



***POWER SYSTEMS  
DEVELOPMENT FACILITY***

***Design, Construction, and  
Commissioning Status***

*DOE Cooperative Agreement No.  
DE-FC21-90MC25140*

*Southern Company Services, Inc.  
Wilsonville, Alabama*

# ***PSDF Program Objective***

Develop advanced coal-based power generation technologies that can produce electricity at competitive cost and meet all environmental standards.



# ***PSDF Program Goal***

**The PSDF is a site where new process configurations and components for advanced power systems can be tested in an integrated process environment at sufficient size to provide data for scale-up toward commercialization. DOE's intent is that:**

- The **PSDF** be recognized by equipment vendors, process developers, and generators of electric power as the **best place to test** new components and integrated process configurations for **advanced power systems**.
- **Data** from the PSDF be recognized as a clear indicator of the usefulness of new components and integrated process configurations for advanced power systems and be **sufficient to support commercial scale-up**.
- Public and private funding agencies recognize the **PSDF** as a readily accessible, politically neutral, **cost effective testing location** for advanced power system components and integrated process configurations.
- The **staff** at the **PSDF** be recognized as **experts** in their respective technologies by all their customers.



# ***Project Overview***

- METC sponsored project to demonstrate two Advanced Coal-fired Power Generation Technologies, three Hot Gas Clean-Up Technologies, and Fuel Cells (future)
- Southern Company Services is acting as Prime Contractor and is responsible for Operation of the facility as well as Design of Balance of Plant (BOP) Equipment, Design Integration, Construction and Start-Up
- M.W. Kellogg (Kellogg), Foster Wheeler (FW), Westinghouse (W), Combustion Power Corp. (CPC) and Industrial Filter and Pump (IF&P) are major participants.



# ***Project Overview***

- Increased integration of process components
- All possible components were commercially available to minimize scale up concerns and allow use of existing technologies if possible.
- Kellogg is supplying a pressurized transport reactor that can be configured as either a combustor or a gasifier.
- Foster Wheeler is supplying an integrated, Advanced Pressurized Fluidized Bed Combustion (APFBC) system, including a gas turbine equipped with a topping combustor supplied by Westinghouse.

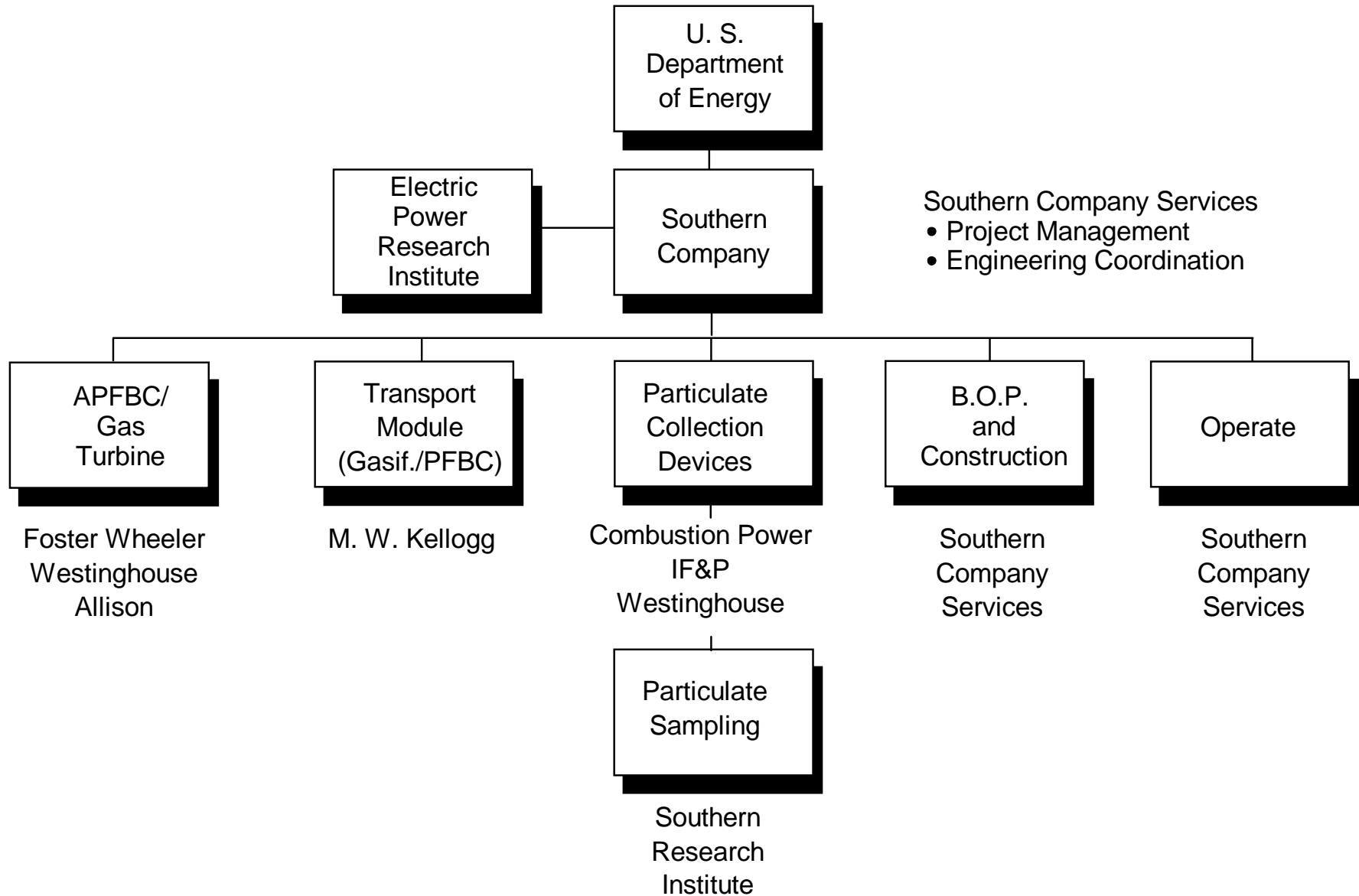


# ***Project Overview***

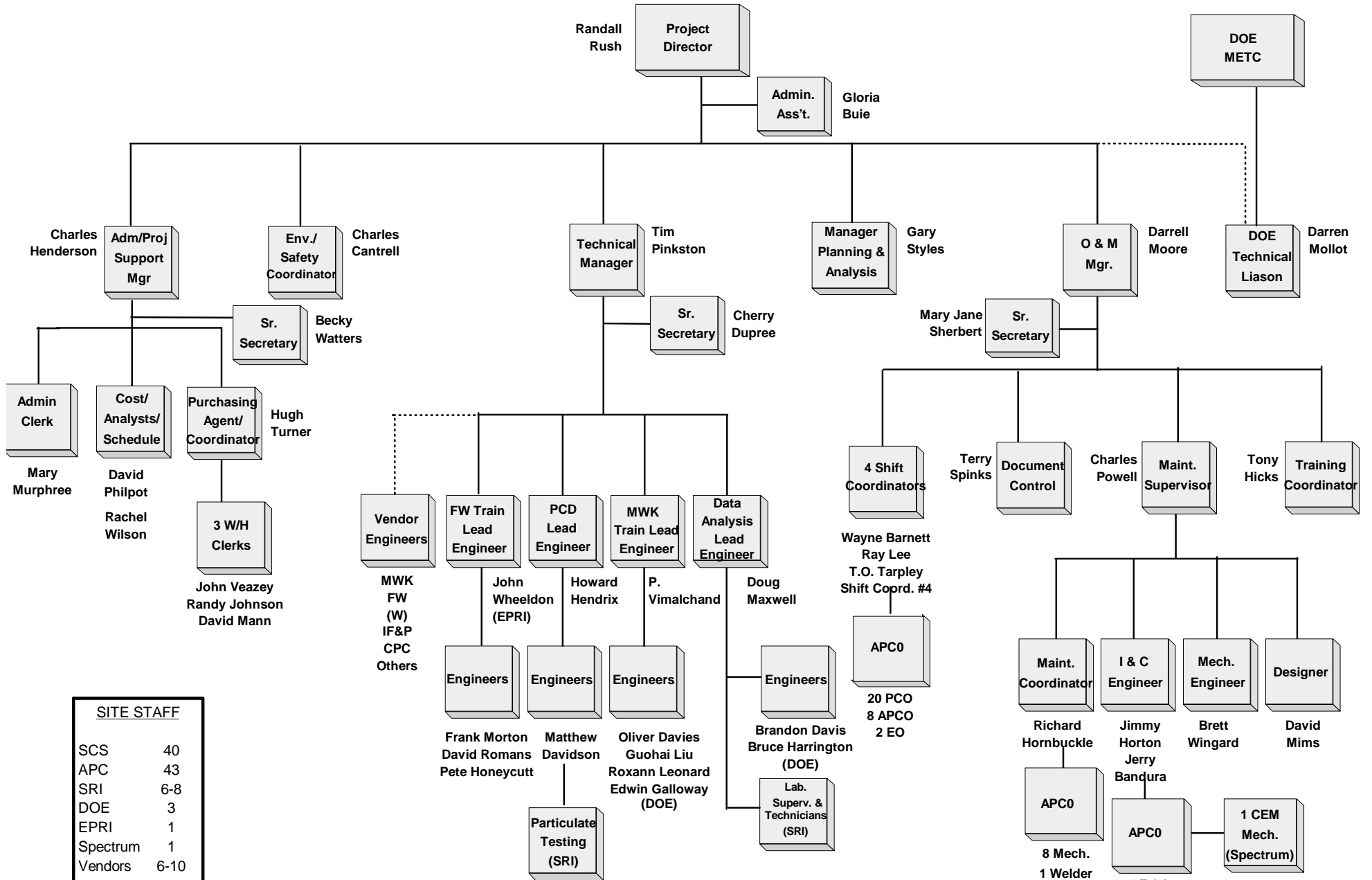
- Particulate Control Devices (or PCD's) are supplied by Westinghouse, CPC, and IF&P.
- Two are using ceramic candle filters (Westinghouse and IF&P).
- CPC is supplying a Granular Bed Filter.
- The ceramic candles are being supplied by several vendors.



# ***PARTICIPANT RESPONSIBILITIES***



# PSDF SITE ORGANIZATION



| SITE STAFF   |                |
|--------------|----------------|
| SCS          | 40             |
| APC          | 43             |
| SRI          | 6-8            |
| DOE          | 3              |
| EPRI         | 1              |
| Spectrum     | 1              |
| Vendors      | 6-10           |
| <b>TOTAL</b> | <b>100-106</b> |



# ***Project Status***

- Design and Engineering are complete, except for electrical integration of Foster Wheeler equipment, which will be complete this fall.
- Construction of Kellogg and Kellogg required BOP equipment is complete.
- Start-up of BOP equipment began last September with the electrical station service.
- Start-up of Kellogg's transport reactor as a combustor is in the final stages.
- Several design enhancements have been incorporated during construction to improve operability during system malfunctions.



# ***Design Enhancements***

- Start-Up Bed Material Injection Spools
- Propane Supply Option Spools
- Steam Supply Piping Modifications
- PCD Warm-Up Modifications
- Using Primary Gas Cooler as a Condensation Heater
- Using Sulfator Start-Up Heater
- Using a Screw Cooler to Cool Pulverized Coal
- Using Process Air to Fluidize the Combustion Heat Exchanger
- Nitrogen Purge Connections



# ***Systems Operational***

- Electrical Station Service
- Distributed Control and Data Collection
- Cooling Water Systems
- Instrument, Control, and Service Air
- Feedstock (Coal and Sorbent) Storage, Reclaim and Preparation
- Condensate and Steam Generation
- Kellogg Process and Transport Air
- Reactor Aeration, Instrument Purge, Spoiling and Fluidization
- Dense Phase Transport of Feedstock and Ash



# ***Systems Operational***

- Burners on Thermal Oxidizer, Sulfator Start-up Heater and Transport Reactor Start-up Heater
- Ash Cooler Heat Transfer Fluid and Screw Coolers
- Recycle Gas Compressor
- Westinghouse PCD Backpulse
- Baghouse and Thermal Dilution Fan
- Liquid Nitrogen Storage and Delivery
- Propane Storage and Delivery
- Backpulse Air



# ***Issues Encountered***

- Piping and electrical conduit density in the process structure
- First of a kind specification requirements
- Aggressive schedule forcing design decisions
- Exotic material requirements due to temperature, pressure and chemical activity
- Designs for single case, limiting range of operation
- Pneumatic pressure boundaries
- Gas sampling at pressure and temperature
- Feedstock injection into pressurized reactor
- Suitable start-up bed materials for reactors



# ***Design Issues***

## ***Piping Density in the Process Structure***

- Due to cost constraints, the structure was reduced in size by 20' in both directions.
- Every pressure tap must be supplied with a purge gas (Nitrogen) that must be metered and flow controlled to minimize biasing.
- Fluidization requires many aeration nozzles to prevent layout of solids.
- Staged combustion and controlled gasification require fine control of location and flow of combustion (oxidizing) air.
- PSDF transport reactor has as many connections as a 150 MW unit would.



# ***Design Issues***

## ***First of a Kind Specification Requirements***

- Specifications for coal and limestone size require additional equipment and feedstock wastage to achieve design requirements.
- Conservatism in inclusion of alkalai getters, cyclones, baghouses, and sulfator into process designs
- High Nitrogen usage, especially during start-ups and shut-downs
- Requirements for specialized alloys of limited availability and high price
- Incomplete or untried control configuration



# ***Design Issues Aggressive Schedule***

- Aggressive schedule forcing design decisions
- Coal (feedstock) prep building started before the pulverizers were purchased, requiring modification before installation could be completed.
- Cooling water system redesign caused by increased requirements of Foster Wheeler, and other vendors' equipment
- Station service equipment being modified in response to increasing electrical loads
- This aggressive schedule did force project to progress.





# ***Design Issues***

## ***Specialized Material Requirements Due to Temperature, Pressure and Chemical Activity***

- Gas Analyzers
- Recycle Gas Compressor Piping
- Foster Wheeler's Carbonizer Gas Valves and Piping
- Reactor Emergency Pressure Let-down Piping
- Gas Cooler Bypass Orifices



# ***Design/Operation Issues***

## ***Designs for Single Case, Limits Range of Operation***

- Several instances of design short-comings
  - *Transport reactor start-up burner*
  - *Transport reactor pressure control valve*
  - *Recycle gas compressor control logic*
  - *Dense phase transport control logic*
  - *Transport reactor process air compressor control logic*
- Kellogg Process Control is not yet integrated, unable to link process variables of different systems to allow smooth parametric changes



# ***Design/Operation Issues***

## ***Pneumatic Pressure Boundaries***

- Reactors using piping lined with two layers of refractory totaling 9 inches thick
- Refractory lined piping 36" in diameter weigh several hundred pounds per running foot
- Due to weight and size, the piping is difficult to assemble in place, requiring each joint to be caulked and sealed with flexatalic gaskets.
- Flexatalic gaskets are fragile during storage and installation and are single use only.



# ***Design/Operation Issues***

## ***Pneumatic Pressure Boundaries***

- Refractory is hygroscopic and requires specialized curing procedures after thirty days at ambient air conditions.
- Problems with long term storage of un-cured refractory required minor repairs.
- Vessels and piping have rate of change restrictions on temperature and pressure to prevent cracking and failures
- A pressure test is required after every inspection or maintenance.



# ***Design/Operation Issues***

## ***Gas Sampling at Pressure and Temperature***

- First of a kind engineering to extract dust- laden samples at temperature and pressure
- Several gas components have dew points over 700F, and the liquid phase is highly corrosive.
- Requires exotic alloys for strength and corrosion protection
- Concentrations and compounds require specialized analyzers.



# ***Design/Operation Issues Feedstock Injection into Pressurized Reactor***

- Tidd and Other PFBC Plants Use Hybrid Slurry Pumps to Inject Feedstock
  - *Add water to process*
  - *High maintenance items*
- PSDF Using Dense Phase Feed Technology
  - *Dry conveying using Nitrogen or air as transport media*
  - *Metering feedstock and transport media*
  - *Using pressures less than 20 psi higher than reactor*



# ***Operation Issues***

## ***Suitable Start-Up Bed Materials for Transport Reactor***

- Friable Alumina Initially Procured and used
  - *Fluidizes well, and temperature resistant*
  - *Twice as dense as other feedstocks, causing problems with dense phase equipment*
  - *Very hard and abrasive, causing failure of control valve*
- Spherical Alumina
  - *Nonabrasive, fluidizes well*
  - *Hard to procure, very dense*



# ***Operation Issues***

## ***Suitable Start-Up Bed Materials for Reactors***

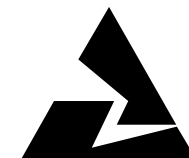
- River Sand
  - *Used at Tidd*
  - *High Silica will not withstand heat*
- Furnace Ash
  - *Difficulty in finding adequate source*
- Conclusion: Use Alumina Until Enough Transport Reactor Ash is Generated.
  - *Pre-sized, dry, inert, temperature resistant*





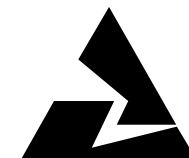
# ***Progress to Report***

- Passed reactor pressure test with no welds failing and few minor flange leaks
- Canded Westinghouse PCD with no candle breakage
- Thermal oxidizer refractory was cured to 1600F, and thermal oxidizer was nearly 1000 hours of operation
- Sulfator/PCD warm-up heater refractory cured in 4 days of operation
- Successfully balanced purge flows to zero differential pressure transmitters at three reactor pressure settings



# ***Progress to Report***

- Successfully fired reactor start-up burner to cure reactor refractory lining to 1000F
- Successfully fluidized reactor with alumina as start-up bed material; circulating bed material through the reactor, riser, and heat exchanger at circulation rates of up to 90,000 lbs/hr and velocities to 45 ft/sec
- Demonstrated operation of feeders under pressure with alumina
- Preparing for the Foster Wheeler combustor refractory cure
- Currently firing with coal at 165 PSI



# ***Future Plans***

- July - Aug: Operate transport reactor as combustor for shake-down trials
- Sept - Oct: Operate transport reactor as combustor for parametric testing
- Oct - Nov: Operate transport reactor as gasifier for shake-down trials
- Nov - Mar '97: Operate transport reactor as gasifier for parametric testing
- Apr - May '97: Operate transport reactor as combustor for shake-down trials of Combustion Power's granular bed filter



# *Future Plans*

- Apr - May '97: Foster Wheeler Combustion Turbine Start-Up
- Sept - Oct '97: PFBC Start-Up of Foster Wheeler
- Jan - Feb '98: APFBC Start-Up of Foster Wheeler

