CROSS FLOW FILTER FOR AEPSC
TIDD SLIPSTREAM HGCU PROJECT
PRELIMINARY DESIGN PACKAGE
FOR
WESTINGHOUSE CROSS FLOW FILTER SYSTEM
JUNE 18, 1989
(Final Submittal)

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JUNE 16, 1989
(FINAL SUBMITTAL)

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1. Cross Flow Filter Technology

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CROSS FLOW FILTER CONCEPT

Schematic Representation of Cross Flow Filter

Dwg. 9402A72

The Westinghouse ceramic cross-flow filter element is illustrated above. The ceramic cross flow filter element is constructed of multiple layers of thin, porous ceramic plates that contain ribs to form gas flow channels. Consecutive layers of the ceramic plates are oriented such

that the channels of alternating plates are at an angle of 90 degrees ("cross flow") to each other. The current size of a ceramic cross flow filter element is 12"x12"x4". Both sides of the short channels (4") are exposed to the particle-laden coal gas. One end of the long (12") channels is sealed while the other end of the long channel is mounted to the clean gas plenum. The particle-laden coal gas flows through the "roof and floor" of the porous ceramic plates that comprise the short, "dirty side" channels. The gas flows through the porous plates to the long, "clean side" channels. The gas flows through the porous plates to the long, "clean side" channels and finally to the clean gas plenum. The dust cake on the "dirty side" channels is periodically removed by applying a high-pressure reverse pulse of dry, clean gas through the clean gas plenum. For the TIDD plant filter slipstream, air will be utilized for filter cleaning.

SCHEMATIC OF CROSS FLOW FILTER ELEMENT

WITH MID-RIB BOND DESIGN

- Moves critical plate bond from high to low stress region
- Permits uniform plate design (minimizes differential plate shrinkage)

CROSS FLOW FILTER TEST UNIT BEING INSTALLED INTO THE PRESSURE VESSEL

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Table 1.1
Cross Flow Filter
Key Technology Milestones - Summary

<u>Milestone</u>	<u>Filter Element Scale - Inch</u>	<u>Summary</u>
Filter Element Development	6x6x2	Over 1000 element hours experienced over wide range test conditions. Demonstrated ceramic cross flow configuration as viable filter approach.
ANL-PFBC	6x6x2	100 hrs operation on single element at 1400°F/120 psig with filter face velocity 12 ft/min, $\Delta p = 10-13$ in wg., $\eta > 99.98$ (significant dust upsets).
METC Gasifier	6x6x2	250 hrs operation at 1200°F, in 5 test segments; operating face velocity varied from 4 to 12 ft/min, 3 different elements tested.
1000 Cycle Test	6x6x2	Operation at 1500°F/150 psig using reentrained PFBC ash. Stable filter cleaning achieved.

Table 1.2

Cross Flow Filter

Key Technology Milestones - Summary

<u>Milestone</u>	<u>Filter Element Scale - Inch</u>	<u>Summary</u>
Filter Element Scaleup	12x12x4	Over 1200 element hours operation at HTHP conditions (9/1/88). Evaluating alternative designs, mounts and dust seal techniques.
Modeling (Pulse Cleaning)	12x12x4	Developed pulse cleaning model; commercial scale module tested to confirm pulse parameters (Ambient)
Subpilot Scale Testing	12x12x4 Multielement Multimodule	Testing focused on filter system development using existing operating facilities. KRW (PFBC - Simulator) - completed 160 hr HTHP test on 8-element, 4 module arrangement NYU-PFBC - completed 83 hr HTHP test on 15-element, 5 module arrangement (see attached Figure) Texaco (Gasifier) - in progress - 4-element unit FW (PFBC) - 10-element, 2 module design - in progress

Table 1.3

CROSS FLOW FILTER - KRW PFBC TEST SUMMARY OF RESULTS

Test	P (psia) T (°F)	Avg. Face Velocity v_f , Ft./Min.	Inlet Dust Load ppm	ΔP Range in H ₂ O	Hours at Condition Hrs.	Outlet Dust Load ppm
1	115 1,550	4.3	1,000	17-27	77	3.6
2	Same	Same	2,000	17-27	3	2.2
3	Same	Same	2,000	18-40	4.5	4.8
4	Same Except 1,600°F	Same	1,000	20-40 23-43	56	3.4
5	78 1,625	6.1	1,000	35-60	11	3.6
6	115 1,550	4.3	1,000	23-30	7	5.2

(w)

CROSS FLOW FILTER KRW TEST OUTLET DUST LOADING

Figure 1.1

Above figure compares measured outlet dust loading in cross flow filter test conducted on KRW-PFBC simulator facility (June 1988). The filter unit consisted of 8-elements in a four module arrangement. Test conditions are provided in Table 1.3.

Table 1.4
SUMMARY OF CROSS FLOW FILTER TESTS AT NYU PFBC

Parameters	Test No. 1	Test No. 2
Flow (lb/hr)	4900	10,000
Pressure (psig)	103	105
Filter Temperature (°F)	<1500	1300
Nominal Face Velocity (ft/min)	5.2	10.4
Hours of Operation (Hr)	5½	30
Cleaning Cycles	60	117

CROSS FLOW FILTER OUTLET LOADINGS SHOWING GRAB AND IMPACTOR SAMPLING (NYU-PFBC)

Figure 1.2 - Cross Flow Filter Test Data Comparing Outlet Loading with Emission Standards and Turbine Tolerance Goals

Figure 1.2 shows performance of cross flow filter in the New York University PFBC facility. The filter unit consisted of 15 elements in a 5-module arrangement. Two tests were conducted corresponding to conditions outlined in Table 1.4. Test #1 operated for 52 hours without incident. During Test #2 three of the five solenoid valves failed and there was an upset in the combustor operation.

Impactor sampling data in Test #1 compared with projected turbine tolerance goals.

Table 1.5

**Nominal Filter Performance Data
April 1989 Texaco Test**

Date & Time (hrs.)	Set Point	Temp. °F	Pressure psig	Gas Flow		Pressure Drop in μ s	
				SCFH	ACFM	Trigger	Baseline
4/26, 1600 to 4/26, 2010 (3.5)	1	1018	330	30770	66	50	8
4/26, 2010, to 4/27, 0000 (3.5)	2	876	330	16120	31	38-50	5
4/27, 0000 to 4/27, 1330 (13)	3	790-845	330	40240*	76	50-70	13-20
4/27, 1330 to 4/27, 1610 (2.5)	4	928	330	47570*	95	80-90	26
4/27, 1610 to 4/27, 2300 (7)	5	990	330	52700*	110	90	32-35
4/27, 2300 to 4/28, 1335 (14.5)	6	934-975	330	48300*	98	95	30-33

*Includes 8000 SCFH cold recycle gas leak from soot blower.

NOTE: Borescope inspection of filter clean side surfaces inside each plenum revealed no evidence of filter delamination or dust seal failures.

Figure 1.3

FILTER MASS LOADING DATA

April 1989 Texaco Data

(w)

Figure 1.4 - Cross Flow Filter for Foster Wheeler Advanced PFBC Pilot Plant

Table 1.6
OVERVIEW OF CROSS FLOW FILTER DEVELOPMENT PROGRAMS AND NEEDS SUPPORTING TIDD 10 MW SLIPSTREAM

Technical Issue	Ongoing Programs	Proposed Actions
Filter Durability	<ul style="list-style-type: none"> • 2000 hr Filter Durability Testing (Item 7) • Mechanical Design Improvements (Item 10) • Long Term Chemical/Thermal/Mechanisms (Item 7) • Ongoing Field Testing (Items 5, 6) 	<ul style="list-style-type: none"> • Additional 1000 hrs Testing
Quality Control	<ul style="list-style-type: none"> • Coors In House Efforts (Items 13, 14) • Improving Filter Specification Basis (Item 10) 	<ul style="list-style-type: none"> • New Tool Sets • Focus ANL Activities (Item 10)
Filter Module Scaleup	<ul style="list-style-type: none"> • 5 Element/Module Foster Wheeler Test Unit • Cold Flow Model of FW Unit (Item 1) • Development of Pulse Cleaning Model 	<ul style="list-style-type: none"> • Utilize FW cold flow model to evaluate Tidd filter inlet design configuration. Extend to include dust reentrainment (Item 2) • Construct large module section and evaluate pulse distribution simulating dirty filter conditions (Item 12)
Lust Seals	<ul style="list-style-type: none"> • Long Term Durability Testing (Item 7) • Field Test Experience (Items 5, 6) 	<ul style="list-style-type: none"> • Accelerated gasket cycle tests, alternate materials (Item 9)
Pulse Valve Reliability	<ul style="list-style-type: none"> • Field Test Experience (Items 5, 6) 	<ul style="list-style-type: none"> • Construct dedicated pulse loop based on proposed Tidd configuration; Conduct accelerated valve testing including simulated valve failures, (Item 9)
Tubesheet Structures	<ul style="list-style-type: none"> • ORNL-High Alloy Materials Evaluation (Item 11) 	<ul style="list-style-type: none"> • Continue following ORNL program.

NOTE: Items in parenthesis refer to writeup following Figure 1.5.

Figure 1.5

SCHEDULE COMPARING TIDD HGC SLIPSTREAM AND NEAR TERM CROSS FLOW FILTER DEVELOPMENT ACTIVITY

NOTE: Number relate to program descriptions provided in attached writeup

Description of Current and Proposed Cross Flow Filter Development Activity Supporting Tidd HGC Slipstream

1. Westinghouse is currently designing and constructing a full scale cold flow model of the cross flow filter unit that will be installed on the Foster Wheeler subpilot scale advanced PFBC test rig. The filter unit uses a tangential gas inlet designed to promote a downflow to the filter elements. The cold flow model will be approximately 3 ft-diameter and incorporate up to 10 cross flow filters. The intent is to trace the gas flow field using neutrally buoyant helium bubbles with filters in place.

2. Using the 3-ft diameter cold flow model facility and further scaling results, the inlet design basis for the Tidd cross flow filter unit would be checked and verified. The scope of the cold flow testing would then be extended to include dust feeding and pulsing to evaluate dust reentrainment factors. These tests would be used to confirm selection of the Tidd unit filter module design.

3. Approximately 20 new cross flow filters will be fabricated for the Foster Wheeler test unit. The intent is to utilize a production press operation and tunnel furnace equipment indicative of the same procedure and equipment that would be used to manufacture the Tidd slipstream filter elements. With this approach, improved quality measures will be implemented since plates will be pressed with the rib structure as opposed to machining the ribs. This should provide more uniform plate dimensions and eliminates machining grooves (inherent flaws). These changes reflect a move by Coors to transfer the filter element fabrication from their new products development activities into their commercial manufacturing operations. These filters for the FW unit will represent the prototype for Tidd.

4. Testing of the filters at the FW site should provide an early confirmation of their design and manufacturing. A procurement schedule for the Tidd cross flow filter would be planned to permit iteration with field test results at FW.

5. During the last week of April, 1989, Westinghouse completed a 50 hour test of a 4-element cross flow filter unit integrated with the Texaco pilot scale entrained bed gasifier unit located at Montebello, California. The operational performance of the filter system and pulse cleaning subsystem were found to be very acceptable. Over the operating period, a total of 220 pulse cleaning cycles were achieved, with an averaged outlet dust loading of about 3 ppm. A borescope inspection of the filter elements from the clean gas side inside each plenum housing and filter mount showed no evidence of dust, no evidence of delamination cracks nor any indication of a dust seal leak.

6. It is anticipated that over 250 hours of cross flow filter operation will be achieved on the Texaco gasifier unit by the end of the calendar year. This experience will provide additional data on the overall operating characteristics of the filter and short term materials durability.

7. Westinghouse has now initiated a cross flow filter durability testing under simulated PFBC conditions (i.e., $T = 1550^{\circ}\text{F}$, $P = 150$ psi, reentrained ash) using high pressure, high temperature combustion gases. (DE-AC21-87MC24022). In these tests the filter unit will be exposed to both filtration and pulse cleaning cycles over continuous operating periods from 100 to 500 hours. It is expected to achieve about 2000 hours of cumulative operating time on the same filter unit by January, 1990. The intent is to characterize the filter performance over life specifically evaluating long term filter permeability trend, collection efficiency and structural behavior of both filter, dust seals and other subsystems and confirm the operating basis for the Tidd slipstream (conditioned filter permeability).

A companion program entitled "Thermal/Chemical Degradation of Ceramic Cross-Flow Filter Materials," DE-AC21-88MC25034, is being conducted to evaluate potential gas-solid reactions with filter materials that could occur at conditions and degrade filter performance, i.e., weaken base material properties, cause changes in pore structure, or simply enhance or accelerate filter blinding. An important consequence of this work is identifying base filter material structure in order to refine base power formulations to eliminate any undesirable glass phase. A similar program is also being carried out by the DOE for the silicon carbide candle system.

8. It is expected that the cross flow filter durability testing will be continued into 1990 such that a cumulative 3000 operating hours will be achieved.

9. Both the cross flow and candle filters require high temperature dust seals at the filter element. Various ceramic fiber based materials have been successfully used over relatively short test periods. The long term resiliency of the materials at temperature and subjected to relatively severe pulse gas loadings needs to be verified. Accelerated gasket cycle testing is proposed to provide the long term exposure and performance data to confirm materials choice and designs. For the cross flow filter, a test rig is proposed where the gasket is placed on a filter mount and mechanically loaded to represent actual operating filter conditions. The unit is placed in a dedicated furnace that is rigged to permit accelerated pulsing at filter operating temperatures.

Companion to this work will be accelerated pulse valve testing to confirm the operating and design basis for the proposed Tidd unit pulse cleaning systems. A single pulse loop (including redundant valve) duplicating the proposed Tidd configuration will be built and operated over extended pulsing periods. A programmable logic controller will be

included to allow simulated faults and the initiation of corrective action (i.e., automatic valve switching and proper alarming). The tests would include plans to achieve over 60,000 pulse cycles on the pulse solenoid valve operated under pressure conditions.

10. Westinghouse continues to improve filter specification criteria to help improve filter quality control. Current specifications which include dimensional tolerance and flow permeability are expected to be updated to include fracture toughness criteria. Westinghouse, working with Argonne National Laboratory (ANL), DE-AC21-86MC23252, has undertaken a study to help develop fracture toughness parameters for the cross flow filter porous materials. ANL will be working with used and new filter media to develop stress models and data that will establish maximum flaw and strength criteria. Separately, DOE is funding studies with Garrett AiResearch to develop high strength SiN material for the cross flow filter. This material is not expected to be a candidate for the Tidd slipstream. However, detailed thermal and mechanical analysis is being conducted as part of this program to characterize filter stresses that are developed within the core and flange sections under transient startup and thermal cycling during pulse cleaning. This information is expected to provide additional insight into the current flanged design and applicable to the Tidd filter system.

11. The Oak Ridge National Laboratory

ORNL is currently conducting a study for DOE to evaluate high temperature metals as candidate tubesheet materials. Fatigue and weldment data at temperature on RA333, Inconel 617, Hanes 556 and 188 are being obtained. Westinghouse is receiving and evaluating this data. The program results should help substantiate the Tidd tubesheet materials selection and data base.

12. Westinghouse proposes constructing a full scale filter module for pulse testing purposes. Pulse cleaning test data would be generated confirming pulse flow distribution over a 40-element module. Cold flow tests are anticipated where the dirty filters are simulated using appropriate porous resistances. The actual mount design would be used. The pulse distribution along the filter plenum would be measured. The pulse intensity would be compared for different initiating conditions against analytical model predictions. The analytical model (already existing) accounts for system temperature and pressure effects and provides pulse dynamics. Other design data that could be obtained from the testing and prove useful include vibration characteristics over the module length and actual induced gas flow rates. By replacing selected porous resistances with actual filter elements, flow distribution through the filter core could be qualitatively evaluated using high speed photography and standard flow visualization techniques. By placing a filter at selected positions along the module length, pulse gas flow distribution through a large cross flow filter module can be evaluated and quantified. For a fixed plenum/nozzle and venturi design, the effect of increased pulse reservoir pressures can be confirmed and support the Tidd design basis.

13. Westinghouse continues to pursue the development and commercialization of the ceramic cross flow filters. Under DOE Contract DE-AC21-86MC23252 Westinghouse and Coors have successfully scaled the cross flow from the 6x6x2 element configuration to the 12x12x4 inch commercial configuration and have made substantial modification in its design to improve its overall durability and performance. To date these include:

- Mid rib configuration
- Radiused flange
- Improved plate to plate bond strength
- High flow permeability.

14. Both Westinghouse and Coors are prepared to continue development in support of the commercialization of the cross flow filter. Future developments are expected to include a wider materials selection, further element scale-up, completely monolithic structure (slip case or formed) and reduced costs.

2. Design Requirements

- Design Objectives
- Scope of Design & Costing
- System Design Requirements
- Component Life Requirements
- Gas Composition
- Applicable Codes and Standards

WESTINGHOUSE DESIGN OBJECTIVES

- Develop a Compact & Economical Filter System for Deployment in Commercial Scale PFBC Units.
- Incorporate Sufficient Critical Component Redundancy & Design Safety Factors to Assure a High Degree of Reliability at TIDD Over the Full Range of Test Parameters.
- Minimize the Number of Engineering Design Extrapolations from Previous Experience on Prototypical Filter Projects & Ongoing Pilot Scale Programs.
- Position the TIDD Filter System Design for Duplication in the Sporn Project. (i.e., Virtually no Scaleup or Extrapolation from TIDD).

SCOPE OF DESIGN AND COST ESTIMATE

WESTINGHOUSE

- Cross Flow Filter Pressure Vessel
- Filter System Internal Support Structures
- Cross Flow Filter Elements
- Vessel Insulation
- Pulse Cleaning System
(ex-pulse accumulation tank)
- Assembly and Installation at Tidd

AEP

- Ash/Fines Discharge System
- Foundations and Support Structures
- Inlet, Outlet Ducting
- Back-up and Emergency Cyclones
- On-line Gas and Particle Sampling
- Pulse Gas Compression and Accumulator Tank
- Filter Vessel Preheating System

SYSTEM DESIGN REQUIREMENTS

<u>Process Design Requirements</u>	<u>Design</u>	<u>Operation</u>
Gas Temperature (F)	1675	1551
Pressure (psia)	200	164
Gas Flow (lbm/hr)	100,900	
Nominal Volumetric Rate (acfm)	7500	
Solids Flow In (lbm/hr)	255	57
Solids Flow Out from Filter (lbm/hr)	1.3	0.3
Pulse Cleaning Gas	Dry Air	
Vessel Heat Loss (Btu/hr ft ²)	150	
Maximum Operating Pressure Drop		
Through Filter Unit (in. wg.)	83	
Turndown (Plant Load)	to 40%	
Minimum Dust Holding Time (hrs)	4	

Basis for Design Life

Vessel (yrs)	10
Tubesheet/Internal Structures (hrs)	15,000
No. Cold Starts Over 2 yr Period	120
No. Cold Starts Over 10 yr Period	565
No. Load Change (100-40%) 1st Year	300
Load Changes (100-40%) (No./yr-avg.)	272
Total System Weight Not to Exceed (Tons)	75
Vessel Pressure Relieve/Vent	None Required
Space Constraints	30'x25'x75' (high)

COMPONENT LIFE REQUIREMENTS

<u>Component</u>	<u>Design Life</u>	<u>Comment</u>
• Vessel	10 yrs	Commercial practices, 5 mill/yr corrosion allowance
• Tubesheet/ Internals	>15,000 hours	To be verified by creep/fatigue and finite element analysis. (>90% probability)
• Filter Elements	>15,000 hours	- Objective of test program - 2000 hr test to be completed - Design basis accommodates worst case permeability reduction
• Dust Seals	>15,000 hours	- Recommend long term dust seal HT testing - Alternate design under consideration
• Vessel Insulation	>15,000 hours	- Commercial product
• Pulse Valves	200,000 cycles	- MTBR*-commercial experience - Represents 4-1/2 minutes maximum cleaning frequency over 15,000 hr period
• Pulse Tubes	1-1/2 yr operation	- Easy access for changeout - Design geometry amenable to double wall construction if required

* Mean Time Between Repairs

GAS COMPOSITION (BY VOLUME)

CO ₂	13.53%
O ₂	3.65%
N ₂	71.78%
SO ₂	228 ppm
H ₂ O	11.01%
Molecular Weight = 29.22	

PROJECTED DUST PROPERTIES

<u>Particle Size</u> (microns)	<u>Mass Fraction Smaller than Stated Size</u> Primary Cyclone Discharge*
1.4	.197
2.0	.586
2.8	.877
4.0	.967
5.6	.987
8.0	.994
11.0	<u>1.0</u>

Average Size = 1.51 microns

* For 500 ppm discharge; actual discharge range is expected to be between 500 and 1500 ppm

APPLICABLE CODES AND STANDARDS

- Pressure Vessel - ANSI/ASME Boiler and Pressure Vessel
Code, Sec VIII Div. 1
- Piping Systems and Components - ANSI/ASME B31.3, Code for
Pressure Piping (Chemical Plant
and Petroleum Refinery)
- NEC Area Classification for Electrical Instruments
 - Remote/Field-mounted: Class I, Division 2, Group D
 - Control Room: Non-hazardous
- American Society of Testing and Materials (ASTM)
- American Institute of Steel Construction (AISC)
- American Welding Society (AWS)
- Environmental Protection Agency (EPA)
- Ohio Occupational Health and Safety Regulations
- Institute of Electrical & Electronics Engineers (IEEE)
- Manufacturer's Standardization Society of the Valve and Fitting
Industry (MSS)
- National Electrical Manufacturer's Association (NEMA)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Act (OSHA)
- Steel Structures Painting Council (SSPC)
- Instrument Society of America (ISA)
- Uniform Building Code (UBC)
- Underwriter's Laboratory (UL)
- Ohio Basic Building Code

3. Cross Flow Element Specification

- Element Specification
- Quality Assurance Overview
- Process Control/Quality Control Methods
- Process Gas Chemistry/Materials (TBD)

CROSS FLOW FILTER ELEMENT SPECIFICATION
(Preliminary)

MaterialP-100-A modified - Coors

Dimensions

Core12 in x 12 in x 4 in (nominal)

Flange5-1/2 inch width

.....0.75 inch height (Flat & Parallel)

All Corners Rounded

Filter Area

Each Element Shall Contain a Minimum 7 ft² of Filter Surface.
(Based on Dirty Channel Side)

Performance

Porosity45 to 55%

Pore Diameter<100 microns

Pressure Drop≤5 in wg at 10 ft/min (STP)

Mechanical Properties

MOR3000 psi ± 150

Fracture Toughness.....TBD

COORS CERAMICS STRUCTURAL COMPANY
QUALITY ASSURANCE
OVERVIEW

The Coors Ceramics Company, Structural Division, Quality System is based on MIL-Q-9858A, "Quality Program Requirements".

Our Inspection System is in conformance with MIL-I-45208A, "Inspection System Requirements".

Our Metrology System is in conformance with MIL-STD-45662, "Calibration System Requirements".

The Structural Division of Coors Ceramics Company is heavily involved in SPC activity from basic P Charts to electronic data gathering equipment resident in the manufacturing processes. In addition, DOE and process optimization techniques are also applied.

This company has undergone and passed various on-site quality audits by a multitude of customers of varied backgrounds and interest, based on these Quality Programs.

Because our customer base numbers in the thousands, the above mentioned Quality Programs generally satisfy most customers requirements. However, we recognize that there are situations where special customer needs exist and we are prepared to discuss them on an individual basis.

PROCESS CONTROL/QUALITY CONTROL METHODS

- A) Ceramic material preparation
 - 1) Raw material acceptance
 - a) verification of: chemical analysis, particle size analysis, surface area, reactivity, pH
 - 2) Batch formulations and processing
 - 3) Batch characterization: measurement of chemical analysis, particle size & distribution, porosity, density and shrinkage.
- B) Forming and firing
 - 1) Shrinkage release to manufacturing for pressing
 - 2) In process inspection, x-ray, weight & thickness
 - 3) Bisque and high temperature kiln profiles
- C) Fired element testing
 - 1) Dimensional tolerances
 - 2) Porosity and pore size (on spare plates)
 - 3) Flatness of critical surfaces
 - 4) Bond strength via burst test: inflation balloon at 400 psi, 20 places
 - 5) Flexural strength: biaxial, 3 point loading, 3Kpsi minimum
 - 6) Visual inspection

4. Process Design Basis

- Design Rationale
- Design Philosophy
- Process Flow Diagram (Dwg. 1D32801)
- Supporting Data

DESIGN RATIONALE

(Logic illustrated in attached Figure 4.1)

- Established Process Flow Diagram, Heat and Material Balance
(see Dwg. 1D32801)
- Design/Operation of Slipstream Based on Conditioned Filter
Parameters (see Figure 4.2)
- Conduct Power Cycle Tradeoffs/Economics to Select Filter
Operating Parameters
 - Establishes Commercial Design Basis and Goals for
Slipstream Testing (see Figure 4.3)
- Evaluate Design Basis for Slipstream
 - Select Operating Conditions Based on Current Test
Experience (see Figure 4.4)
 - Meet Loading, ΔP Requirements, Define Operating
Flexibility (see Figure 4.5)
 - Minimize System Footprint Maintaining Acceptable
Entry/Exit Losses (see Figure 4.6)
- Configure Filter Test Unit to Operate over Desired Test Range

Figure 4.1

OVERALL DESIGN LOGIC FOR PFBC CROSS FLOW FILTER SYSTEM DESIGN

Figure 4.2

PERMEABILITY TRENDS FOR CROSS FLOW FILTERS

- All types of barrier filters exhibit a permanent loss of permeability over their service life. The effective permeability stabilizes to 20-35% of virgin permeability after 2000 cycles. (Candle filter data)
- TIDD design basis assumes long term filter permeability of 20% of Virgin (worst case) based on 6x6x2 single element test.
- Cross Flow Filter Systems using multielement, multimodule configuration show significantly better permeability trend but data limited to less than 200 cycles.
- Current program will verify long term filter permeability trend over 2000 (or more) cycles for 12x12x4 elements by 4th Quarter, 1989.

Figure 4.3
CROSS FLOW FILTER SYSTEM DESIGN
PARAMETRIC TRADEOFFS

Above curves show approximate effects of filter system pressure drop and pulse cleaning requirements on gas turbines power cycle output. Analysis assumes TIDD plant filter slipstream design parameters including:

- 2500 ppm inlet dust loading, with $d_{50} = 1.51 \mu\text{m}$
- conditioned filter at 5X new filter resistance

Power cycle losses include effects of cake, filter and gas path flow losses through the filter module (including venturi section and expansion losses), the pulse compressor power requirements and temperature dilution (but mass addition) effect of pulse gas on gas turbine output.

The Analysis shows that there exists a minimum point for each filter face velocity corresponding to lowest power loss. As expected, power cycle losses increase with increased face velocity with a corresponding shift in the minimum power loss condition. The numbers given on each face velocity curve show filtration cycle times (in minutes). To the left of the minimum points, the filter pulse cleaning becomes very frequent and dominates power cycle losses. To the right of the minimums, pulse cleaning is less frequent and the power cycle losses reduce to only the parasitic flow losses (pressure drop).

For PFBC combined cycle, the gas turbine net output represents about 20% of the plant output. With the relative impact of the filter system representing about a 1% net decrease in the gas turbine power output (at minimum conditions), the total impact on plant output will be relatively small (~0.2% loss) over the range of filter face velocities considered. Thus, the expected impact on operating costs due to the cross flow filter will be small (<0.1 mill/kW hr).

Figure 4.4

- Commercial Design Basis 10 FPM
- TIDD Slipstream Basis (with Design Margin) 6.7 FPM
- TIDD Slipstream Test Capability up to 10 ft/min

Figure 4.5

OPERATING WINDOW FOR PFBC CROSS-FLOW FILTER
Maximum DP=80 in., Fully Conditioned Coors Element

- Recommended Face Velocity for the TIDD Demonstration Project Includes 33 Percent Design Margin
- TIDD Operation with Reduced Filter Area Will Verify Commercial Design Basis
- Sporn Project Will Require Only 12 TIDD-Size Filter Modules, Under Commercial Basis Face Velocity

Figure 4.6

- Acceptable DP Involves Tradeoffs Between Reducing Plenum Size (and Overall System Footprint) Vs Reducing Plenum Pressure Drop
- TIDD Design Basis:
 - (A) 4 Plenum Numbers, Each 8" Nominal Diameter
 - (B) or 9 Plenum Numbers, Each 5" Nominal Diameter

5. Design for 10 MW Cross Flow Filter TIDD Slipstream Test Unit

- Plant Arrangement
 - Facility Integration (Fig. 5.1)
 - Breakdown of Filter System Weight by Major Subassembly (Table 5.1)
 - Weights and Overhead Clearance Requirements (Table 5.2)
- Filter General Arrangement
 - Design Rationale
 - Gas Inlet Configuration
 - Plenum Layout
 - Alternate Plenum Layout
- Specification
 - Vessel
 - Tubesheet/Filter Plenum
- Filter System Scaleup Factors (Table 5.3)

Figure 5.1
WESTINGHOUSE CROSS FLOW FILTER
TIDD STRUCTURE LAYOUT
W.J.D. 3-28-89

0.342.PL.

Table 5.1
Breakdown of Filter System Weight by Major Subassembly

<u>Component</u>	<u>Weights., lbs (tons)</u>	
	<u>Reference Design</u>	<u>Alternate Design</u>
Pressure Vessel		
• Shell with Girth Flange & Insulation	31,600 (16) *	40,500 (20)
• Head with Girth Flange & Insulation	10,400	10,400
• Liner	<u>1,600</u>	<u>2,400</u>
Subassembly	43,600 (22)	53,300 (27)
Internals		
• Tubesheet Structure including Plate, Expansion Cone, Ring and Shroud	10,200	10,200
• Plenums/Mounts with Filters	<u>7,000</u>	<u>9,600</u>
Subassembly	17,200 (9)	19,800 (10)
• Misc. (Steel/Piping Manifold)	7,100	7,100
Total Assembled Wt.	67,900 (34)	80,200 (40)
• Contingency; Ash excess load if fines fill filter vessel hopper	48,000 (24)	48,000 (24)

* Assumes shorter shell consistent with 40 element single plenum mount. Preliminary design however assumes common vessel.

Structural design basis should include contingency allowance for dust accumulation. Structural design basis (worst case)

40 T - Filter Assembly
24 T - Contingency
 64 T - Total

Table 5.2
WEIGHTS & OVERHEAD CLEARANCE REQUIREMENTS

- Total Weight of the Filter Vessel, Inclusive of Assembled Tubesheet, Elements and Structural Steel, is 34 tons.
- Installation of the Vessel into the Structure Will Require a Minimum 20 ton Lift Capacity.
- A Minimum 10 Ton Capacity Overhead Hoist and Monorail Is Required on the Centerline of the Vessel to Install the Vessel Head and Assembled Tubesheet.
- Breakdown of Filter System Weight by Major Subassembly Is Given in Table 5.1
- Minimum Clearance Between the Monorail Elevation and the Vessel Girth Flange Is Shown on the Facility Drawing.

PLENUM - 310 SST
 TUBESHEET - RA 333
 FILTERS - SINTERED ALUMINA

WESTINGHOUSE CROSS FLOW FILTER VES-
 GENERAL ASSEMBLY
 W. J. D. 3-23-85

ALL DIMENSIONS IN INCHES

DESIGN RATIONALE - GAS INLET CONFIGURATION

- Tangential Inlet Through Rectangular Channel to Promote Axisymmetric, Uniform Distribution of Gas & Solids
- Upflow & Deceleration in Annulus Formed by Inlet Shroud and Internal Liner
- Overflow Across Weir at Constant Velocity Into Filtration Zone
- Substantial Downflow to Provide Cake Sweeping Flow Across Entire Plenum Length
- Detailed Design Will Be Supported by Hydrodynamically - Scaled Cold Flow Model Studies, Planned for 1989-90.
- Sufficient Space Available to Incorporate Baffle Plates between Modules (not shown)

ALL DIMENSIONS IN INCHES

WESTINGHOUSE CROSS FLOW FILTER GAS ENTRY & DISTRIBUTION DESIGN

51

Downflow Velocity, fps
3.2 @ First Row
1.92 @ Fifth Row
0.32 @ Tenth Row

SCALE-UP DESIGN STRATEGY FOR FILTER/PLENUM LAYOUT

As is evident from the drawings, several cross flow filter elements are attached to a common mast or plenum which serves as a manifold to collect and exhaust the filtered gas from the individual elements. In addition, the plenum functions as a common distribution point for the reverse pulse cleaning gas which is injected concentrically into the upper open end of the plenum pipe. We have examined the system footprint and cleaning effectiveness tradeoffs of several plenum configurations and have chosen two designs which are suitable for the current study.

The first design, referred to as the base case design, consists of 40 elements arranged in 10 equally spaced rows in a cross pattern. This design is the most compact plenum arrangement for a commercial scale filter system and would require the fewest number of pulse cleaning loops. A cold flow mock-up of this plenum configuration using flow impedance boxes was tested in 1986-87 and showed that the pulse intensity, gas inducement into the venturi, motive gas pressure and flow requirements can be reliably predicted from our previous understanding of the pulse cleaning dynamics.

Whereas this test showed that the hydrodynamic cleaning action of the pulse jet would propagate along the entire length of a commercial-scale plenum with several filter elements, the test ignored the effect of the dust cake. In particular, the test did not determine the trajectory of the cake after it is dislodged from the upper rows, and whether this cake would redeposit immediately on the lower elements of the same plenum, or on adjacent plenums. Leith and First at Harvard University studied the problem of filter cake redeposition on industrial scale pulse jet baghouses and found that the problem is indeed serious with 15' to 20' long bags at face velocities approaching 10 fpm.*

*EPA Report PB-266-233, March 1977.

In view of this potential problem with large scale plenums we have adopted the following two-pronged strategy for the TIDD preliminary design effort:

- Because the purpose of the current study is to bracket the cost of the filter system, we have assumed the worst-case scenario of cake redeposition and developed a contingency plenum design which increases the height of the pressure vessel by roughly 7 feet. In this design the height of each individual plenum is restricted to 5 rows, which is identical to our current Foster Wheeler test unit. By judiciously integrating the smaller plenums into a cluster, we were able to eliminate the penalty of system footprint enlargement.
- We also recommend a cold flow test on a hydrodynamically scaled 10-row plenum using prototypical PFBC dust (from Grimethorpe), to assess the problem of cake redeposition with cross flow filters. The results of the study would be available within 3 months of the start of the detailed design effort, at which point the plenum design would be frozen. The contingency design configuration will also be tested in the cold flow model such that during the detailed design phase we can, select one of the two plenum designs depending on the severity of cake redeposition identified by the cold flow test.

DESIGN - PLENUM LAYOUT

Reference Design

- Four Plenums each Containing 40 Elements in X- Configuration (10 Rows) for Total of 160 Elements.
- Maximum Dust Cake Free-Fall Length is 14 Feet (Equivalent to 10 Assembled Filter Lengths).
- Plenum Made of Standard 8" Pipe with 5" Venturi (20°/20°) to Assist Pulse Cleaning.
- Each Plenum Serviced by a Dedicated Pulse Cleaning Loop, for Total of Four Loops.

Contingency Design

- Nine Plenums Arranged in Three Sets of Stacked Cluster Arrangement. Each Set has 50 Elements for Total of 150 Elements.
- Maximum Dust Cake Free-Fall Length is 7 Feet (Equivalent to 5 Assembled Filter Lengths).
- Plenums Made of 5" Pipe with 3" Venturi (20°/20°).
- Each Plenum Serviced by a Dedicated Pulse Cleaning Loop, for a Total of Nine Loops.

Containment Design Basis

- Internal Volume Sized to Accommodate the Larger Plenum Layout Required by the Contingency Case.
- Cold Flow Studies of Simulated Stack Arrangements (5 vs 10 Rows) Will Aid in the Final Selection of the Plenum Design.

ALL DIMENSIONS IN INCHES

T- TOP CLUSTER
M- MIDDLE CLUSTER
B- BOTTOM CLUSTER

LAYOUT OF STACKED CLUSTER CONFIGURATION
(50 ELEMENTS PER SET)

FILTER VESSEL SPECIFICATION

- Vessel Fabricated Per BPV Code from SA515 GR70 Carbon Steel, with Seal Welded Girth Flanges.
- Internal Insulation Consists of 7 Inch Layer of Fibrous Blanket, Stackbonded & Attached by Anchor/Clip Arrangement. (Quotes Obtained on Recommended Design from J. Manville and Carborundum). Maximum Operating Temperature of Insulation - 2300°F.
- Skin Heat Loss < 136 Btu/Hr Ft²; Skin Temperature Estimated to be 127°F.
- Internal Lining of 310 SS Further Protects the Blanket Lining from Gas/Solids Erosion.
- Pulse Cleaning Lines Inserted from the Top of the Elliptical Head to Assure Close Centering of Nozzles Over Plenum Throats & Also Provide Access for Borescope Inspection.

INSULATION REQUIREMENTS
 MAX INT. TEMP. 1850 F
 HEAT LOSS LESS THAN
 150 BTU/HR FT
 20 START UP CYCLES
 PER YEAR
 LIFE 10 YEARS
 INTERNAL GAS 44% CO₂, 57% N₂
 17% MOISTURE, 47% O₂

DESIGN SPECS:

1. DESIGN CONDITIONS 100 PSIA - 650 °F
2. INSULATION TO BE 100% COMPLETE DUE TO DYE PERMANENT TEST
3. CODE REQUIREMENTS ASME SECT VIII
4. TESTS TO BE PERFORMED AS PER CODE
5. TESTING - 250 PSIA HYDROSTATIC COMPLETE ASSY
6. STAMPING - PER CODE

WESTINGHOUSE CROSS FLOW PUMP VESSEL
 VESSEL DETAILS
 W J D 3-29-85

ALL DIMENSIONS IN INCHES

DESIGN RATIONALE - TUBESHEET & FILTER PLENUMS

- Overall Design Philosophy & Choice of Materials for the Tubesheet are Similar to Grimethorpe Design; Diameter of Tubesheet is Identical to Grimethorpe Design. Grimethorpe Design Improved.
- The Position of the V Shaped Expansion Joint is Inverted to:
 - Improve Space Utilization in Lower Vessel Section which Houses the Filter Elements.
 - Provide Access to the Critical Stress Concentration Zones without the Need for Tubesheet Removal from Vessel.
 - Shield the Insulated V-Section in a Relatively Quiescent Area to Prevent the Loss of Insulation & the Attendant Temperature Excursions (Experienced in Grimethorpe)
 - Critical V-Joint Temperature Below Creep/Fatigue Temperature Limit
 - Insulation Around Expansion Cone Restrained by Metal Radiation Shield
- The Material of Construction of the Tubesheet, Support Cone & Outer Ring is Rolled Alloy's RA-333 Material.
- The Detailed Design and Life Cycle Assessment will be Supported by the WECAN (Westinghouse) Finite Element Analysis Program.
- Configuration of the Filter Plenums and Support Structures is Similar to that Used in Previous Testing on Cross Flow Filters.
- Design Based on Horizontal Support Ledges Welded to 8 inch Standard Pipe Serving as the Plenum.
- Each Element is Anchored to the Ledge with a Clamping Plate, and Braced with Ceramic Rods to Apply Compression Loading to the Element Body.
- Target Stress Criteria to Meet 15,000 hr Life
 - Tubesheet to Cone Joint <4000 psi
(High Temperature Creep Rupture Strength)
 - V-Joint 80% of Yield at 800°F
 - Ring Flange 80% of Yield at 250°F

Table 5.3

COMPARISON OF CROSS FLOW FILTER EXPERIENCE WITH TIDD AND COMMERCIAL DESIGNS

<u>Scaling Issue</u>	<u>Current Test Experience</u>	<u>Projected Test Experience By 1990</u>	<u>TIDD Slipstream Design Reference</u>	<u>Contingency</u>	<u>Sporn Design</u>
Filter Element Size, in.	12x12x4	12x12x4	12x12x4	12x12x4	12x12x4
Module Size (Element/Module)	3	5	40	15-20	TBD
Tubesheet Dia., feet	6	6	6	6	TBD
Blowback Solenoids Valve Size, in.	2	2	2	2	2
Cleaning Cycles/ Element	1000	6000+	11250	11250	TBD
Hours Operation per Element	250	2000+	15000	15000	TBD
Max Plenum Height in Element Lengths	3	5	10	5	5-10

- Key scaleup parameter to be demonstrated includes module size, long term operation.
- Module size scaleup to be supported by cold flow studies

6. Pulse Cleaning System and P&ID's

- Design Rationale
- Pulse Cleaning System Design Basis
- Pulse Dynamics
- Pulse System Control
- P&ID - Pulse System
- P&ID - General

DESIGN RATIONALE - PULSE CLEANING SYSTEM

- Design Tool - Westinghouse Dynamic Model which Simulates by Mass, Momentum & Energy Balances, the Flow, Pressure & Temperature Transients Occurring in the Pulse Cleaning Flow Loop & Filter Plenum
- Inputs
 - Pulse Accumulator Volume
 - Valve Opening Characteristics
 - Velocity Heads of Irreversible Line Losses
 - Configuration of Plenum, Venturi, Nozzle
 - Wall Resistance of Elements^a
 - Cake Resistance^{*}
 - Cake Dislodgement Force^{*}
 - Trigger DP to Initiate Pulse
 - Capacitance of System to Absorb Transient
 - Face Velocity, & Other Operating Conditions
- Outputs
 - Minimum Pulse Tank Pressure to Dislodge Cake
 - Nominal Pulse Gas Usage
 - Minimum Gas Temperature Inside Plenum
 - Complete Profiles of Pressures, Flows, Temperatures During Pulse

a. Empirically Determined Using Data from Westinghouse PFBC Simulator Test Rig on Grimethorpe PFBC Ash & Various X-Flow Elements.

DESIGN RATIONALE - PULSE CLEANING VALVES

- An optimally designed pulse system requires fast-acting solenoid valves, with response times of 500 milliseconds or less.
- We have preliminary selected 3-way pilot piston operated 2" Atkomatic valves, without a mechanical linkage between the plunger and piston. Tests have shown that mechanical open times of 400 milliseconds can be obtained.
- History of Atkomatic valves has been mixed (see Table 6.1). KRW and Westinghouse experience suggests that valve failures can be minimized by:
 - a. Increasing pulse interval to >3 mins (particularly for semi direct lift valves).
 - b. Protecting the valve from particulates and/or oil/moisture.
 - c. Using pilot-operated valves (without any mechanical linkage).

Table 6.1

HISTORICAL EXPERIENCE WITH SOLENOID VALVES

Facility	Valve Type	Operating Hrs	Failures Experienced	Attributed To	Operating Conditions	
					P, Psi	T, °F
1. KRW Gasifier Metal Filter Campaign	3/4" Semi Direct Lift	800	Yes	Dirt/Scale in Pulse Lines, Insufficient Pressure	700	70
2. Grimethorpe PFBC	2" Semi Direct Lift	790	Yes	Linkage Broken, Insufficient Pressure, Dirt/Scale in Lines.	520	70
3. W/NYU PFBC	2" Semi Direct Lift	73	Yes	Linkage Broken	250	350
4. W/KRW PFBC	1" Internal Pilot Piston Lift	159	None		350	70
5. KRW Gasifier Ceramic Filter Campaign	3/4" Semi Direct Lift	653	None		700	70
6. R&D Center 301 Test Facility	3/4" Direct Lift	980	None		500	70
7. W/Texaco Gasifier	1" External Pilot Piston Lift	50	None		1100	70

PULSE CLEANING SYSTEM DESIGN BASIS

Fixed

Tank Size	- 1' dia x 4' long (4-required)
Valve Type	- 3-Ported/Atkomatic Series 35000
Valve Size	- 2"
Nozzle Size	- 1.5"
Venturi Size	- 5" dia 20°/20° - See Figure 6.1
Plenum Size	- 8" dia

Variable

Operating Pressure	580 - 1300 psig
Pulse Gas Temperature	300°F
Mass Flow Pulse	2 - 4 lb
Max. Pulse Gas Consumption	55 lb/hr
Supply Capacity to Reservoir	320 lb/hr

Pulse Dynamics - See Figure 6.2

- Design Basis Permits Pulse Cleaning Operation over Range of Cake Dislodgement Characteristics - See Table 6.2
- Recommend Spare (Redundant) Compressor for Operating Reliability

Figure 6.1

EFFECT OF VENTURI SIZE ON PULSE GAS REQUIREMENTS
Reference Design, 8" Plenum, 2" Solenoid Valve

- 5" Venturi Represents the Optimum Configuration for 8" Plenum Size

Figure 6.2
DYNAMICS OF PULSE FLOW TRANSIENTS
TIDD BASE DESIGN, HEATED PULSE GAS

NOZZLE & FILTER FLOWS
Reference Design with 8" plenum & 5" venturi

PLENUM PRESSURE & TEMPERATURE
Reference Design, 8" plenum with 5" venturi

Table 6.2
EFFECT OF CAKE DISLODGE^MENT
PARAMETER ON PULSE GAS REQUIREMENTS

<u>Ash</u>	<u>Mean dia.</u> <u>μm</u>	<u>Pulse Gas Requirements *</u>	
		<u>Pressure</u> <u>psia</u>	<u>Flow</u> <u>lb/hr</u>
Prototypical Measured (Grimethorpe Catch)	5	580	4
TIDD Estimated	1.5	1090	8

* for 560 ppm loading, nozzle flow only

PULSE CLEANING - PROCESS CONTROL SYSTEM

- Pulse Cleaning System Consists of Pulse Accumulator Tank and 2 Dedicated Parallel Pairs of Fast-Acting Solenoid & Remotely Actuated Isolation Valves for each Plenum. (On-Line Redundancy)
- Microprocessor-based Controls for Automatic Unattended Operation; and Datalogging of Operating Parameters
- Diagnostics Include:
 - Low Pressure Switch on Pulse Tank to Verify Valve Closure
 - Strain Gage or Vibration Device on each Pulse Line to Verify Valve Opening
- A Hierarchy of Logic Interlocks Used to Activate Pulse Action to Any Plenum:
 - A- Minimum Pulse Tank Pressure (for Efficient Cleaning)
 - B- Maximum Pressure Drop Across Filter (Trigger DP)
 - C- Contact Closures on Parallel Isolation Valves (Verify that Primary and Backup Valves are Armed)
 - D- Pulse Verified on Previous Plenum in Sequence
 - E- Time Interval Between Consecutive Pulses Satisfied
- A Programmable Logic Controller (PLC) Used in Conjunction with a Data/Logger to Provide:
 - 1. Flexibility for Adjusting Interlock Logic & Permissive Settings
 - 2. Capability for Ramping Set Points for Individual Control Loops (e.g., Increase Trigger DP Set Point During Conditioning)
 - 3. Automatic Isolation in the Event of Valve Open Failure or Automatic Switching to Back-Up Solenoid in the Event of Valve Closed Failure

Revision 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4.0 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 5.0 5.1 5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9 6.0 6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8 6.9 7.0 7.1 7.2 7.3 7.4 7.5 7.6 7.7 7.8 7.9 8.0 8.1 8.2 8.3 8.4 8.5 8.6 8.7 8.8 8.9 9.0 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 10.0 10.1 10.2 10.3 10.4 10.5 10.6 10.7 10.8 10.9 11.0 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 12.0 12.1 12.2 12.3 12.4 12.5 12.6 12.7 12.8 12.9 13.0 13.1 13.2 13.3 13.4 13.5 13.6 13.7 13.8 13.9 14.0 14.1 14.2 14.3 14.4 14.5 14.6 14.7 14.8 14.9 15.0 15.1 15.2 15.3 15.4 15.5 15.6 15.7 15.8 15.9 16.0 16.1 16.2 16.3 16.4 16.5 16.6 16.7 16.8 16.9 17.0 17.1 17.2 17.3 17.4 17.5 17.6 17.7 17.8 17.9 18.0 18.1 18.2 18.3 18.4 18.5 18.6 18.7 18.8 18.9 19.0 19.1 19.2 19.3 19.4 19.5 19.6 19.7 19.8 19.9 20.0 20.1 20.2 20.3 20.4 20.5 20.6 20.7 20.8 20.9 21.0 21.1 21.2 21.3 21.4 21.5 21.6 21.7 21.8 21.9 22.0 22.1 22.2 22.3 22.4 22.5 22.6 22.7 22.8 22.9 23.0 23.1 23.2 23.3 23.4 23.5 23.6 23.7 23.8 23.9 24.0 24.1 24.2 24.3 24.4 24.5 24.6 24.7 24.8 24.9 25.0 25.1 25.2 25.3 25.4 25.5 25.6 25.7 25.8 25.9 26.0 26.1 26.2 26.3 26.4 26.5 26.6 26.7 26.8 26.9 27.0 27.1 27.2 27.3 27.4 27.5 27.6 27.7 27.8 27.9 28.0 28.1 28.2 28.3 28.4 28.5 28.6 28.7 28.8 28.9 29.0 29.1 29.2 29.3 29.4 29.5 29.6 29.7 29.8 29.9 30.0 30.1 30.2 30.3 30.4 30.5 30.6 30.7 30.8 30.9 31.0 31.1 31.2 31.3 31.4 31.5 31.6 31.7 31.8 31.9 32.0 32.1 32.2 32.3 32.4 32.5 32.6 32.7 32.8 32.9 33.0 33.1 33.2 33.3 33.4 33.5 33.6 33.7 33.8 33.9 34.0 34.1 34.2 34.3 34.4 34.5 34.6 34.7 34.8 34.9 35.0 35.1 35.2 35.3 35.4 35.5 35.6 35.7 35.8 35.9 36.0 36.1 36.2 36.3 36.4 36.5 36.6 36.7 36.8 36.9 37.0 37.1 37.2 37.3 37.4 37.5 37.6 37.7 37.8 37.9 38.0 38.1 38.2 38.3 38.4 38.5 38.6 38.7 38.8 38.9 39.0 39.1 39.2 39.3 39.4 39.5 39.6 39.7 39.8 39.9 40.0 40.1 40.2 40.3 40.4 40.5 40.6 40.7 40.8 40.9 41.0 41.1 41.2 41.3 41.4 41.5 41.6 41.7 41.8 41.9 42.0 42.1 42.2 42.3 42.4 42.5 42.6 42.7 42.8 42.9 43.0 43.1 43.2 43.3 43.4 43.5 43.6 43.7 43.8 43.9 44.0 44.1 44.2 44.3 44.4 44.5 44.6 44.7 44.8 44.9 45.0 45.1 45.2 45.3 45.4 45.5 45.6 45.7 45.8 45.9 46.0 46.1 46.2 46.3 46.4 46.5 46.6 46.7 46.8 46.9 47.0 47.1 47.2 47.3 47.4 47.5 47.6 47.7 47.8 47.9 48.0 48.1 48.2 48.3 48.4 48.5 48.6 48.7 48.8 48.9 49.0 49.1 49.2 49.3 49.4 49.5 49.6 49.7 49.8 49.9 50.0 50.1 50.2 50.3 50.4 50.5 50.6 50.7 50.8 50.9 51.0 51.1 51.2 51.3 51.4 51.5 51.6 51.7 51.8 51.9 52.0 52.1 52.2 52.3 52.4 52.5 52.6 52.7 52.8 52.9 53.0 53.1 53.2 53.3 53.4 53.5 53.6 53.7 53.8 53.9 54.0 54.1 54.2 54.3 54.4 54.5 54.6 54.7 54.8 54.9 55.0 55.1 55.2 55.3 55.4 55.5 55.6 55.7 55.8 55.9 56.0 56.1 56.2 56.3 56.4 56.5 56.6 56.7 56.8 56.9 57.0 57.1 57.2 57.3 57.4 57.5 57.6 57.7 57.8 57.9 58.0 58.1 58.2 58.3 58.4 58.5 58.6 58.7 58.8 58.9 59.0 59.1 59.2 59.3 59.4 59.5 59.6 59.7 59.8 59.9 60.0 60.1 60.2 60.3 60.4 60.5 60.6 60.7 60.8 60.9 61.0 61.1 61.2 61.3 61.4 61.5 61.6 61.7 61.8 61.9 62.0 62.1 62.2 62.3 62.4 62.5 62.6 62.7 62.8 62.9 63.0 63.1 63.2 63.3 63.4 63.5 63.6 63.7 63.8 63.9 64.0 64.1 64.2 64.3 64.4 64.5 64.6 64.7 64.8 64.9 65.0 65.1 65.2 65.3 65.4 65.5 65.6 65.7 65.8 65.9 66.0 66.1 66.2 66.3 66.4 66.5 66.6 66.7 66.8 66.9 67.0 67.1 67.2 67.3 67.4 67.5 67.6 67.7 67.8 67.9 68.0 68.1 68.2 68.3 68.4 68.5 68.6 68.7 68.8 68.9 69.0 69.1 69.2 69.3 69.4 69.5 69.6 69.7 69.8 69.9 70.0 70.1 70.2 70.3 70.4 70.5 70.6 70.7 70.8 70.9 71.0 71.1 71.2 71.3 71.4 71.5 71.6 71.7 71.8 71.9 72.0 72.1 72.2 72.3 72.4 72.5 72.6 72.7 72.8 72.9 73.0 73.1 73.2 73.3 73.4 73.5 73.6 73.7 73.8 73.9 74.0 74.1 74.2 74.3 74.4 74.5 74.6 74.7 74.8 74.9 75.0 75.1 75.2 75.3 75.4 75.5 75.6 75.7 75.8 75.9 76.0 76.1 76.2 76.3 76.4 76.5 76.6 76.7 76.8 76.9 77.0 77.1 77.2 77.3 77.4 77.5 77.6 77.7 77.8 77.9 78.0 78.1 78.2 78.3 78.4 78.5 78.6 78.7 78.8 78.9 79.0 79.1 79.2 79.3 79.4 79.5 79.6 79.7 79.8 79.9 80.0 80.1 80.2 80.3 80.4 80.5 80.6 80.7 80.8 80.9 81.0 81.1 81.2 81.3 81.4 81.5 81.6 81.7 81.8 81.9 82.0 82.1 82.2 82.3 82.4 82.5 82.6 82.7 82.8 82.9 83.0 83.1 83.2 83.3 83.4 83.5 83.6 83.7 83.8 83.9 84.0 84.1 84.2 84.3 84.4 84.5 84.6 84.7 84.8 84.9 85.0 85.1 85.2 85.3 85.4 85.5 85.6 85.7 85.8 85.9 86.0 86.1 86.2 86.3 86.4 86.5 86.6 86.7 86.8 86.9 87.0 87.1 87.2 87.3 87.4 87.5 87.6 87.7 87.8 87.9 88.0 88.1 88.2 88.3 88.4 88.5 88.6 88.7 88.8 88.9 89.0 89.1 89.2 89.3 89.4 89.5 89.6 89.7 89.8 89.9 90.0 90.1 90.2 90.3 90.4 90.5 90.6 90.7 90.8 90.9 91.0 91.1 91.2 91.3 91.4 91.5 91.6 91.7 91.8 91.9 92.0 92.1 92.2 92.3 92.4 92.5 92.6 92.7 92.8 92.9 93.0 93.1 93.2 93.3 93.4 93.5 93.6 93.7 93.8 93.9 94.0 94.1 94.2 94.3 94.4 94.5 94.6 94.7 94.8 94.9 95.0 95.1 95.2 95.3 95.4 95.5 95.6 95.7 95.8 95.9 96.0 96.1 96.2 96.3 96.4 96.5 96.6 96.7 96.8 96.9 97.0 97.1 97.2 97.3 97.4 97.5 97.6 97.7 97.8 97.9 98.0 98.1 98.2 98.3 98.4 98.5 98.6 98.7 98.8 98.9 99.0 99.1 99.2 99.3 99.4 99.5 99.6 99.7 99.8 99.9 100.0 100.1 100.2 100.3 100.4 100.5 100.6 100.7 100.8 100.9 101.0 101.1 101.2 101.3 101.4 101.5 101.6 101.7 101.8 101.9 102.0 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7. Budgetary Cost Estimates

- **Cost Estimating Basis**
- **Scope of Supply and Interfaces**
- **Summary of Budgetary Costs for Tidd Slipstream HGCU Project**
- **Scope of Detailed Design**
- **Breakdown of Budgetary Equipment and Installation Costs**

COST ESTIMATING BASIS

- Pressure vessel (SA 515 Grade 70; Carbon Steel), 310 stainless steel plenum/mounts, RA-333 tubesheet prorated from as-built costs for 3 pilot scale filter systems (Nov. 1988) and Grimethorpe design. Materials cost estimate from Rolled Alloys.
- Internal insulation costs from 2 vendor quotations for TIDD system
- I&C equipment from vendor quotations
- Filter elements from COORS budgetary quotation
- Structural framing, freight, setting in place, assembly and painting based on factored estimates

SCOPE OF SUPPLY AND INTERFACES

	<u>W</u>	<u>AEP or OTHER</u>
• Detailed Test Plan	X	
• Software Development	X	
• Test System Facilities, Specification		X
• Detailed Design of Filter Unit	X	
• Equipment Procurement	X	
• Installation of Equipment	X	X
• Preoperational Testing	X	X
• Experimental Method Verification		X
• Operational Testing	X	X
• Materials Evaluation	X	X
• Instrumentation & Data Acquisition		
- Data Acquisition (Filter Unit)	X	
- Gas and Dust Sampling		X
- Ash Flow Measurement		X
- Solids Analysis		X
- Air and Flue Gas Flow Measurements		X

SUMMARY OF BUDGETARY COSTS FOR
TIDD SLIPSTREAM HGCU PROJECT

Program Element	Estimated Labor Hours	Budgetary Price (1000 Dollars)
Detailed Design	5200	490
Equipment Procurement Assembly and Installation	4800	1620
Commissioning/Operation Decommissioning	3200	260
Post Test Materials Evaluation	1160	90
Subtotal for Design/Supply/Testing		2460
Support Programs		
1. Cold Flow Tests FW Unit	1280	170
2. Gasket/Valve Reliability	1430	150
3. Large Module Pulse Tests	2350	250
4. Cake Adhesion/Release	1580	150
Subtotal for Support Programs		720
ESTIMATED TOTAL COSTS		3180

	Costs by Calendar Year			
	1989	1990	1991	1992
Design/Supply/Operate	-	600	1570	290
Support Programs	150	570		
	150	1170	1570	290

SCOPE OF DETAILED DESIGN

ACTIVITY	SCOPE
Project Technical Requirements	AEP/DOE/Westinghouse Design Reviews Review Field Test Results Review Bench/Field Tests HGCU Test Program Definition Assemble Procurement Packages Finalize Cost and Schedule Estimates Quality Assurance Management/Topical Reports
System Design	Finalize PFD's and H&M Balances Thermal Analysis of Startup and Shutdown Subsystem Interface Requirements Operating Procedures Failure Modes and Hazards Analysis Specify Utility Requirements
Mechanical Design	Tubesheet Finite Element Analysis Tubesheet Life Cycle Assessment Tubesheet Welding Specifications General Assembly of System Pressure Vessel Details Internal Lining Details Tubesheet Details Blowback Components
I&C Components	P&I Diagrams: Overall System P&I Diagrams: Blowback System Electrical Wiring Diagrams DAS Interface Requirements Finalize Valve Specifications
Filter Media	X-Flow Midrib/Flange Details Field Mounting and Assembly Plan Post Test Inspection/Cleanout Plan Define Qualifications Criteria

BREAKDOWN OF BUDGETARY EQUIPMENT AND INSTALLATION COSTS

1. Equipment Costs	
Filter Vessel	\$ 93,240
Internal Insulation	38,190
Tubesheet Assembly	153,400
Shroud/Liner Plenums	101,340
Filter Elements (25% Spare)	240,000
	<hr/>
Subtotal	\$ 626,170
2. Auxiliary Equipment and Installation Costs	
I&C with Panel, Installed	\$ 211,500
Pulse Air Supply (Spare Compressor)	34,300
Vessel Support Frame	9,000
Labor to Set/Assemble Internals	57,370
Misc. (Freight, Painting, Travel, etc.)	71,700
	<hr/>
Subtotal	\$ 383,870
3. Engineering, Support and Indirects	\$ 610,240

8. PROGRAM SCHEDULE AND COMPONENT LEAD TIMES

- Schedule Rationale
- Program Schedule (Revised)
- Major Equipment Lead Times
- Identification of I&C Delivery

SCHEDULE RATIONALE

- Detailed design likely to begin by January 1990.
- Schedule assumes W would place order for RA333 Billet to be rolled into plate prior to selecting fabricator. This is to ensure on time delivery of plate to selected fabricator.
- Schedule assumes boiler code hydro testing includes tubesheet assembly. Pressure vessel could likely be hydro tested without tubesheet assembly should delays occur.
- Schedule includes assembly fit-up at pressure vessel fabricator site prior to shipping to Tidd site.
- Filter elements delivered to Westinghouse for inspection, testing and plenum fit-up.

MAJOR EQUIPMENT LIST

Material Identification and Procurement Lead Time
(Cross Flow Filter System for TIDD Slipstream HGCU)

<u>No.</u>	<u>Item</u>	<u>Material</u>	<u>Lead Time weeks</u>
1.0	PRESSURE VESSEL		
	Shell	SA-515-Gr 70	18
	Inlet/Outlet Piping	SA-515-Gr 70	18
	Girth Flanges	SA-105	20
	Flange Bolts	SA-193 B7	4
	Internal Insulation	Ceramic Fiber Blanket	4
	Internal Liner	310 S.S.	10
	Vessel Support Steel	SA-283-Gr C	4
	Gaskets	Spiral Wound Asbestos/304 SS	4
	Gas Distribution Shroud	Incoloy 800 H	16
2.0	FILTER INTERNALS		
	Cross Flow Filter Elements	Alumina per Coors Formula	18-24
	Filter Plenums & Mounts	310 S. S.	16
	Filter Braces	Alumina Tie Rods	4
	Dust Seals	Encapsulated Interam or eq.	4
	Mounting Clamps	310 S. S.	4
	Tubesheet/Expansion Joint	RA-333	22-36
3.0	PULSE CLEANING SYSTEM		
	Accumulator Tank	To Be Provided by AEPSC	
	Compressor	To Be Provided by AEPSC	
	Isolation Valves	See I & C List	8
	Solenoid Valves	See I & C List	10
	Internal Pulse Tubes	Incoloy 800 H	18
	Venturi Tubes	310 S. S.	16
	Misc. I & C Equipment	See I & C List	2-6

ID no.	Item/Function	Quantity	Vendor (Preliminary)	Lead Time (weeks)
<u>Indicators</u>				
TI-101	Temperature Indicator - Multichannel (#400A1A-OK-F-001A)	1	Marlin	5
	Switch for above (#405A-10)	1	Marlin	5
PI-101	Pressure Indicator - Digital (model DP202)	2	Omega	2
<u>Recorders/Data Acquisition</u>				
FR-101	Flow Recorder (model 2702)	1	Molytec (32 channels)	6
PR-101	Pressure Recorder (P/N P100M/13/111/111)	1	Capp (3 Pen)	6
TR-101	Temperature Recorder (model 2702)	1	Molytec (32 channels)	6
PDR-102	High-Speed Recorder for Plenum Pulse Pressures (N-08377-80)	1	Cole-Parmer	6
DAC-100	PC-Computer/Drive/Printer	1	IBM	4
<u>Thermocouples</u>				
TE-101	Dirty Gas Temperatures in Filter Vessel (# 040-310-K-1G-0-0-1PF-84)	3	Marlin	5
TE-102	Multipoint Tubesheet & Plenum Temps. (# 040-310-K-1G-0-0-1PF-48)	6	Marlin	5
TE-103	Clean Gas Temperature (after filtration) (# 040-310-K-1G-0-0-1PF-48)	3	Marlin	5
<u>Transmitters</u>				
FT-101	Venturi Gas Flows (#1151DP 4E 22 B1, I5)	4 or 9*	Rosemount	6
PT-101	Clean Side of Tubesheet Gas Pressure (model 1144G 0600A 12 I5)	1	Rosemount	6
PDT-101	Differential Pressure across Tubesheet (#1151DP 4E 22 B1, I5)	1	Rosemount	6
PDT-102	Plenum Pulse Differential Pressures (model 220)	4 or 9*	Viatran	6
FT-201	Flow Sensor for Blowback Lines (FPT-6230)	3 or 4*	Omega	6
PT-201	Blowback Pulse Tank Pressure (model 1144G 2000A 12 I5)	1	Rosemount	2
<u>Valves</u>				
HV-101	Instrumentation Valves (# SS-1VS4)	40	Whitey	2
FV-101	Solenoid Valves for Protection of Instr from Press Pulse (#8262A131-E)	30	ASCO	5
HV-201	Ball Valves for Isolation of Solenoid Valves (#4B2200RT)	12 or 16*	Jamesbury	8
FV-201	Blowback Pulse Solenoid Valves (# 35871)	6 or 8*	Atkomatic	10
FV-202	Ball Valves w/ Remote Actuator for Blowback Lines (#4B2200RT)	8 or 15*	Jamesbury	8
PCV-201	Pressure Regulator for Blowback Gas Accumulator Tank (# 44-1012-24)	1	Tescom	3
PCV-202	Pressure Regulator for Blowback Solenoid Valve Pilots (#44-112-24)	1	Tescom	3
PSV-201	Pressure Safety Valve for Blowback Accumulator Tank (Fig. 264)	1	Kunkle	2

Venturi FE-101 Venturi for each Filter Plenum (W design)

	4 or 9*	Harliss Metal Fabricators	6
<u>Other Components</u>			
Metal Gaskets & Spares Vessel Head & Nozzles	14	Argo Packing	4
Programmable Logic Controller	1	Modicon or Allen-Bradley	5
Control cabinets (Bud #AGR-9304)	2	Pioneer	4
Heat Tracing for Blowback Accumulator Tank (# D/R24S2/23/155/120/14/Y/EP)	1	Chromalox	2
Controllers for above - (AR-514EP & AR-715EP)	1	Chromalox	2
Tubing & Fittings for instrumentation lines (field fitted)	various	Pgh. Valve	2
Conax fittings (sealing glands)	various	M.S. Jacobs	5
Spare Thermocouples (# 040-310-K-1G-0-0-1PF- various lengths)	6	Marlin	3
Spare ASCO Solenoid Valves ((#8262A131-E)	4	ASCO	6
Rosemont Power Supply for Pressure Transmitters (Mod 515)	2	Rosemont	2
Terminal Box for above (part no. 2002188)	1	Rosemont	2

* Item quantity depends on whether 4 or 9 plenum design is chosen.

END

**DATE
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