Moving Bed Granular Bed Filter Development Program

Topical Report
September 1994

By:
J.C. Haas
J.W. Prudhomme
K. W. Wilson

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

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

By
Combustion Power Company
Oakland, California
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P.O. Box 880
Morgantown, West Virginia 26507-0880

By
Combustion Power Company
201 Webster Street
Suite 1700
Oakland, California 94612
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1.0 INTRODUCTION

Five test arrangements have been designed to support the Granular Bed Filter Development Program as defined in the Test Plan described in Task 3. The first arrangement is a 3.6 ft diameter half filter, with a glass covering along the cross section to allow visual examination of the granular alumina material passing through the filter. This unit will be used to evaluate up to 4 different filter discharge hopper designs and two different air inlet pipe configurations.

The second test arrangement is a 3.6 ft diameter full size filter having refractory lining to simulate actual surface roughness conditions. Results from the half filter testing will be applied to the hopper and inlet pipe design and positioning on the full size filter.

The third test arrangement will examine filter geometry scale up by testing a 6.0 ft diameter full size filter. The 6.0 ft filter will also have refractory lining to simulate actual surface roughness. All three of the filter units will be supported from a common structure and will use a common pneumatic transport system to circulate alumina from the filter drain back to the filter top.

The forth Test Arrangement consists of a small 12 inch diameter fluidizer to measure the minimum fluidization velocity of the 7 mm (approximate size) alumina material to be used in the filter assemblies.

The last Test Unit is used to evaluate relative abrasion characteristics of potential refractory and ceramic materials to be installed in high abrasion areas in the pneumatic transport piping. The unit consists of several 40" diameter cylinders each having a liner sample and alumina material. Each revolution alumina falls on to the liner surface causing some level of abrasion. The test is designed to run for 1000 hrs.
2.0 DESCRIPTION OF PROCESS CONTROLS

2.1 Granular Bed Filter Controls

The instrumentation and valving for the granular bed filter test units are defined on the Piping and Instrument Diagram included in this report. Air is supplied to the filter inlet using one or two blowers, depending on the filter size and capacity. Air flow is controlled manually with butterfly valves at each blower inlet. Flow is measured using an orifice.

For some of the planned tests, ash is introduced into the inlet air stream to determine the effects of ash on alumina material flow characteristics. The ash is from a local coal fired power plant and is metered into the air stream using a small bin with a variable speed, screw conveyor. An eductor is used to overcome the inlet air pressure and pneumatically convey the ash to the filter inlet pipe.

Inside the filter, the ash is captured by the granular alumina material and clean air exits the filter top. The test arrangement is located outdoors so the filter top is open to atmosphere. The filter material and ash drain out the filter bottom through a seal leg to a pneumatic lift pipe to return the alumina back to the filter top for another cycle. During the pneumatic transport process, ash is dislodged from the alumina and the ash exits with the lift air at the de-entrainment vessel, due to the size and density difference. Instrumentation is positioned on the filter to manually record filter pressure drop, filter seal leg pressure drops, lift pipe pressure drop and de-entrainment vessel pressure. The filter pressure drop versus filter air flow are important performance measurements. The seal leg pressure drop is used to confirm that air is exiting from the filter rather than entering the filter at the seal leg. The out flow of air at the seal leg is necessary to maintain proper ash flow draining from the filter. A bleed line is mounted from the seal leg to the ash collection baghouse to maintain air flow down the seal leg when lift pipe air pressure is higher than the filter pressure.

The alumina circulation rate is controlled by varying the amount of injection air on the "L- Valve" at the base of the seal leg. The alumina flow rate is proportional to the lift pipe pressure drop and is used to set the circulation rate. A sight glass is mounted on the seal leg to visually measure the alumina velocity which is used to confirm the material mass flow. The lift air is supplied by a separate positive displacement type blower. The lift air flow is established by venting excess air at the blower discharge because the blower has fixed speed.
In addition to filter pressure drop, the filter flow characteristics will be determined by measuring the air flow distribution at the filter top using a thermoanemometer (designed for low air velocities). The alumina flow distribution will be determined by the movement of metal rods which descend into the filter with the alumina granules. The 3.6 ft diameter half filter will also allow visual observation of the alumina flow profile.

From the de-entrainment vessel, ash is pneumatically transported to a baghouse where the ash is separated from the air. The ash particles drain from the baghouse hopper to a 55 gallon drum for reuse or disposal. A suction fan is mounted downstream of the baghouse to control the de-entrainment vessel near atmospheric pressure. The fan is controlled manually by adjusting the inlet butterfly, similar to the air supply blowers.

2.2 Alumina Fluidizer Controls

The fluidizer unit is used to measure the minimum fluidization velocity of the 7 mm alumina material. Fluidizing air is supplied by one of the air supply blowers as described in Section 2.1. The unit is operated by gradually increasing the air flow while measuring the pressure drop across the bed until the bed begins to fluidize. The pressure drop versus air flow data as well as visual observation determine when fluidization begins.

2.3 Lift Pipe Liner Abrasion Unit Controls

Candidate refractory and ceramic materials will be tested for abrasion using a rotating drum abrasion test unit. Each refractory sample will be mounted in a separate fabricated enclosed cylinder along with a defined amount of 7 mm alumina. With each revolution alumina will drop on the test sample surface at a velocity similar to that inside the filter pneumatic lift pipe.

Each sample will be fired to typical operating temperatures (~1600 F) and weighed before testing. The cylinders are then assembled together to form one drum which mounts on a standard drum rotator. The 1/2 horsepower drum rotator operates at 10 RPM for 1000 Hours. Each refractory sample is divided into two sections to simplify casting and each weigh approximately 30 lbs, depending on the sample thickness and material. The dust and media will be collected and weighed for mass balance.
3.0 DESCRIPTION OF SAMPLING AND ANALYTICAL EQUIPMENT

- Toledo Digital Scale (0-100 lbs, accuracy to .01 lbs)
- Triple Beam Balance (0-2 kg, accuracy to .1 g)

4.0 EQUIPMENT SPECIFICATIONS

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<th>ITEM</th>
<th>MANUFACTURER</th>
<th>STATUS</th>
<th>CAPACITY</th>
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<td>Hoffman</td>
<td>Existing</td>
<td>2570 ACFM at 6.3 PSIG</td>
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<td>2100 ACFM at 6.3 PSIG</td>
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<td>CPC or Fox</td>
<td>New</td>
<td>2&quot; Dia</td>
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<td>Ash Feeder</td>
<td>Acrison or Eq.</td>
<td>Rental</td>
<td>12 Lb/Hr</td>
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<td>Granular Bed Filter</td>
<td>CPC</td>
<td>New</td>
<td>3.6 and 6.0 Ft Dia</td>
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<td>CPC or Fox</td>
<td>New</td>
<td>1.5&quot; Dia</td>
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<td>Rental</td>
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<td>Micropul</td>
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<td>Suction Fan</td>
<td>Buffalo Forge</td>
<td>Existing</td>
<td>850 ACFM at 16 IKG static DP</td>
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<td>US Rental</td>
<td>Rental</td>
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<td>Abrasion Test Drums</td>
<td>CPC</td>
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<td>Drum Rotator</td>
<td>Advanced Handling Sys.</td>
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<td>400 Lbs max at 10 RPM</td>
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## 5.0 INSTRUMENT AND VALVE SPECIFICATIONS

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<th>Pressure Range</th>
<th>Temperature Range</th>
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<td>PCV  105</td>
<td>Air Pressure Regulator</td>
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<td>0-30 PSIG</td>
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<td>PI  105</td>
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<td>0-30 PSIG</td>
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<tr>
<td>TI  108</td>
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<td>CPC</td>
<td>0-250 F</td>
<td>Bi-metalic</td>
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<tr>
<td>FE  108</td>
<td>Inlet Air Flow Orifice</td>
<td>Dwyer</td>
<td>0-20 IWG</td>
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<td>Inlet Air Orifice Dp</td>
<td>Dwyer</td>
<td>0-5 IWG</td>
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<td>PI  110</td>
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<td>FI  112</td>
<td>Alumina Velocity Probe</td>
<td>CPC</td>
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<td>FI  115</td>
<td>Air Velocity Anemometer</td>
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<td>PCV  116</td>
<td>Air Pressure Regulator</td>
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<td>0-10 PSIG</td>
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<td>Upper Seal Leg Dp</td>
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<td>0-2 IWG</td>
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<td>Lower Seal Leg Dp</td>
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<td>FI  122</td>
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<td>0-250 F</td>
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<td>FE  135</td>
<td>Lift Air Flow Orifice</td>
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<td>PDI  135</td>
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<td>PI  135</td>
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<td>0-5 PSIG</td>
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<tr>
<td>FE  139</td>
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<td>Dwyer</td>
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<td>PDI  138</td>
<td>Injection Air Pitot Tube Dp</td>
<td>Dwyer</td>
<td>0-5 IWG</td>
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<td>YO  139</td>
<td>Lift Air Restriction Orifice</td>
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<td>0-150 IWG</td>
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<td>Baghouse Dp</td>
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<td>FE  201</td>
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<td>PDI  210</td>
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### VALVES:

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<th>Valve</th>
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<td>Dezurick or Eq.</td>
<td>8&quot; Dia</td>
<td>Butterfly</td>
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<td>HV  102</td>
<td>Blower No.2 Inlet Valve</td>
<td>Dezurick or Eq.</td>
<td>8&quot; Dia</td>
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<td>HV  105</td>
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<td>HV  136</td>
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<td>Gate</td>
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<td>HV  158</td>
<td>Suction Fan Inlet Valve</td>
<td>Dezurick or Eq.</td>
<td>8&quot; Dia</td>
<td>Butterfly</td>
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6.0 UTILITY REQUIREMENTS

6.1 Compressed Air:

- Ash Eductor Air 51 SCFM @ 25 psig
- Bleed Eductor Air 36 SCFM @ 5 psig
- Baghouse Pulse Air 5 SCFM @ 80 psig

Total Air 92 SCFM

6.1 Electrical: (Installed Horsepower)

- Hoffman Blower Motor 125 HP @ 230VAC, 3 phase
- Lamson Blower Motor 100 HP @ 230VAC, 3 phase
- Suction Fan Motor 5 HP @ 230VAC, 3 phase
- Lift Air Blower Motor 15 HP @ 230VAC, 3 phase
- Ash Feeder Motor 1/2 HP @ 115VAC, 1 phase
- Drum Rotator 1/2 HP @ 115VAC, 1 phase

6.2 Diesel Fuel:

- Air Compressor 1.5-2 Gal/Hr
7.0 ESTIMATED COSTS

7.1 Task 5: Fabrication and Installation Costs:

Fabrication and installed costs are defined below using the cost format from the Option I Cost Proposal submitted to the U.S. Department of Energy during April, 1994. Some of the equipment costs are higher than originally estimated based on fabricator quotations. Also, some additional equipment must be rented that were originally thought to be available at CPC. These additional costs are listed separately. Every effort will be made to reduce costs in other areas to compensate for cost increases. Section 7.2 provides a detailed breakdown of the cost increases.

| April-1994 Cost Proposal Additional Estimate Costs |
|---------------------------------------------|-----------------|
| Item 1a: Purchased Parts $37,600 $11,240 |
| Item 1b: Subcont. Items $130,035 $6,460 |
| Item 3: Direct Labor $10,172 $0 |
| Item 4: Labor Overhead $15,258 $0 |
| Item 7: Travel $44 $0 |

April 1994 Total Task 5 Direct Cost and Overhead $193,109
Revised Task 5 Total Direct Cost and Overhead $210,809

7.2 Task 5 Detail of Cost Changes

Item 1a: Purchased Parts

Addition: Added Costs for Half Filter Assy. $7,255
Added Costs for Media Fluidizer $1,235
Added Costs for Liner Abrasion Unit (due to sampling preparation) $2,750
Total $11,240

Item 1b: Subcontracts

Addition: Rental of PD Blower @$400/mo $1,600 (4 mo)
Rental of Ash Feeder @$465/mo $1,860 (4 mo)
Rental of Air Compressor @$1000/mo $3,000 (3 mo)
Total $6,460

7.3 Total OPTION I Costs

The current cost trend for Option 3 is upward by about 5% based on the above changes in above costs. This is only a small part of the total contract. There are lots of opportunities to offset this trend in other tasks and stay
within budget.
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<th>OPTION 1: COMPONENT TEST FACILITY</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
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<td>Support Structure &amp; Pneumatic System</td>
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<td>Scale Up Filter - 6 Ft Dia</td>
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Schedule: 10/5/84
9.0 ENGINEERING DRAWINGS
### ESTIMATED MAXIMUM FLOW CONDITIONS

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<th>Filter Type</th>
<th>Blower Inlet</th>
<th>Eductor Inlet</th>
<th>Ash Inlet</th>
<th>GBF Outlet</th>
<th>GBF Supply Outlet</th>
<th>Lift Blower Outlet</th>
<th>Real Leg Outlet</th>
<th>DEV Outlet</th>
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<td>167</td>
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**AIR MASS FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 167
- 3.6FT DIA. FULL FILTER: 333
- 6.0FT DIA. FULL FILTER: 400

**PRESSURE, PSIA**
- 2.6FT DIA. SPLIT FILTER: 14.7
- 3.6FT DIA. FULL FILTER: 14.7
- 6.0FT DIA. FULL FILTER: 14.7

**TEMPERATURE, F**
- 2.6FT DIA. SPLIT FILTER: 80
- 3.6FT DIA. FULL FILTER: 80
- 6.0FT DIA. FULL FILTER: 80

**AIR VOLUME FLOW, ACFM**
- 2.6FT DIA. SPLIT FILTER: 2270
- 3.6FT DIA. FULL FILTER: 4530
- 6.0FT DIA. FULL FILTER: 5440

**MEDIA FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 120
- 3.6FT DIA. FULL FILTER: 240
- 6.0FT DIA. FULL FILTER: 240

**ASH FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 6
- 3.6FT DIA. FULL FILTER: 6
- 6.0FT DIA. FULL FILTER: 6

**ASH FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 6
- 3.6FT DIA. FULL FILTER: 6
- 6.0FT DIA. FULL FILTER: 6

**PRESSURE, PSIA**
- 2.6FT DIA. SPLIT FILTER: 14.7
- 3.6FT DIA. FULL FILTER: 14.7
- 6.0FT DIA. FULL FILTER: 14.7

**TEMPERATURE, F**
- 2.6FT DIA. SPLIT FILTER: 80
- 3.6FT DIA. FULL FILTER: 80
- 6.0FT DIA. FULL FILTER: 80

**AIR VOLUME FLOW, ACFM**
- 2.6FT DIA. SPLIT FILTER: 14
- 3.6FT DIA. FULL FILTER: 14
- 6.0FT DIA. FULL FILTER: 14

**MEDIA FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 120
- 3.6FT DIA. FULL FILTER: 240
- 6.0FT DIA. FULL FILTER: 240

**ASH FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 6
- 3.6FT DIA. FULL FILTER: 6
- 6.0FT DIA. FULL FILTER: 6

**PRESSURE, PSIA**
- 2.6FT DIA. SPLIT FILTER: 14.7
- 3.6FT DIA. FULL FILTER: 14.7
- 6.0FT DIA. FULL FILTER: 14.7

**TEMPERATURE, F**
- 2.6FT DIA. SPLIT FILTER: 80
- 3.6FT DIA. FULL FILTER: 80
- 6.0FT DIA. FULL FILTER: 80

**AIR VOLUME FLOW, ACFM**
- 2.6FT DIA. SPLIT FILTER: 14
- 3.6FT DIA. FULL FILTER: 14
- 6.0FT DIA. FULL FILTER: 14

**MEDIA FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 120
- 3.6FT DIA. FULL FILTER: 240
- 6.0FT DIA. FULL FILTER: 240

**ASH FLOW, LB/MIN**
- 2.6FT DIA. SPLIT FILTER: 6
- 3.6FT DIA. FULL FILTER: 6
- 6.0FT DIA. FULL FILTER: 6
**TED MAXIMUM FLOW CONDITIONS**

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<tr>
<th>SH</th>
<th>GBF AIR SUPPLY</th>
<th>GBF SQUIRREL OUTFIT</th>
<th>LIFT BLOWER INLET</th>
<th>STEALER BLEED AIR</th>
<th>DEV OUTLET</th>
<th>BAGHOUSE SUCTION ASHMWAIR FAN INLET</th>
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DEPARTMENT OF ENERGY
MOVING BED GRANULAR BED FILTER
DEVELOPMENT PROGRAM

PROCESS FLOW DIAGRAM
GRANULAR BED FILTER - TEST UNITS

COMBUSTION POWER
Combustion Power Company, Oakland, California
REVISIONS
FOR DESCRIPTION OF CHG SEE L. D
NO. | BY | DATE | APPR
--- | --- | --- | ---
01 | JAY | 9-28-44 | KO

ASH FEEDER

BLOWER NO. 2
(REQUIRED FOR FULL SIZE 3.6 FT AND 6.0 FT FILTERS)

BLOWER NO. 1

DEPARTMENT OF ENERGY
MOVING BED GRANULAR BED FILTER
DEVELOPMENT PROGRAM

PIPING AND INSTRUMENT
DIAGRAM
GRANULAR BED FILTER-TEST UNITS

Combustion Power Company, Oakland, California
NOTE: INSIDE SURFACES AND JOINTS SHALL BE SMOOTH AND WITHOUT JEDGES
DETAIL K
3/8 DIA BOLT X 1 1/2 LG W/ NUT & TAPD. WASHER (GFL)

FILTER INLET

DETAIL L

DIA. - 15/32 TAPPED HOLE

J-J

DIAGRAM

ION F-E

1/2 DIA. BOLT X 2 LG W/ NUT (94 PL.)

SPACER BAR TACK WELD TO HALF FILTER PLG.

CLAMPING FRAME

3N G-G

5/8" C-CLAMP OR ETC. (9 PL.)

3N H-H

DETAIL OF

1/2" THK. TEMPERED GLASS

NOTES:

1. STEEL FABRICATION PER GRP 5T1133.
2. BREAK ALL SHARP EDGES.
3. WELD PER GRP 5T1132

HALF FILTER VESSEL
ASSEMBLY

COMBUSTION
POWER

Combustion Power Company, Whittier Park, California
6. BRICK SHELVES WILL BE DEFINED BY REFRACTORY CONTRACTOR.

5. REFRACTORY: SUPER-DUTY BRICK OR EQUAL.

4. ALL 3/16" THK. CYLINDRICAL OR CONICAL PARTS SHALL BE JOINED WITH FULL PENETRATION BUTT WELD.

3. BREAK ALL SHARP EDGES.

2. ALLOY STEEL FABRICATION PER CPC ST1133.

1. ALL CARBON STEEL SHAPES AND PLATE MATERIAL PER ASTM A36 OR EQ.

NOTES:
FILTER VESSEL
ASSEMBLIES - 
3' - 7" DIA. AND 6' - 0" DIA.

COMBUSTION POWER
Combustion Power Company, Oakland, California
FILTER INLET 5CS
9 3/8" I.D.
HALF-MODEL
FILTER INLET NYU
5 7/8" I.D.
HALF-MODEL

2. BREAK ALL SHARP EDGES.
1. STEEL FABRICATION PER CFC ST1133 & WELDING PER CFC ST1132.

NOTES:
CUT AND REMOVE EXISTING REDUCER PIPE SECTION. GRIND ALL CUT SURFACES CLEAN PRIOR TO WELDING NEW SECTION.

SPIDER ASSY - 50S 1/2-MODEL

USING 200W/60H MODEL - FOR WELDING

DETAILS NOT SHOWN 5BB NYU MODEL

SPIDER 3/4-
SPIDER ASSY. YU MODEL

SPIDER ASSY - SCS MODEL
(3'-7" I.D. FILTER)

SPIDER ASSY - SCS MODEL
(6'-0" I.D. FILTER)
SPIDER ASSY - SCS MODEL
(6'-0" I.D. FILTER)
18 GA COLD ROLLED CARBON STEEL SHEET STRETCHER LEVELED PER ASTM A366

SECTION B-B
NOTE 1. ASSEMBLY MOUNTS ON DRUM ROTATOR.
SHELF PLATE POSITIONED IN FIELD

END PLATE (2 PL. PER SECTION) 3/16" THK X 6" X 3"

REFRACTORY SAMPLE (THICKNESS MAY VARY UP TO 3 DEPENDING ON MFG'S REQUIREMENTS)

SECTION A-A

TOTAL

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DEPARTMENT OF ENERGY MOVING GRANULAR BED FILTER DEVELOPMENT PROGRAM

ABRASION TEST UNIT ASSEMBLY

COMBUSTION POWER

Combustion Power Company, Oakland, California