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ENGINEERING DEVELOPMENT OF COAL-FIRED HIGH-PERFORMANCE POWER SYSTEMS

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TECHNICAL PROGRESS REPORT 1
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INTRODUCTION

In Phase 1 of the project, a conceptual design of a coal-fired high performance power system was developed, and small scale R&D was done in critical areas of the design. The current Phase of the project includes development through the pilot plant stage, and design of a prototype plant that would be built in Phase 3.

Foster Wheeler Development Corporation (FWDC) is leading a team of companies in this effort. These companies are:

- AlliedSignal Aerospace Equipment Systems
- Bechtel Corporation
- TRW, Inc.
- University of Tennessee Space Institute (UTSI)
- Westinghouse Electric Corporation

The power generating system being developed in this project will be an improvement over current coal-fired systems. Goals have been identified that relate to the efficiency, emissions, costs and general operation of the system. These goals are:

- Total station efficiency of at least 47 percent on a higher heating value basis.
- Emissions:
  - NOx < 0.06 lb/MMBtu
  - SOx < 0.06 lb/MMBtu
  - Particulates < 0.003 lb/MMBtu
- All solid wastes must be benign with regard to disposal.
- Over 95 percent of the total heat input is ultimately from coal, with initial systems capable of using coal for at least 65 percent of the heat input.
- Ten percent lower cost of electricity (COE) relative to a modern coal-fired plant conforming to NSPS.

The base case arrangement of the HIPPS cycle is shown in Figure 1. It is a combined cycle plant. This arrangement is referred to as the All Coal HIPPS because it does not require any other fuels for normal operation. A fluidized bed, air blown pyrolyzer converts coal into fuel gas and char. The char is fired in a high temperature advanced furnace (HITAF) which heats both air for a gas turbine and steam for a steam turbine. The air is heated up to 1400 F in the HITAF, and the tube banks for heating the air are constructed of alloy tubes. The fuel gas from the pyrolyzer goes to a topping combustor where it is used to raise the air entering the gas turbine to 2350°F. In addition to the HITAF, steam duty is achieved with a heat recovery steam generator (HRSG) in the gas turbine exhaust stream and economizers in the HITAF flue gas exhaust stream.

An alternative HIPPS cycle is shown in Figure 2. This arrangement uses a ceramic air heater to heat the air to temperatures above what can be achieved with alloy tubes. This arrangement is referred to as the 35 percent natural gas HIPPS. A pyrolyzer is used as in the base case HIPPS, but the fuel gas generated is fired upstream of the ceramic air heater instead of in the topping combustor. Gas turbine air is heated to 1400 F in alloy tubes the same as in the All Coal HIPPS. This air then goes to the ceramic air heater where it is heated further before going to the topping combustor. The temperature of the air leaving the ceramic air heater will depend on technological developments in that component. An air exit temperature of 1800°F will result in 35 percent of the heat input from natural gas.

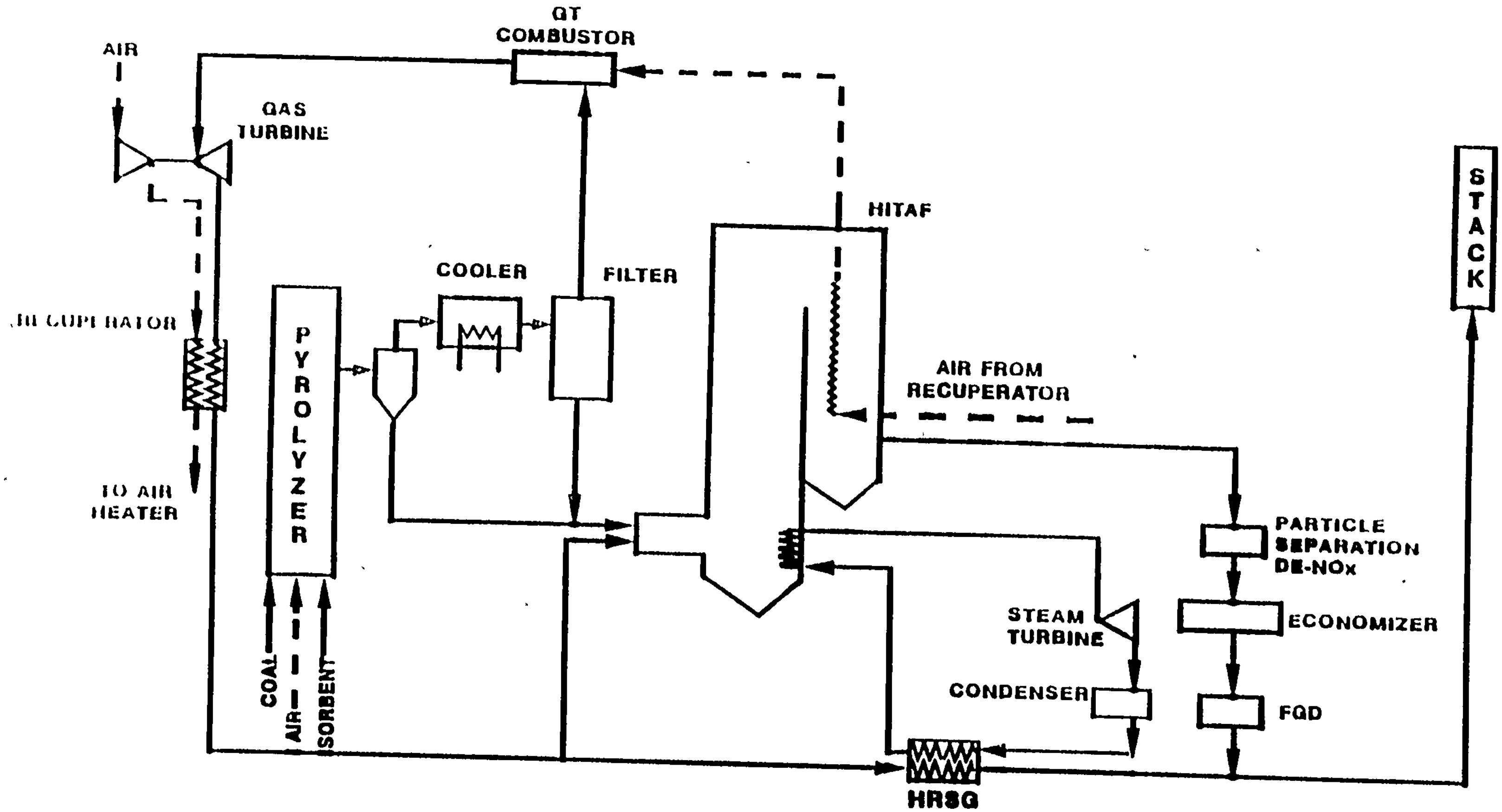


Figure 1 All Coal-Fired HIPPS

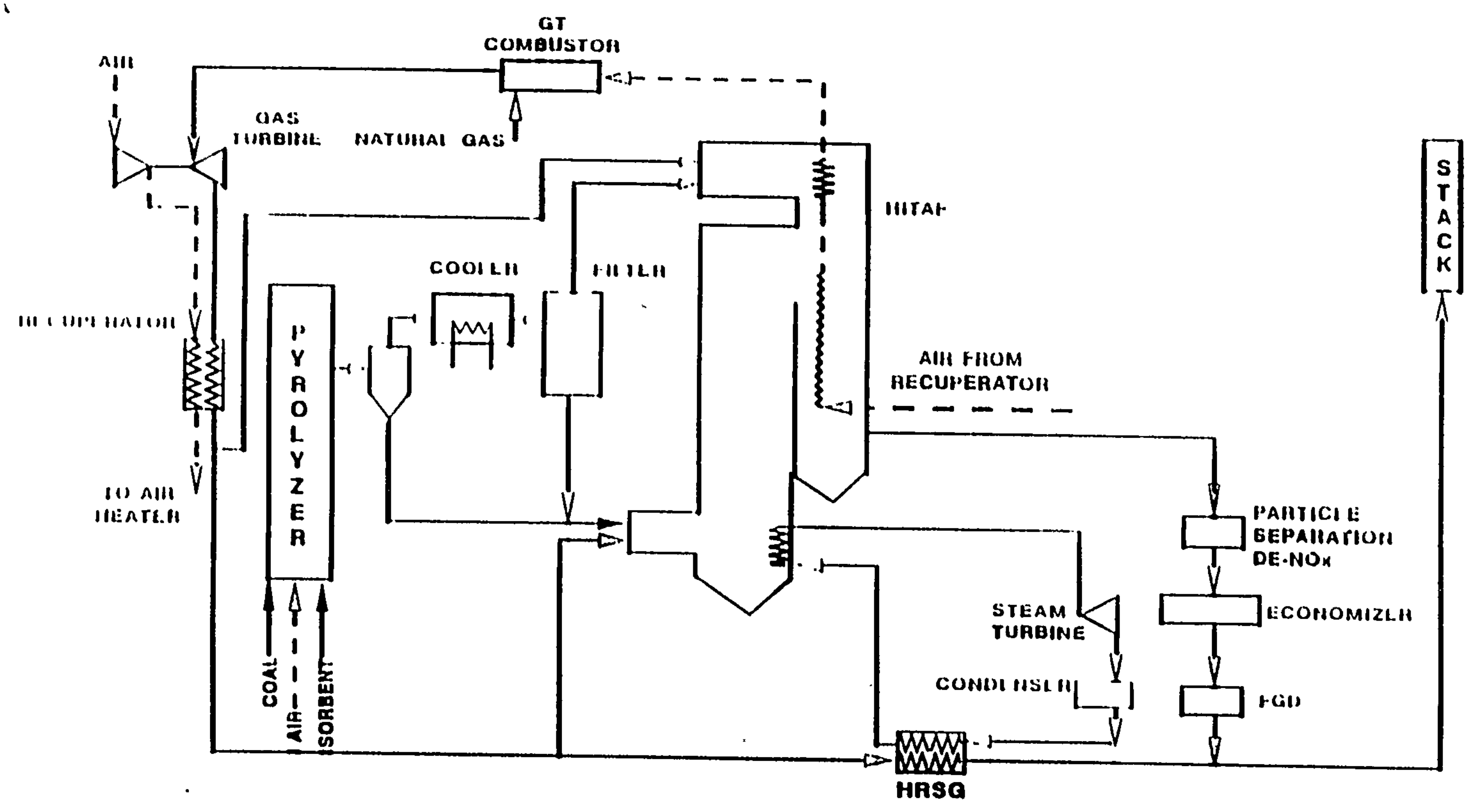


Figure 2 35 Percent Natural Gas HIPPS

TECHNICAL PROGRESS

Task 1 - Project Planning and Management

The following technical and management reports were completed and submitted to DOE in this quarter:

- Project Plan
- Management Plan
- Environmental Plan
- Hazardous Substance Plan

A meeting was held at PETC on October 31 and November 1. All the team members were represented as were personnel from PETC and project advisors. Team members presented the status of the various required technologies and the plan for HIPPS development. Phase 1 R&D results were presented along with the planned activities for Phase 2.

As specified in the Phase 2 Statement of Work, Bechtel is reviewing the Commercial Plant design that was developed in Phase 1. One area that is being revisited is the feeding of char and sorbent to the pyrolyzer. In the Phase 1 design, a paste feed system was specified. Using a paste feed system puts additional constraints on the particle size distributions (PSD) of the feedstocks. The feedstock size requirements that will yield acceptable char PSD's for the char combustor will not necessarily be optimum for a paste feed. Bechtel is in the process of doing plant performance analyses with dry feed to the pyrolyzer.

Task 2 - Engineering Research and Development

Subtask 2.2 - Restrictive Pipe Discharge (RPD) System Cold Test

The test rig for the cold RPD tests has been designed, and construction has started. The design is based on the dimensions that will be used in the Pyrolyzer/Char Transport Test (PCTT). The RPD pipe will be 4 in. I.D. x 20 ft. Long. A schematic diagram of the test rig is shown in Figure 3.

Char/sorbent material from the Second-Generation PFB pilot plant tests has been sent to IGT for use in the cold RPD tests. Quantities sufficient for tests of three different PSD's have been included in the shipment. These PSD's are shown in Figure 4. The middle PSD approximates the PSD that is expected with the base case HIPPS design. This would be the situation where char is generated in the pyrolyzer in the right size range to be fed directly to the TRW char combustor. The coarser size distribution approximates what would be expected if a jetting bed pyrolyzer were used and the char was depressurized, cooled and sent to pulverizers. This type of system is being considered as a near term option for repowering. The finest char/sorbent distribution

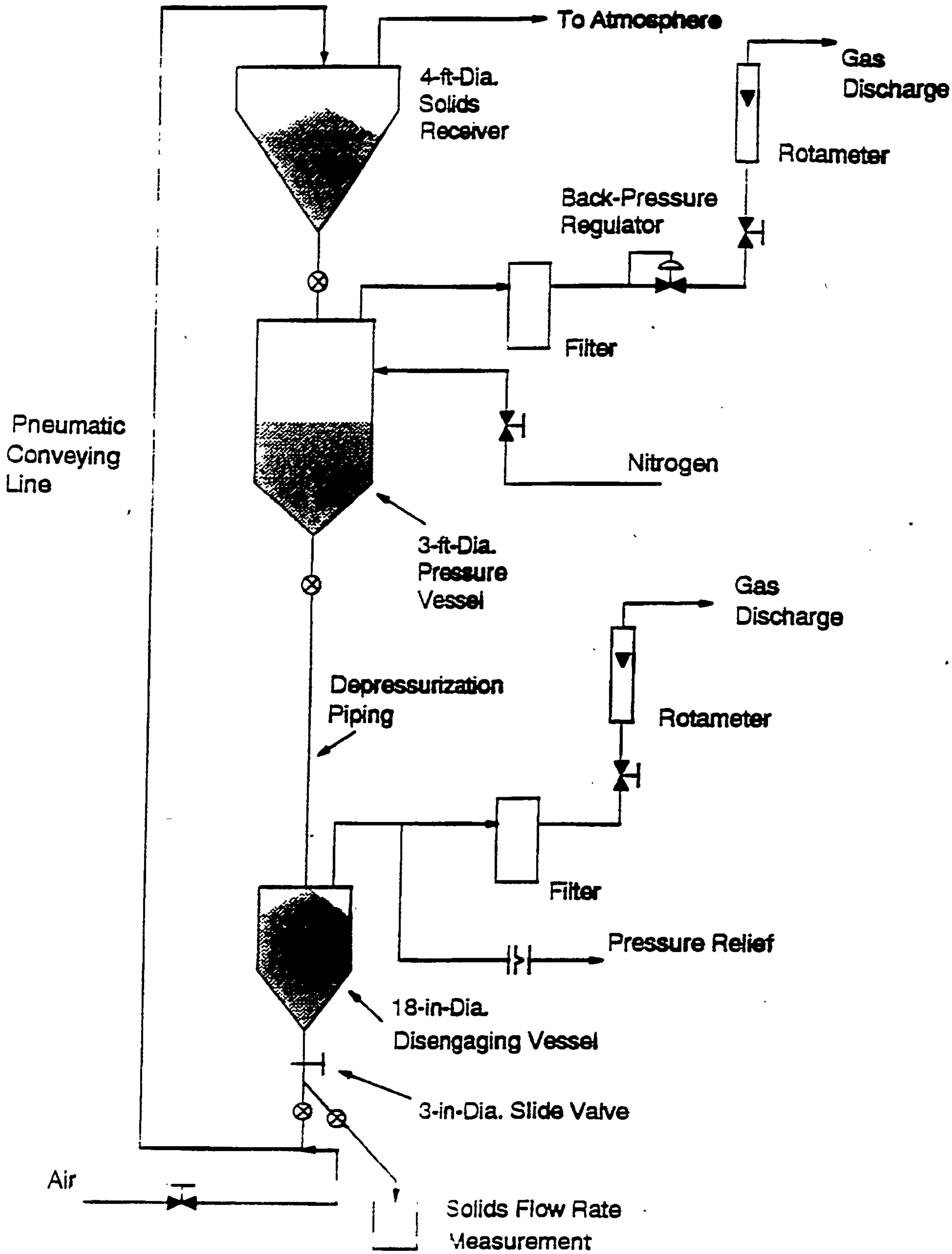


Figure 3 Schematic Drawing of RPDS Test Facility

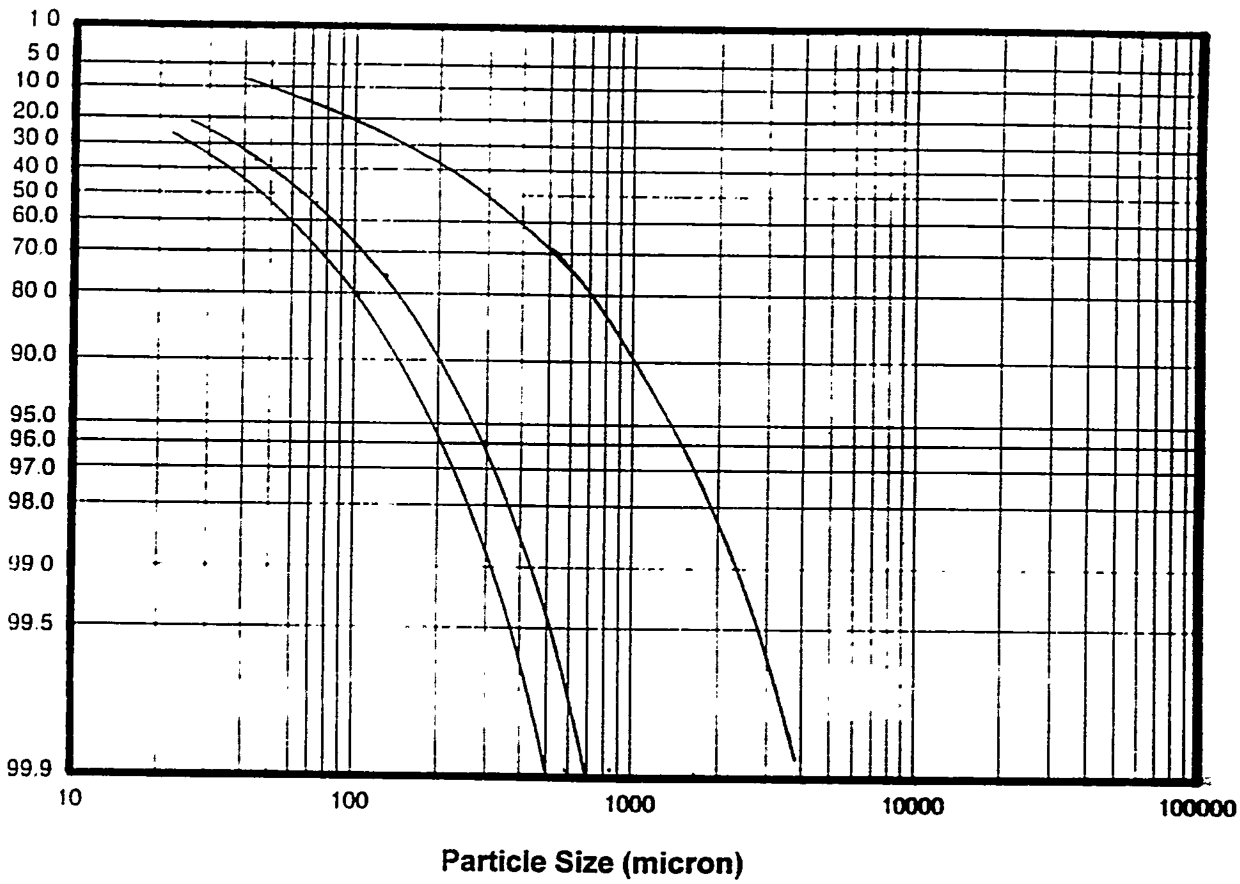


Figure 4   Approximate Particle Size Distributions for RPD Cold RPD Tests

represents the fine end of a range of PSD's that could be used in the TRW combustor.

A test matrix for the cold RPD tests is contained in Table 1. Solids flow rates and pressures correspond to the range that is expected in the PCTT. In addition to general operability information, the following data will be obtained at each operating point:

- Solids flow rate in depressurization pipe
- Gas flow rate from disengaging vessel
- Pressure profile in depressurization pipe
- Pressures in pressure vessel and disengaging vessel

The cold RPD testing is expected to begin in January.

Task 3 - Subsystem Test Unit Design

Subtask 3.1 - Pyrolyzer/Char Transport Test Design

The Second-Generation PFB pilot plant in Livingston, New Jersey is being modified for use as the PCTT. A schematic diagram of the PCTT is shown in Figure 5a and 5b.

The existing pyrolyzer will be modified to operate as a circulating fluidized bed. The facility has the capability of both dry and paste feed to the pyrolyzer. It is planned that at least the initial runs will be with dry feed. There will be provision for changing the cyclone design during the test campaign. Solids will be drained from the bottom of the bed as required to maintain bed level, but the goal is to have almost all the char leave the primary cyclone with the fuel gas.

In the initial test runs, the char/fuel gas stream will go directly to the barrier filter vessel where the solids will be separated from the fuel gas. The barrier filter is part of the existing pilot plant. It is a Westinghouse design using ceramic candle filter elements. The barrier filter vessel will also serve as the upper hopper of an RPD system that will be used to depressurize the char. The barrier filter will be modified to accommodate the additional function. A six foot high spool piece will be added to the vessel to add a surge volume and to keep the solids level safely below the candles. Depending on the operating characteristics of the pyrolyzer/riser system, a classifier may be added later. This device would be located between the primary cyclone and the barrier filter as shown in Figure 5a.

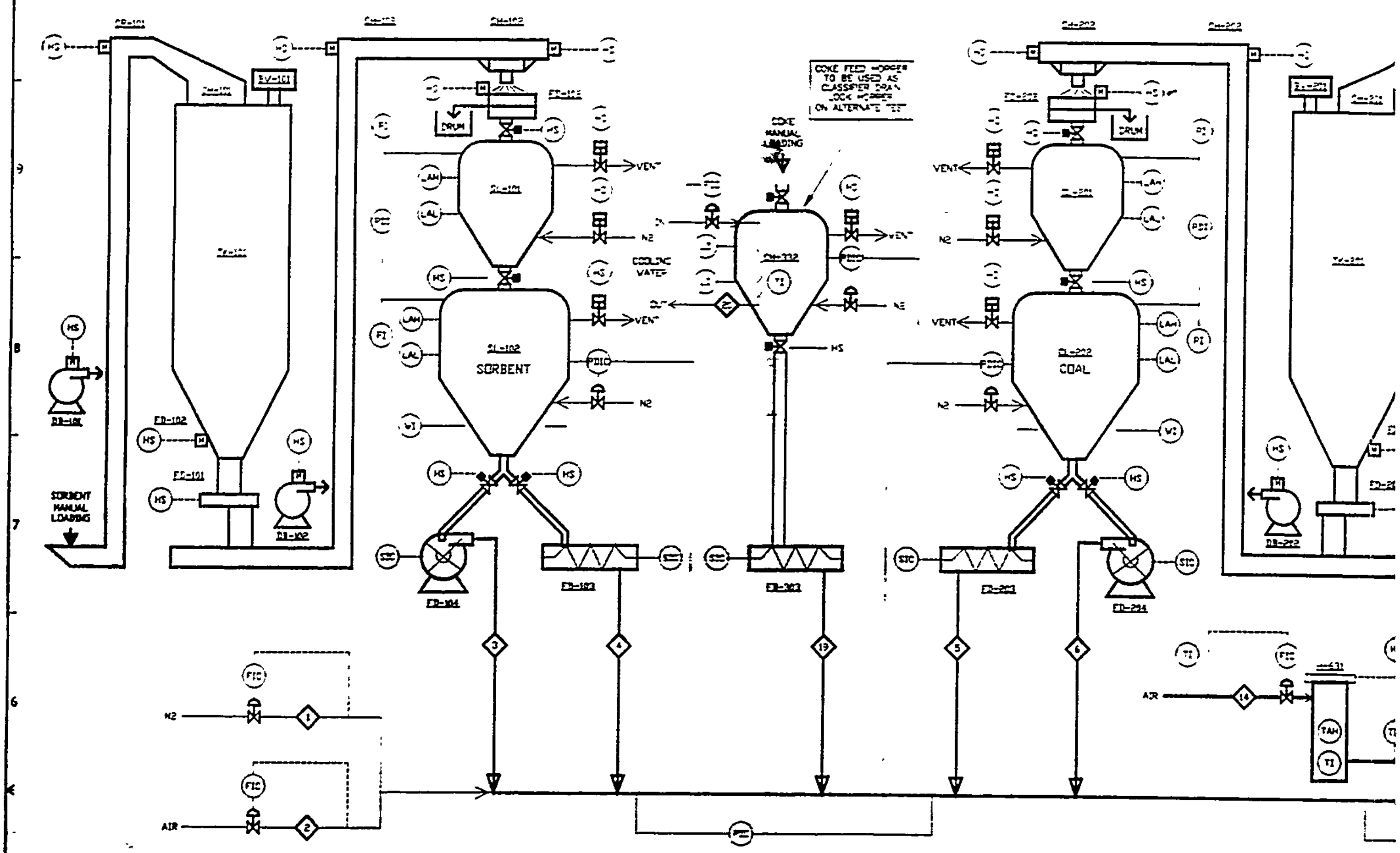
An RPD pipe will be added to the bottom of the barrier filter vessel. A combination of cooling from a steam jacket and direct nitrogen injection will be used to lower the solids temperature to about 450 F entering the lower RPD hopper. Although in normal operation the lower RPD hopper will be at low pressure, the system is being designed for full system pressure through the screw feeder. This approach will give an additional margin of safety. The lower RPD hopper and pressurized

Table 1 RPD Test Matrix

Test No.	Average Particle Size Microns	Pressure psig	Solids Flow Rate lb/h
1	45	225	300
2	45	225	145
3	45	225	80
4	45	225	min
5	45	100	300
6	45	100	145
7	45	100	80
8	45	100	min
9	45	50	300
10	45	50	145
11	45	50	80
12	45	50	min
13	70	225	300
14	70	225	145
15	70	225	80
16	70	225	min
17	70	100	300
18	70	100	145
19	70	100	80
20	70	100	min
21	70	50	300
22	70	50	145
23	70	50	80
24	70	50	min

Table 1 RPD Test Matrix (continued)

Test No.	Average Particle Size Microns	Pressure psig	Solids Flow Rate lb/h
25	300	225	300
26	300	225	145
27	300	225	80
28	300	225	min
29	300	100	300
30	300	100	145
31	300	100	80
32	300	100	min
33	300	50	300
34	300	50	145
35	300	55	80
36	300	50	min



DB-101	**CH-101**	**BV-101**	**DB-102**	**CR-102**	**FD-102**	**SL-102**
DUST BLOWER #1	SORBENT SHUTE #1	SORBENT SILO BIN VENT	DUST BLOWER #2	SORBENT FEED Z CONVEYOR	SORBENT SILO SCREEN DECK	SORBENT FEED HOPPER
HP ___ CFM ___	MAX ___ LB/HR	HP ___ CFM ___	HP ___ CFM ___	MAX ___ LB/HR	MAX ___ LB/HR	VOL ___ LB LO LVL ___ LB HI LVL ___ LB

FD-104	**CK-302**	**CL-202**	**FD-202**
FIRTH PUMP	COKE FEED HOPPER	COAL FEED HOPPER	COAL SILO SCREEN DECK
MAX ___ LB/HR	VOL ___ LB LO LVL ___ LB HI LVL ___ LB	VOL ___ LB LO LVL ___ LB HI LVL ___ LB	MAX LB/HR ___

CR-101	**TK-101**	**FD-102**	**FD-101**	**CH-102**	**SL-101**	**FD-103**
SORBENT SILO BUCKET ELEVATOR	SORBENT SILO	LIVE BOTTOM	SORBENT VIBRATING FEEDER	SORBENT SHUTE #2	SORBENT PRESSURIZING LOCK HOPPER	SORBENT SCREW FEEDER
MAX ___ LB/HR	MAX ___ LB/HR	HP ___	MAX ___ LB/HR	MAX ___ LB/HR	VOL ___ LB LO LVL ___ LB HI LVL ___ LB	MAX ___ LB/HR

FD-204	**FD-203**	**CL-201**
FIRTH PUMP	COAL SCREW FEEDER	COAL PRESSURIZING LOCK HOPPER
MAX ___ LB/HR	MAX ___ LB/HR	VOL ___ LB LO LVL ___ LB HI LVL ___ LB

STREAM NUMBER	1		2		3		4		5		6		7		8		9		10	11	12	13
	AIR TRANSPORT		NITROGEN TRANSPORT		FIRTH PUMP FEED		SORBENT FEED		FIRTH PUMP FEED		COAL SCREW FEED		PYROLYZER COMBINED FEED		RETURN J VALVE HEEL		RETURN J VALVE TOE		PYROLYZER BOTTOM N2	PYROLYZER DRAIN	CLASSIFIER DRAIN	CLASSIFIER STEAM
	FPS	LB/HR	FPS	LB/HR	RPM	LB/HR	RPM	LB/HR	RPM	LB/HR	RPM	LB/HR	FPS	LB/HR	FPS	LB/HR	FPS	LB/HR	LB/HR	LB/HR	LB/HR	LB/HR
													AIR	SOLID								
DESIGN FLOW																						
MAX FLOW																						
MIN FLOW																						
DESIGN PRESS																						
MAX PRESS																						
MIN PRESS																						
DESIGN TEMP																						
MAX TEMP																						
MIN TEMP																						

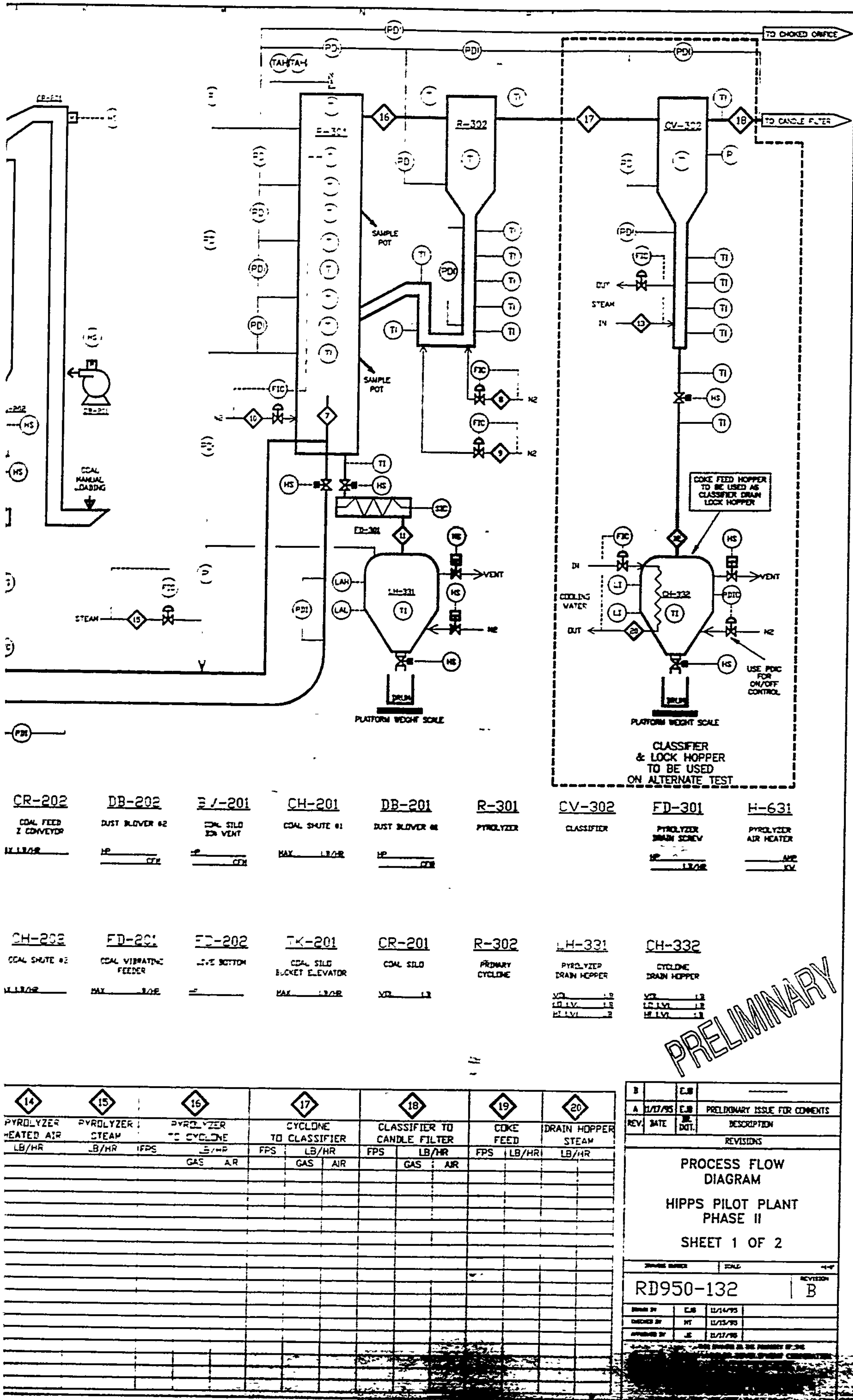
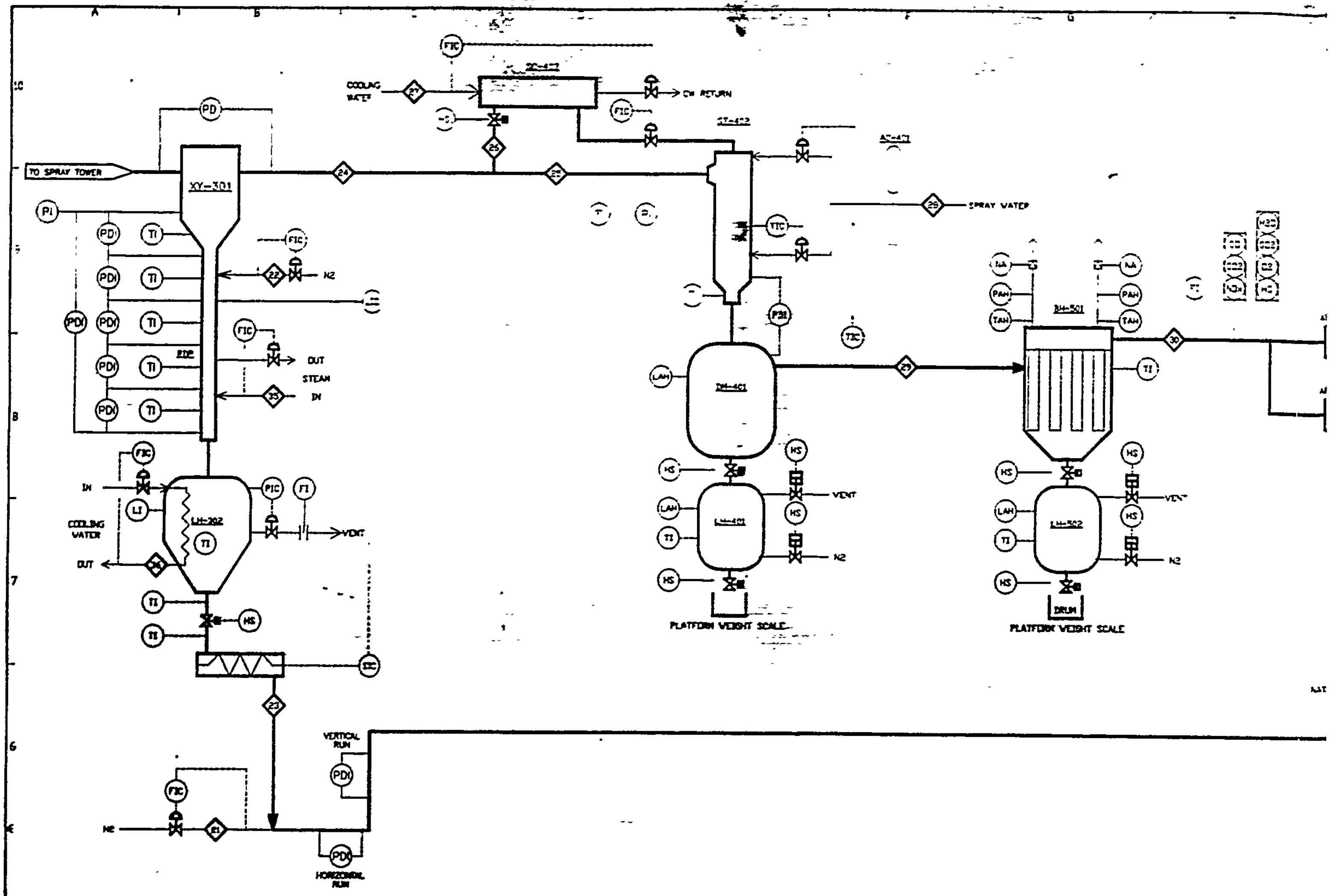


Figure 5a Process Flow Diagram: sheet 1



XY-301
CANDLE FILTER

FD-302
CANDLE FILTER DRAIN SCREW
HP ____ LB/HR

ST-402
SPRAY TOWER
GPM ____ CFM

SC-403
SYNGAS COOLER
MAX ____ LB/HR

AC-401
ACCUMULATOR TANK
HP ____ CFM

BH-501
CARBONIZER BAGHOUSE
MAX ____ LB/HR

B-507
INCINERATOR FAN COMBUSTION AIR
MAX ____ CFM

LH-302
CANDLE FILTER DRAIN HOPPER
VOL ____ LB
LO LVL ____ LB
HI LVL ____ LB

DM-401
DEMISTER KNOCKOUT POT
VOL ____ LB
LO LVL ____ LB
HI LVL ____ LB

LH-401
TAR/OIL DRAIN HOPPER
VOL ____ LB
LO LVL ____ LB
HI LVL ____ LB

LH-502
BAGHOUSE LOCK HOPPER
VOL ____ LB
LO LVL ____ LB
HI LVL ____ LB

I-509
INCINERATOR VENDOR CONTROL PANEL

STREAM NUMBER	20	21		22		23	24	25	26	27	28	29	30	INCIN
	RPD SCREW COOLING WATER	RPD AIR TRANSPORT		RPD N2		CANDLE FILTER DRAIN	CANDLE FILTER TO SPRAY TOWER	SPRAY TOWER INLET	SYNGAS COOLER INLET	SYNGAS COOLER COOLING WATER	SPRAY TOWER SPRAY WATER	BAGHOUSE INLET	BAGHOUSE TO STACK	
	GPM	FPS	LB/HR	FPS	LB/HR	LB/HR	LB/HR	LB/HR	LB/HR	GPM	GPM	LB/HR	LB/HR	LB
DESIGN FLOW														
MAX FLOW														
MIN FLOW														
DESIGN PRESS														
MAX PRESS														
MIN PRESS														
DESIGN TEMP														
MAX TEMP														
MIN TEMP														
DENSITY														

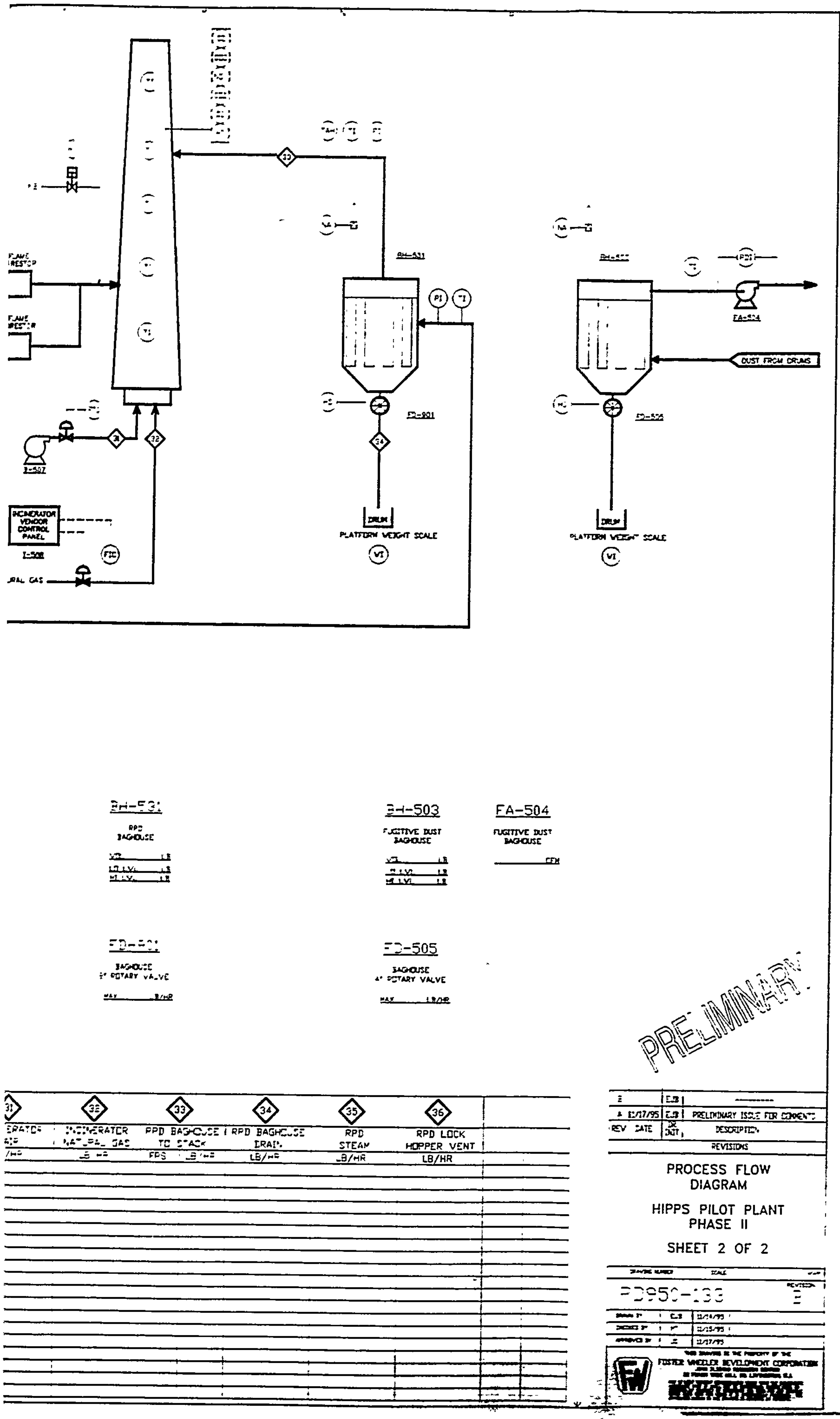


Figure 5b Process Flow Diagram: sheet 2

screw feeder were previously used for other functions in the pilot plant.

Solids from the RPD system will be Pneumatically transported with nitrogen. They will be transported about 50 feet to a baghouse where the solids will be separated from the transport gas. This baghouse is also a component from the original pilot plant that will be reused in the PCTT.

The fuel gas leaving the barrier filter will be divided into two streams. One stream will go to a fixed orifice. This type of a backpressure device approximates the pressure-flow characteristics of a gas turbine, but it will result in a nearly constant pyrolyzer superficial velocity over the range of testing. It is desired to investigate the effects of pyrolyzer superficial velocity in the PCTT so a branch line with a control valve has been added to the system. Adjusting this control valve will in effect allow us to simulate variations in pyrolyzer riser diameters by operating at the superficial velocities that would result from those diameters

Next, the fuel gas goes through a spray cooler and then a final baghouse. After the baghouse, it goes to an incinerator where it is burned before being discharged from the stack.

Work is in progress on the test matrix, process design and equipment design. The system is being modeled on ASPEN to determine the process conditions throughout the planned range of test operation. Preliminary sizing of new pressure vessels and piping has been completed, and an preliminary arrangement drawing has also been completed. Analysis of instrumentation requirements and existing instrumentation availability is in progress. Detailed design of components and specifications for instrumentation will be done in the next Quarter.

Subtask 3.3 - Integrated System Test Design

Most of the design for the Integrated System Test (IST) is not scheduled until later in the project; however, the University of Tennessee Space Institute (UTSI) has started doing some preliminary work on emissions permitting and characterization of furnace performance under HIPPS conditions.

A letter has been received from the State of Tennessee, Air Pollution Control Division, that formally notified UTSI that an air permit will be issued for the existing stack. It will be permitted as a "conditional major source" under Title V of the Clean Air Act Amendments. An additional permit will be required for the flare stack that will burn the fuel gas from the pyrolyzer.

Existing computer models of the UTSI furnace and superheater are being benchmarked with MHD test data and modified to predict operation under HIPPS conditions. Initial estimates indicate the furnace exit temperature will be around 2000 F which is in line with predictions for the commercial plant conceptual design.