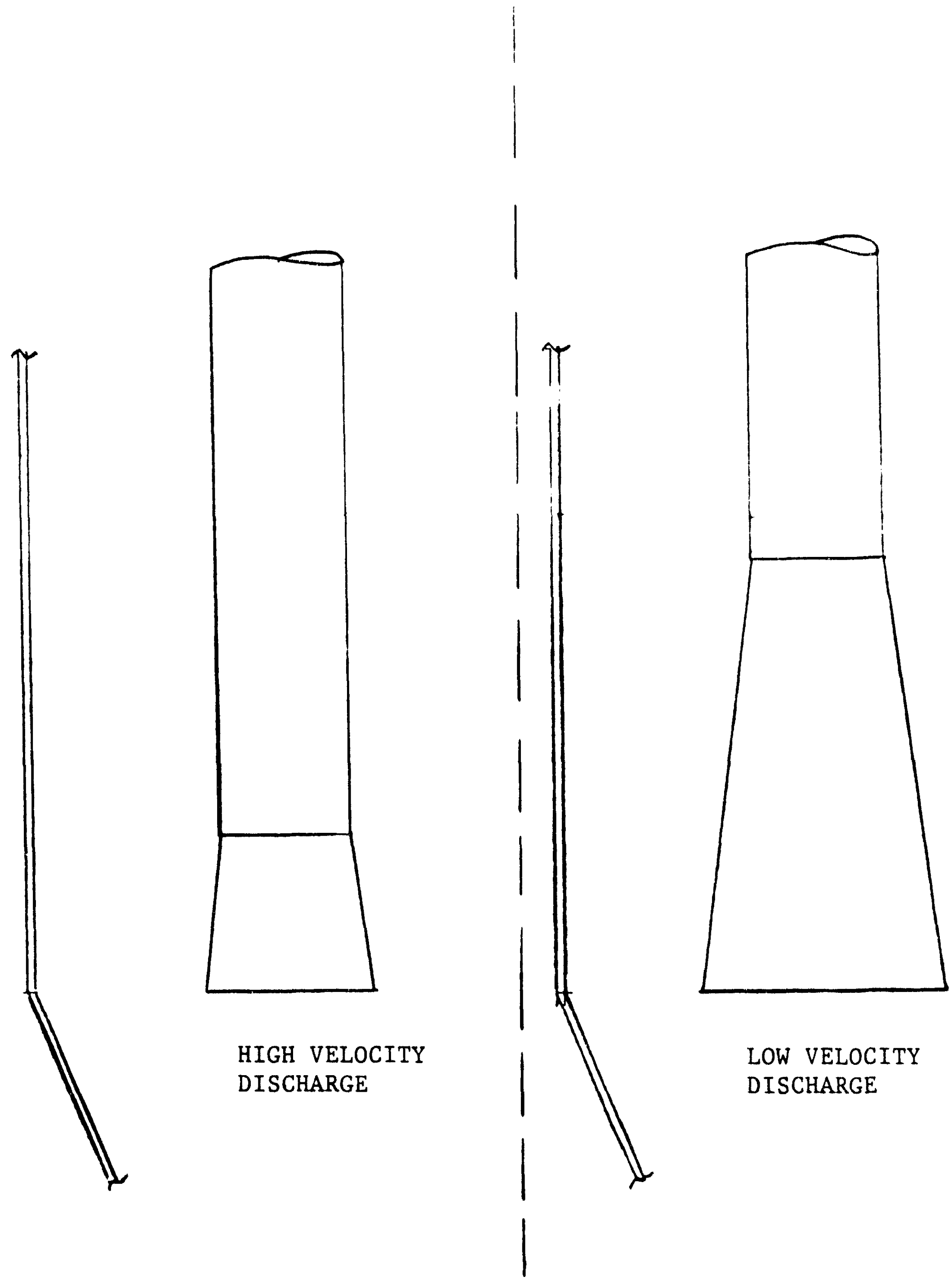

Figure 3 3.5 Ft. Diameter Split Filter Inlet Pipe Configuration

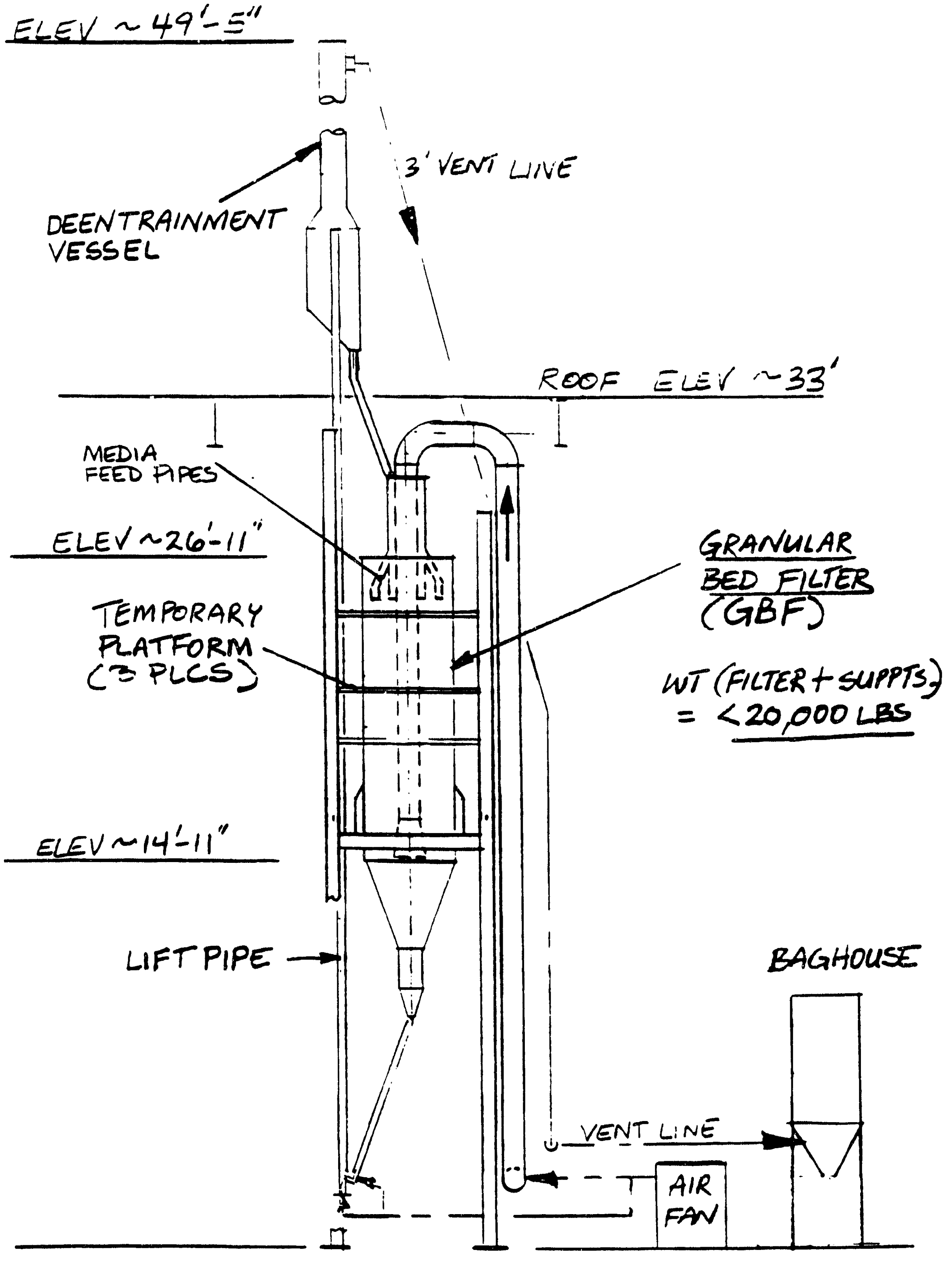

Figure 4 Full Circumference Filter Test Unit

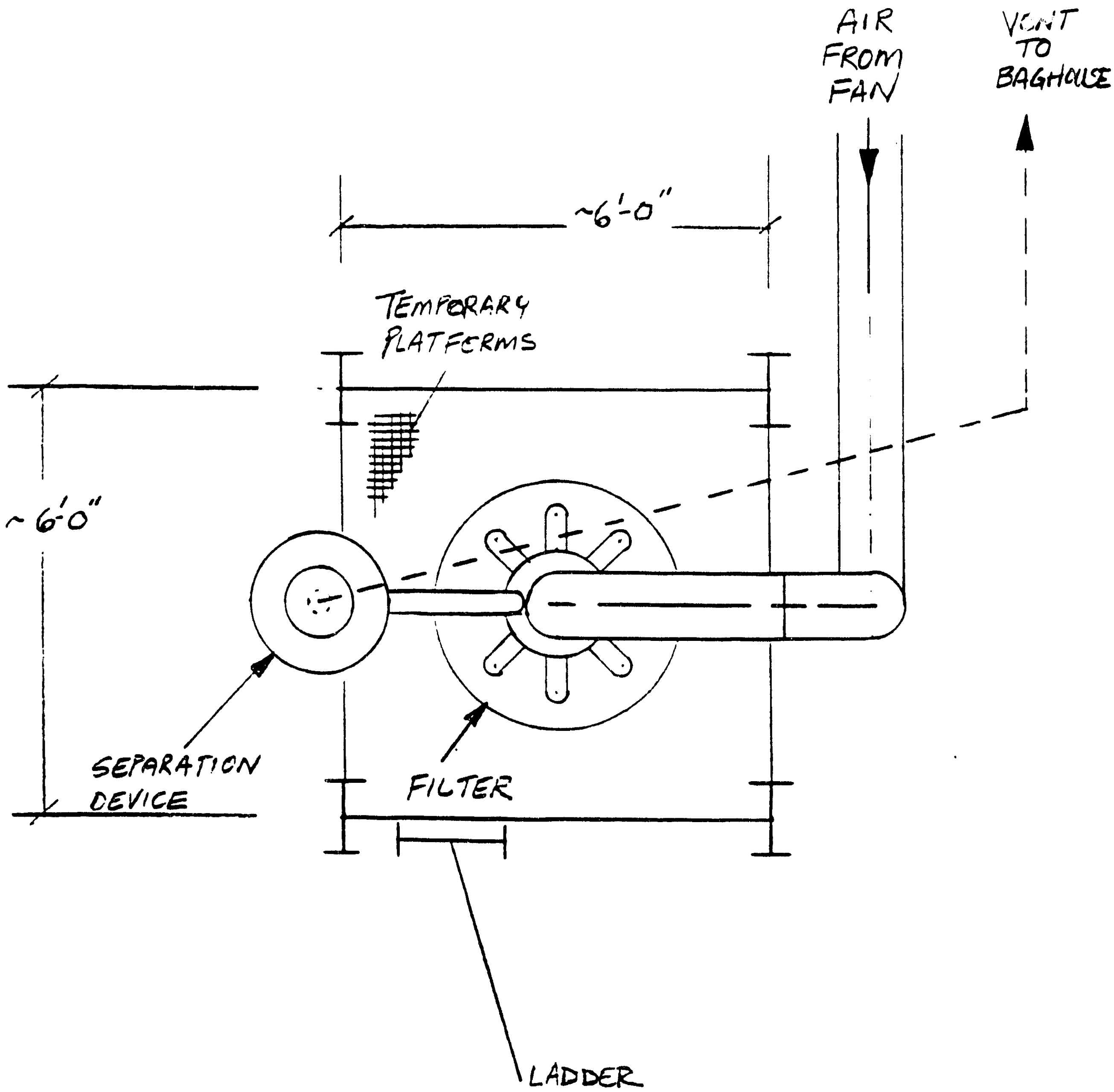

Figure 5 Full Circumference Filter Plan View

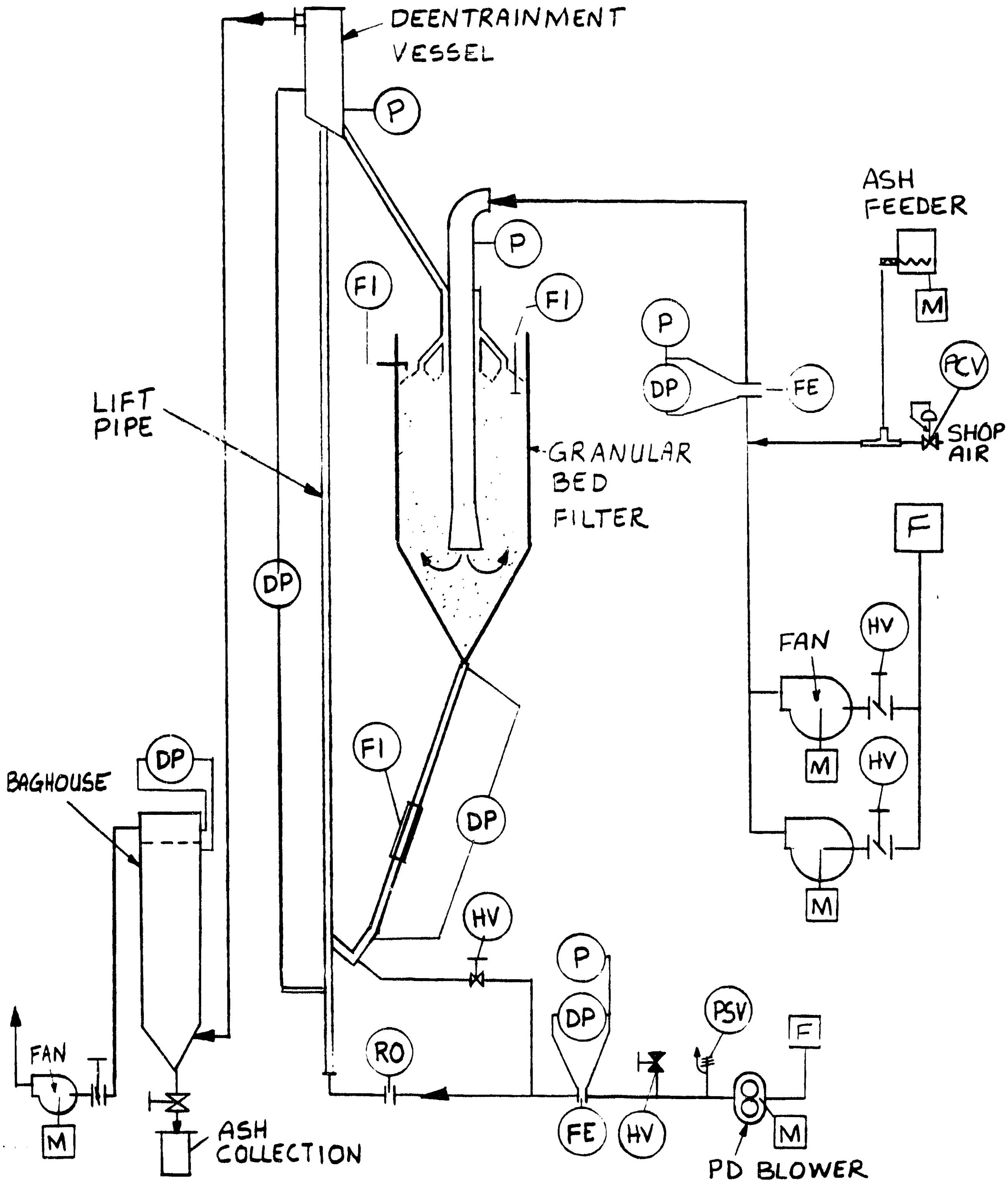

Figure 6 Full Circumference Filter Piping and Instrumentation Diagram

3.6 Pipe Liner Abrasion Test Equipment

Abrasion tests will be conducted on potential lift pipe liner materials proposed commercially and proposed for PSDF components. An abrasion test unit will be designed to allow 6 mm media to free fall onto liner test samples. Tests will be conducted in a 3 ft diameter drum which allows a small mass of media to fall ~3 ft every revolution, onto a contained sample that will be weighed before and after testing for material loss. Refer to Figure 7. The 3 ft free fall will achieve an impact velocity near 14 ft/sec, similar to the media velocity in the lift pipe. Samples of different liner materials will be mounted in separate sections of the drum so that several liner materials can be tested at once. With this configuration, tests can conveniently run for long periods(1000 hour).

3.7 Fluidization Test Equipment

A single test will be performed using an existing 238 sq. inch vessel with uniform air distribution to determine minimum fluidization for 6 mm media. Refer to Figure 8 for equipment arrangement. The results will be compared to measured spouting velocity from the filter tests where the air distribution is a function of the filter geometry.

3.8 Equipment and Instrumentation List

The following equipment will be required for completing the cold flow testing. Equipment labeled as "Existing" are currently available for use in CPC's test facility. Equipment labeled as "New" will require either purchase or rental. Equipment labeled as "Shared" will be shared between different test facilities.

A. <u>3.5 Ft Diameter Split Filter Test Equipment</u>

3.5 Ft Diameter Split Filter Test Equipment	Condition
Split Filter Assembly	New
Support Structure/Platforms	New
Drain Barrels w/ filter	New
Vibrating Feeder	Existing
6 mm Media	New/Shared
Hoffman Air Supply Blower	Exist/Shared
Temporary Noise Enclosure	New/Shared
Air Supply Piping	New/Shared
Ash Feeder	Exist/Shared
Ash Eductor	New/Shared

media returns by gravity to the top surface of the filter. The separated fines are conveyed with the transport air to a baghouse before exhausting to ambient.

Tests are planned with fly ash injection into the filter inlet air as with the split filter tests. This will determine if ash effects the media flow characteristics during cold filter operation.

The 3.5 ft diameter filter vessel will be fabricated with 3/16" thick carbon steel and refractory lined with "Super Duty" type fire brick. The refractory lining will allow evaluation of surface roughness effects on media flow. It is important to determine that the 6 mm media does not become trapped in the brick joints and subsequently hold up media above it.

3.3 Scale Up Filter - 6 Ft Diameter

Having completed testing with the 3.5 ft diameter filters, a 6 ft diameter filter will be constructed using the chosen cone and inlet pipe configuration to evaluate scale up relationships. Computational fluid dynamic modeling will be used to establish the size of the enlarged the inlet pipe for the increased flow capacity. The type of tests performed will be largely based upon the results of the previous tests indicating what parameters effect the flow characteristics of media and air. Due to limitations in blower capacity the filter air flow will be the same as in the previous tests, resulting in a maximum flow of approximately 25% of estimated minimum fluidization flow. Ash will be available for injection in the filter air inlet if ash tests are necessary. Media will be circulated pneumatically with the same equipment as with the 3.5 ft diameter filter set up.

3.4 Air Velocity Profile Measurement

A hand held thermoanemometer(ALNOR Instruments or equal) will be used to measure the low air velocity at the top of the filter. The filter will be traversed at two locations, 90 degrees apart for each test condition. The flow measurement device will be inserted through a port mounted on the filter side wall. Access ports will be positioned at each of the test bed heights.

3.5 Media Velocity Profile Measurement

Media velocity will be measured by positioning a vertical rod having a small base plate, or using a nut attached to a string, onto the top surface of the filter bed and measuring the depth of penetration with time. The filter top will be traversed at two locations, 90 degrees apart.

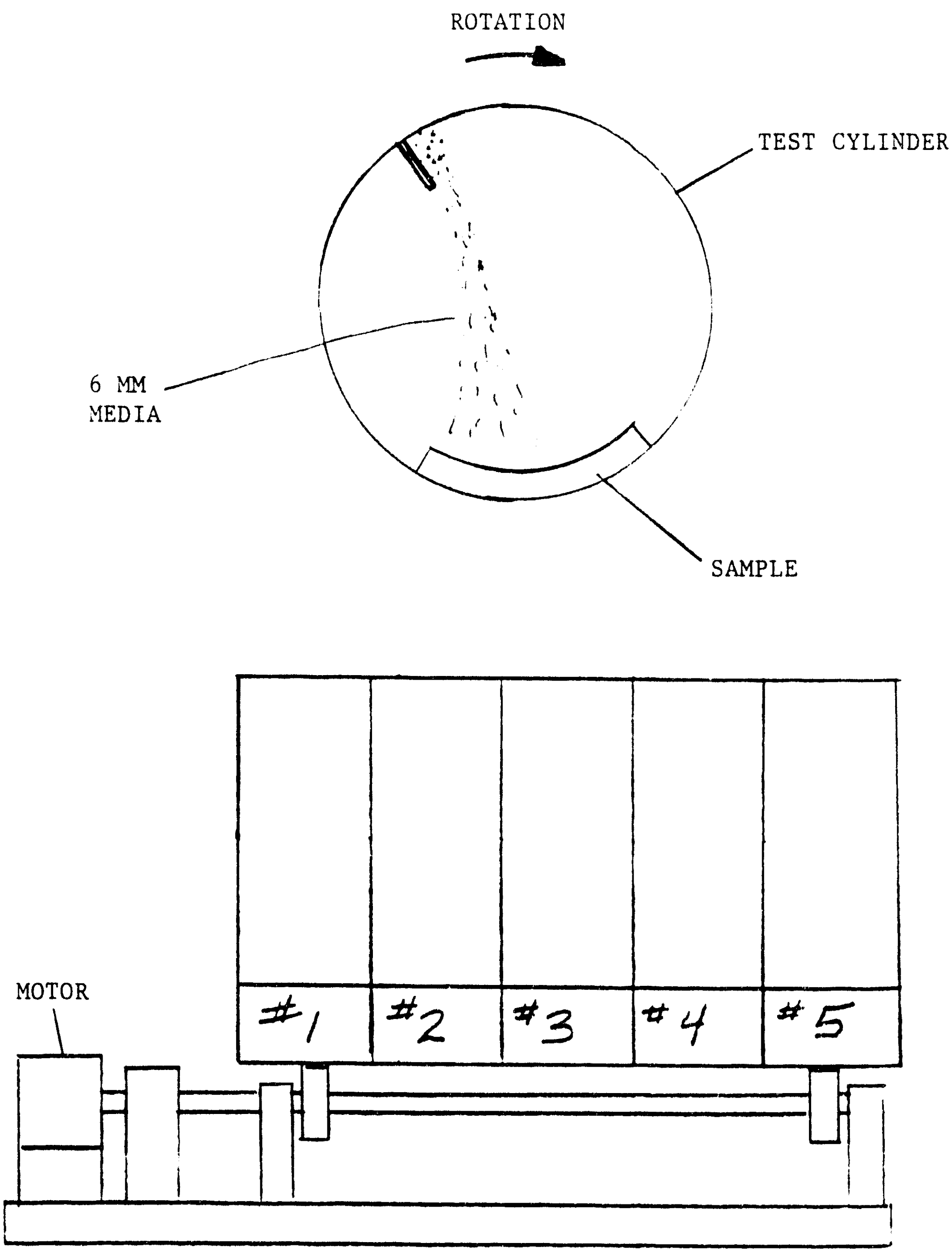

Figure 7 Lift Pipe Liner Abrasion Test Unit

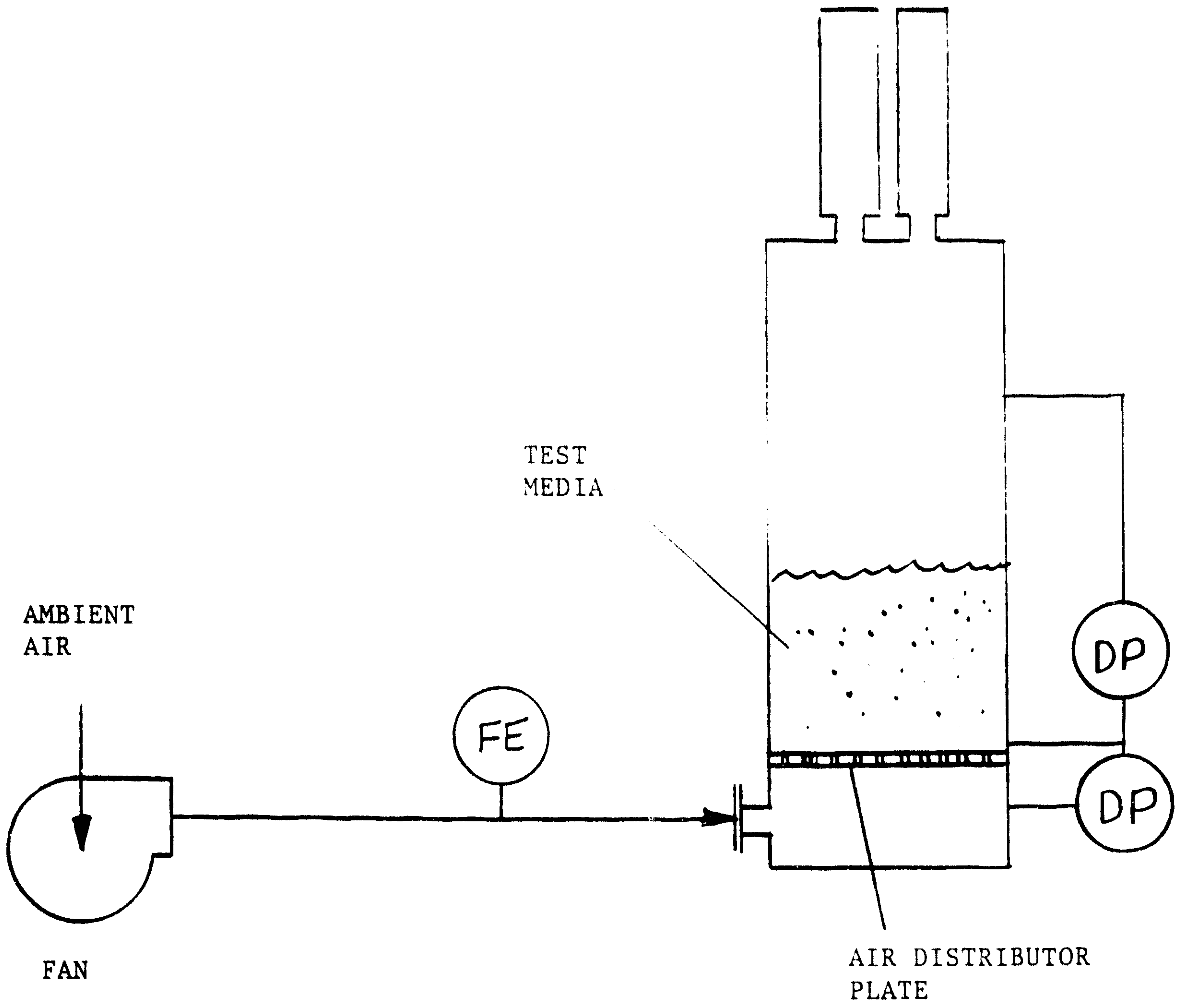

Figure 8 Fluidization Test Unit

B.	<u>3.5 Ft Diameter Full Size Filter and Media Circulation System</u>	<u>Condition</u>
	Filter Assembly	New
	Media Circulation System	New/Shared
	Support Structure/Platforms	New/Shared
	6 mm Media	New/Shared
	Hoffman Air Supply Blower	Exist/Shared
	Supplement Blower	New/Rental
	Temporary Noise Enclosure	New/Shared
	Ash Feeder	Exist/Shared
	Ash Eductor	New/Shared
	Baghouse	Exist/Shared
	Air Supply Piping	New/Shared
	Pneumatic Return Line to Baghouse	New/Shared
	I.D. Fan at Baghouse Outlet	Exist/Shared

C.	<u>6 Ft Diameter Filter Test Equipment</u>	
	Filter Assembly	New
	Media Circulation System	New/Shared
	Support Structure/Platforms	New/Shared
	6 mm Media	New/Shared
	Hoffman Air Supply Blower	Exist/Shared
	Supplement Blower	New/Shared
	Ash Feeder	Exist/Shared
	Ash Eductor	New/Shared
	Baghouse	Exist/Shared
	Air Supply Piping	New/Shared
	Pneumatic Return Line to Baghouse	New/Shared
	I.D. Fan at Baghouse Outlet	Exist/Shared

D.	Filter System Instruments	Condition
	Supp. Blwr Inlet Valve	New
	Air Flow DP	Existing
	Air Supply Press	Existing
	Air Supply Temp	Existing
	Pneum. Air Restrict. Orifice	New
	Pneum. Air Gate Valve	New
	Pneum. Inj. Air Gate Valve	New
	Filter Press. Drop	New
	Deentrainment Vessel Press.	New
	Thermoanemometer	New
	Media Flow Device	New
	Strain Gauge Test Kit	New
E.	Pipe Liner Abrasion Test Equipment	
	Abrasion Test Drums	New
	Abrasion Test Candidate Materials	
	Thermal Ceramics - Kaocrete HS	New
	Thermal Ceramics - Kaotuff C	New
	Thermal Ceramics - Kaotuff CV	New
	Thermal Ceramics - 80 D Fire Brick	New
	Norton - Crystolon CN 163, Sil. Carb.	New
	AP Green - Lo Abrade	New
	Corguard	New
	Drum Rotator - Advanced Handling Equip	New
	Triple Beam Balance Scale	Existing
F.	Fluidization Test Equipment	
	Fluid Bed Unit-238 sq. inch.	Existing
	Air Supply Blower and Piping	Existing
	Air Distributor Plate	New

G. Fluidization Instruments

Fluidization Instruments	Condition
Air Isolation Valve	Existing
Air Supply Press	Existing
3" Air Line Flow Orifice	Existing
Air Flow DP	Existing
Air Supply Temp	Existing
Air Distributor Plate DP	Existing
Media Bed DP	Existing

4.0 SPLIT FILTER TESTING - 3.5 FT DIAMETER

4.1 Objectives

The primary objective of using the 3.5 ft diameter Split Filter Model is to confirm the proper geometry of the filter cone and gas inlet pipe. The goal of this testing is to determine if the cone angle may be reduced to lower the overall filter height, and still maintain proper plug flow through the filter area.

The testing will address specific areas as follows:

- Effect of surface roughness on media flow characteristics.
- Effect of the inlet pipe geometry and position on media flow characteristics using both the NYU tested geometry and new geometry derived from computational fluid dynamic modeling. The CFD design is intended to reduce overall filter pressure drop by lowering the inlet pipe exit velocity.
- Determine relative spouting velocities for the different tested geometries.
- Determine if the media flow characteristics are effected by the introduction of ash with the air flow.
- Determine if an enlarged cylindrical discharge below the cone improves the media flow characteristics.

4.2 Reference Testing - Scaled NYU Filter Geometry Test, with Smooth Metal Surface

Configuration:
- Figure 2
- 3.5 ft diameter filter
- 70 degree cone angle
- No discharge cylinder
- Smooth metal surfaces
- NYU tested inlet pipe configuration

A. Test No. 1: Media Flow Only With Continuous Refilling

Media drain rate - 60 lb/min, Repeat at 240 lb/min
Air flow - none
Bed height - 5 ft
Observe media flow profile

Measure the media velocity at the filter top along the annular centerline at 45, 90 and 135 degrees. Also, measure the media velocity at radial positions of 45 and 135 degree positions with 4 measurements at equally space intervals along each radial.

B. Test No. 2: Media Flow Only With No Refilling

Media drain rate - 60 lb/min, Repeat at 240 lb/min
Air flow - none
Bed height - 5 ft at start
Observe media flow profile

Measure the media profile height from the top of the filter every ~ 500 lbs drained. Measure the profile at 3 locations(every 45 degrees) along the filter annular centerline. Measure the profile cross section at 4 equally spaced traverse points at the 45 degree and 135 degree positions. Stop collecting measurements when the media level drops below the inlet pipe discharge.

C. Test No 3: Air flow With No Media Flow

Media Rate - 0 lb/min
Air Flow - Increase air flow gradually until spouting velocity is reached.
Bed height - 5 ft
Measurements - Collect the following measurements at each step increase in air flow:

Filter DP
Air Flow Orifice DP
Air Pressure
Air Temperature
Air Flow Traverse - at top of filter bed from two ports, one at 45 degrees and one at 135 degrees.

D. Test No. 4: Air flow With Media Flow

Media Rate - 60 lb/min, Repeat at 240 lb/min
Air Flow - Increase air flow gradually until spouting velocity is reached.
Bed height - 5 ft
Measurements - Repeat the same measurements as is in Test No. 3. Additionally, observe the media flow movement for plug flow and measure the media velocity along the

filter annular cross section. Measure the media velocity at radial positions of 45 and 135 degree positions with 4 measurements at equally space intervals along each radial.

E. Test No. 5 Air Flow With Media Flow and Ash Flow

Media Rate -	60 lb/min
Air Flow -	75 % of Spouting Velocity
Bed height -	5 ft
Ash Rate -	6 lb/min (fed with air flow)
Measurements -	Repeat the same measurements as in Test No. 4 at the one air flow.

4.3 Reference Testing - Scaled NYU Filter Geometry, w/ Rough Metal Surface

Configuration:
- Figure 2
- 3.5 ft diameter filter
- 70 degree cone angle
- No discharge cylinder
- Rough metal surface using glued sand paper or sand particles
- NYU tested inlet pipe configuration

Repeat Tests No. 1 through 5 of Section 4.2

4.4 Testing With 60 Degree Cone

Configuration:
- Figure 2
- 3.5 ft diameter filter
- 60 degree cone angle
- 12" dia x 18" discharge cylinder
- Rough metal surface using glued sand paper or sand particles
- CFD model inlet pipe configuration

Repeat Tests No. 1 through 5 of Section 4.2

4.5 Testing With Compound Cone Angle - 60 Deg Followed By 70 Deg

Configuration:
- Figure 2
- 3.5 ft diameter filter
- Top cone at 70 degree angle
- Bottom cone at 60 degree angle

- 12" dia x 18" discharge cylinder
- Rough metal surface using glued sand paper or sand particles
- CFD model inlet pipe configuration

. Repeat Tests No. 1 through 5 of Section 4.2

4.6 Optional Test - 70 Deg Cone Angle With Discharge Cylinder

Configuration:
- Figure 2
- 3.5 ft diameter filter
- 70 degree cone
- 12" dia x 18" discharge cylinder
- Rough metal surface using glued sand paper or sand particles
- CFD model inlet pipe configuration

. Repeat Test No.1 through 5 of Section 4.2

5.0 FULL CIRCUMFERENCE FILTER TESTING - 3.5 FT DIAMETER

5.1 Objectives

Cold flow test with a full circumference 3.5 ft diameter will verify the results on the filter cone and inlet pipe geometry derived from the split filter tests. The full size filter as opposed to the split filter is not limited by wall effects due to the split geometry and consequently will give more accurate measurements of air flow profile and media flow characteristics. The test program will address the following specific areas:

- Filter spouting velocity as a function of bed height and media rate
- Confirmation of media flow characteristics as observed in the split filter testing
- Air flow profile as measure from the top of the filter bed as a function of air flow and bed height
- The effect of ash on media flow characteristics
- The effect of refractory lining on media flow characteristics
- Determine the filter gas inlet pipe maximum stress, deflection and forces

5.2 General Testing Sequence

Testing will begin with deep bed heights and reduce to minimum bed heights in order to allow visual observation of the filter top. The bed heights will be tested in sequence at 10, 5 and 3 feet. After measurements are completed at a particular level, the filter sidewall will be cut lower for lower bed level measurements. By lowering the side wall visual observations are easier especially when viewing spouting conditions and measuring the media velocity.

5.3 Baseline Testing - No Ash Flow

Repeat the following tests at 10, 5 and 3 foot bed heights with the media circulation rate at 60 and 240 lb/hr (visual method from the seal leg sight glass).

A. Increase filter air flow gradually until spouting velocity is reached. At each step record the following data:

    Air Flow DP
    Air Supply Pressure

Air Supply Temperature
Filter Pressure Drop
Deentrainment Vessel Pressure
Inlet Pipe Strain Gauges
Record Observations During Flow Increase and at Spouting Conditions

B. Repeat the following measurements at ~25%, 50%, 75% and 90% of spouting velocity.

Air Flow DP
Air Supply Pressure
Air Supply Temperature
Filter Pressure Drop
Deentrainment Vessel Pressure
Inlet Pipe Strain Gauges

Air velocity profile at top of filter at two, 90 degree apart locations, with a six point traverse at each location.

Measure the media velocity in the filter in inches/min at two, 90 degree apart locations. Perform a 4 point traverse at each location. Also, measure the media velocity along the centerline of the filter annular space at 90 degree increments.

5.4 Effect of Ash Flow on Media Flow Characteristics

These tests will be completed at the 5 ft bed height position before starting the 3 ft height tests defined in Section 5.3.

A. Set up the filter air flow at 75% of spouting velocity with the media flow rate at 100 lb/hr. Determine the required bed depth to provide the necessary pressure balance across the drain seal leg so that leakage will be from the filter down the seal leg.

B. Operate at the following media flow and ash feed rate combinations:

Media Rate	Ash Rate(% of Media Rate)
60 lb/min	2%, 10%
120 lb/min	2%, 5%
240 lb/min	2%

C. Make the following measurements after the filter has reached steady state conditions with ash flow at each media/ash condition:

Filter Pressure Drop
Air Flow Orifice DP
Air Supply Pressure
Air Supply Temperature
Drain Seal Leg DP
Deentrainment Vessel DP

Air Velocity Flow Profile at Top of Filter - Collect a 6 point traverse at two, 90 degree apart locations.

Media Flow Profile - Measure the media velocity at the filter top every 90 degrees along the filter annular centerline. Also, collect a four point traverse at two, 90 degree apart locations.

6.0 SCALE UP FILTER TESTING - 6 FT DIAMETER

6.1 Objectives/Guidelines

Cold flow testing with a 6 ft diameter filter will allow confirmation that the selected filter geometry constraints from tests with the 3.5 ft diameter filter, result in similar media and gas flow characteristics.

- Determine if the 3.5 ft diameter geometry scaled to the 6 ft diameter filter produces similar media and gas flow patterns.

- If the 6 ft diameter geometry does not produce similar flow characteristics, determine the inlet pipe geometry required to achieve the desired flow characteristics.

- Use the results of 3.5 ft diameter testing to determine what tests are appropriate for the 6 ft diameter filter(i.e., ash injection, media flow rate, gas flow rate, bed height and surface roughness).

- All filter tests will be run at bed heights of 5 ft or less.

- Use available blowers from 3.5 ft diameter filter tests which will allow maximum air flow of approximately 25 % of minimum fluidization.

6.2 Baseline Testing - No Ash Flow

A. Test No. 1: Media Flow Only With No Refilling

1. Beginning with the bed height at 5 ft, level the media at top of the filter so that it is even height in all areas.

2. Start Draining media at a rate of 250 lb/min into 55 gallon barrels or equal, without replenishing the media. For every ~ 1000 lbs of media drained, stop and measure the drop in bed height along the annular centerline, every 45 degrees. Also, measure bed height, radially at 8 equally spaced traverse points, each at two locations 90 degrees apart.

3. Stop the test when the bed height reaches the bottom of the gas inlet pipe.

B. Test No. 2: Air Flow Test with 5 FT Bed Height

1. Set up the filter with a 5 ft bed height in the standard configuration.

2. Establish filter air flow of ~ 25 % of minimum fluidization velocity(maximum of blower capacity).

3. Set the media drain rate at 250 lb/min and collect the following data:

   Filter Pressure Drop
   Air Flow Orifice Pressure Drop
   Air Supply Pressure
   Air Supply Temperature

   Media Flow Traverse - Measure the media velocity along the filter annular centerline at each 90 degree position. Measure the media velocity at 8 equally spaced traverse points, each at two ports, 90 degrees apart.

   Air Flow Traverse - Measure the air velocity along the filter annular centerline at each 90 degree position. Measure the air velocity at 8 equally spaced traverse points, each at two ports, 90 degrees apart.

6.3 Ash Flow Tests

If ash tests using the 3.5 ft diameter filter indicated that ash effected the media flow characteristics, then ash tests will also be performed on the 6 ft diameter filter.

1. Set up the same flow conditions as in test 6.2.B.

2. Inject fly ash into the air supply piping at a rate of 5% of the media rate(12.5 lb/min).

3. Collect the same measurements as in test 6.2.B.3

6.4 Additional Tests

If the media flow characteristics are not similar to tests with the 3.5 ft diameter filter, modify the inlet pipe design and repeat tests as defined in sections 6.2 and 6.3.

7.0 PIPE LINER ABRASION TESTING

A. Perform a 1000 hr abrasion test using the rotating drum test equipment. Install test refractory and silicon carbide samples and add approximately 5 lbs of 6 mm alumina silicate media as the abrasive solids, into each drum section.

The drum will rotate at ~ 20 RPM. With each rotation the media will drop from the highest point of rotation to the test samples approximately 3 ft below.

B. Each test sample will be weighed before and after testing to determine loss of material.

8.0 MINIMUM FLUIDIZATION TEST AND MEDIA ATTRITION TESTS

A. Media will be tested for minimum fluidization velocity in the 238 sq. in. unit at ambient conditions and with a 24 inch static bed height. Fluidization tests will be scheduled so that the results are available before the filter tests.

B. The air flow will be increased gradually until fluidization velocity is reached. Data will be collected, as defined below, at incremental flows in order to characterize velocity versus bed pressure drop.

Air Supply Pressure
Air Flow Orifice DP
Air Temperature
Air Distributor DP
Bed DP

C. The 3 mm media used in previous test GBF tests at New York University and the 6 mm media to be used in future testing will be evaluated for their relative attrition resistance using ASTM D 4058-92 procedure. If the larger media has significantly different attrition characteristics than the 3 mm media, 6 mm media from other sources will be evaluated.

9.0 INTERPRETATION OF TEST RESULTS

The results from initial cold flow tests using a 180 degree, 3.5 ft diameter, split filter with a transparent cross section will allow visual examination of media flow characteristics. The results will confirm that the selected filter cone and inlet pipe geometry establishes media plug flow.

The cold flow tests will measure, at atmospheric conditions the media's minimum fluidization velocity and its spouting velocity in a 3.5 ft diameter filter. The spouting velocity establishes the theoretical maximum gas capacity for a filter. We expect that geometrically similar filters will have the same spouting velocity and a geometrically proportional maximum gas capacity. We also expect that the ratio of the spouting velocity to the minimum fluidization velocity will not change with gas temperature and pressure. Correlations exist to predict the minimum fluidization velocity as a function of gas temperature and pressure. Using these standard correlations for minimum fluidization velocity we will able to predict the filter's theoretical maximum gas capacity at any operating condition. The theoretical maximum filter gas capacity is a useful design parameter which we will have quantified in these tests.

Effective use of the filter requires that the gas be evenly distributed across the filter. The measurement of the gas velocity profile at the top of the filter is an indication of the gas distribution in the filter. At very shallow bed depths the gas will be un-evenly distributed. Increasing the bed depth causes the gas flow through the filter to be better distributed across the filter. The cold flow test will determine the minimum bed depth necessary to have the gas evenly distributed across the filter. This will establish the lowest bed depth commercial possible.

The test which evaluates the effect of surface roughness on media flow will provide guidance on the surface finish requirements for commercial filters. The 3.5 ft diameter cold flow GBF vessel will be bricked with a similar shaped brick as would be used commercially. It is important to determine that the 6 mm media does not become trapped in the brick joints and subsequently hold up media above it. The results of the media flow pattern tests will determine if the brick surface interferes with the flow of media through the filter.

The question of scale up will be evaluated using a 6 ft diameter, full circumference filter, to confirm that the media and gas flow characteristics are similar using similar geometry design factors. Constructing a larger filter is impractical for the available facilities. The filter inlet pipe geometry will be calculated using a computerized fluid dynamic model holding the same constraints as used on the finalized geometry for the 3.5 ft diameter filter. The results will be used to define how to scale up the geometry so that the media flow characteristics remain constant.

The results of the wear tests on candidate materials for the lift pipe and seal legs will be used to select the most appropriate material to be used commercially and if practical, the selected material will be utilized at the PSDF.

There is some concern regarding the loads imposed on the filter gas inlet pipe due to the undefined forces from gas maldistribution and consequent variation of media voidage. This is especially important now that deeper bed depths are being considered. Strain gage measurements will allow determination of imposed stresses, forces and deflection at the cantilevered support. The results will be used to confirm the suitability of the design of this support.

Working with the 6 mm media during the test program will help identify any potential problems with media strength. The media attrition tests will compare the attrition resistance of the current media to that of 3 mm media used in past testing. A significant increase in attrition will prompt evaluation of alternate filter media.

10. Cost Estimate

Table 1 shows the estimated cost of the design of the test facilities; the fabrication, installation and dismantling of facilities; the testing and reporting of results. These costs will be broken down with more precision and accuracy in a cost proposal to be submitted soon.

Table 1 Estimated Costs of Component Testing

Work Step	Estimated Cost
Design of Test Facilities	$60,000
Fabrication, Installation and Dismantling	$225,000
Testing	$70,000
Topical Report	$25,0000
Total Estimated Cost	$380,000

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