RECOVERY OF WATER FROM BOILER FLUE GAS

DOE Project DE-FC26-06NT42727

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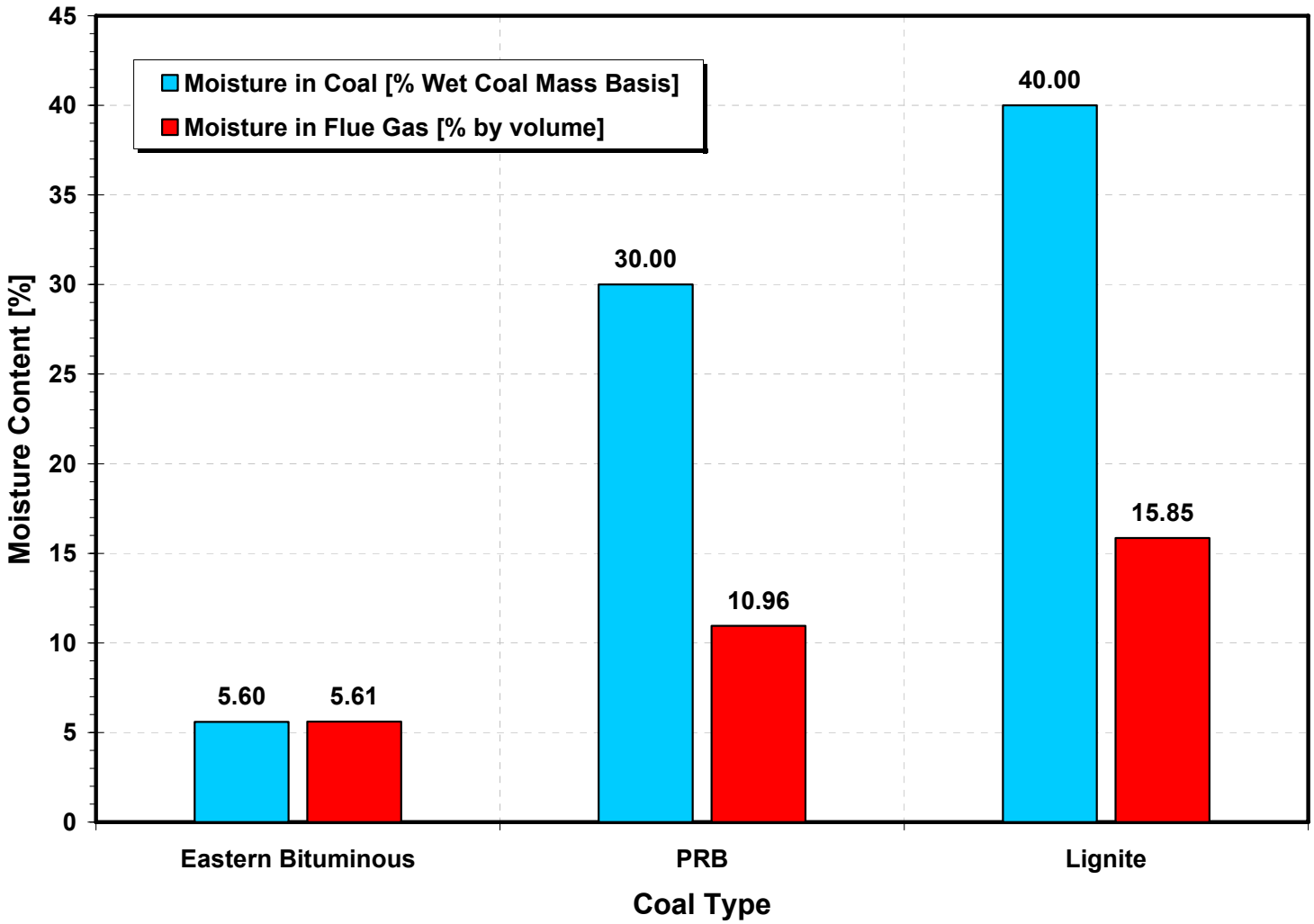
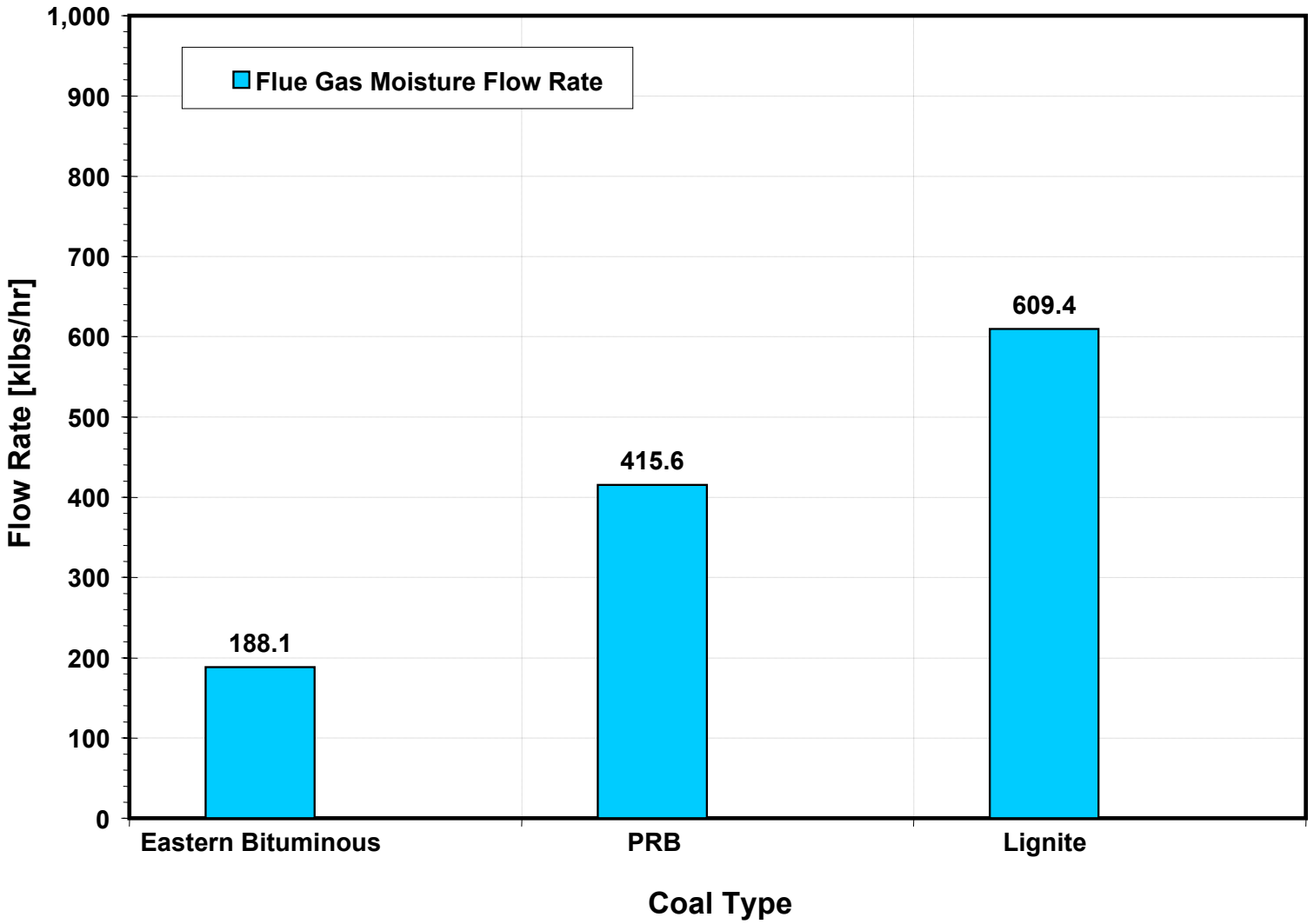
MOISTURE IN BOILER FLUE GAS

- Fuel Moisture
- H_2O From Oxidation of Fuel Hydrogen
- Water Vapor in Combustion Air



Effects of Coal Rank on Coal Moisture and Flue Gas Moisture



Typical Coal and Flue Gas Moisture Flow Rates for 600 MW Power Plants

- **FLUE GAS MOISTURE FLOW RATE IN 600 MW UNIT**

  0.2 to 0.6 x 10^6 lbm/hr

- **TYPICAL COOLING TOWER WATER EVAPORATION RATE**

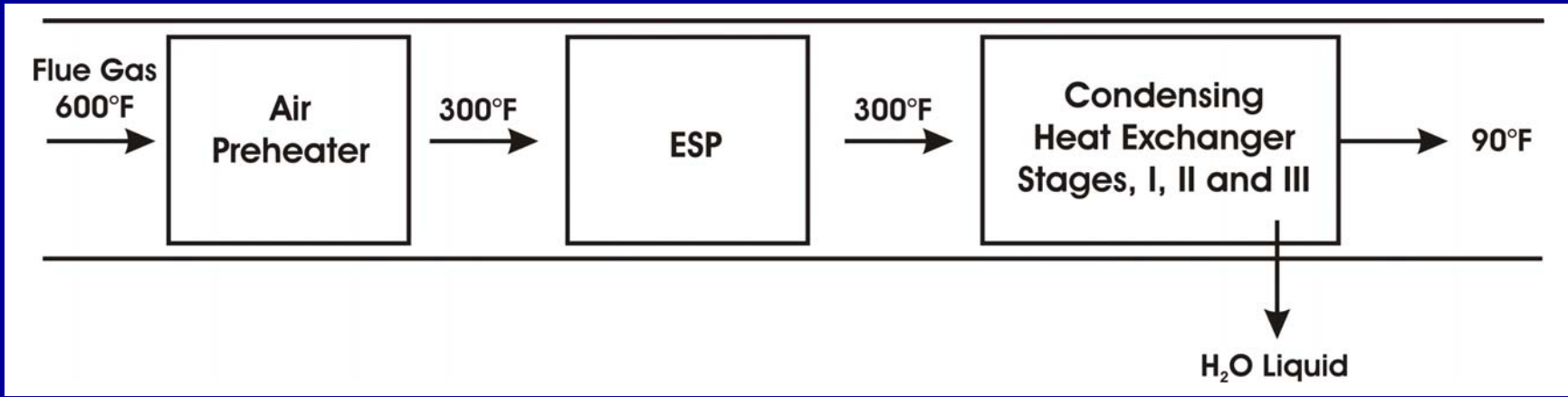
  1.6 x 10^6 lbm/hr

- **IF COULD EXTRACT ALL THE FLUE GAS MOISTURE AND USE IT FOR COOLING TOWER MAKEUP**

	% of Cooling Tower Makeup
PRB	25
Lignite	37

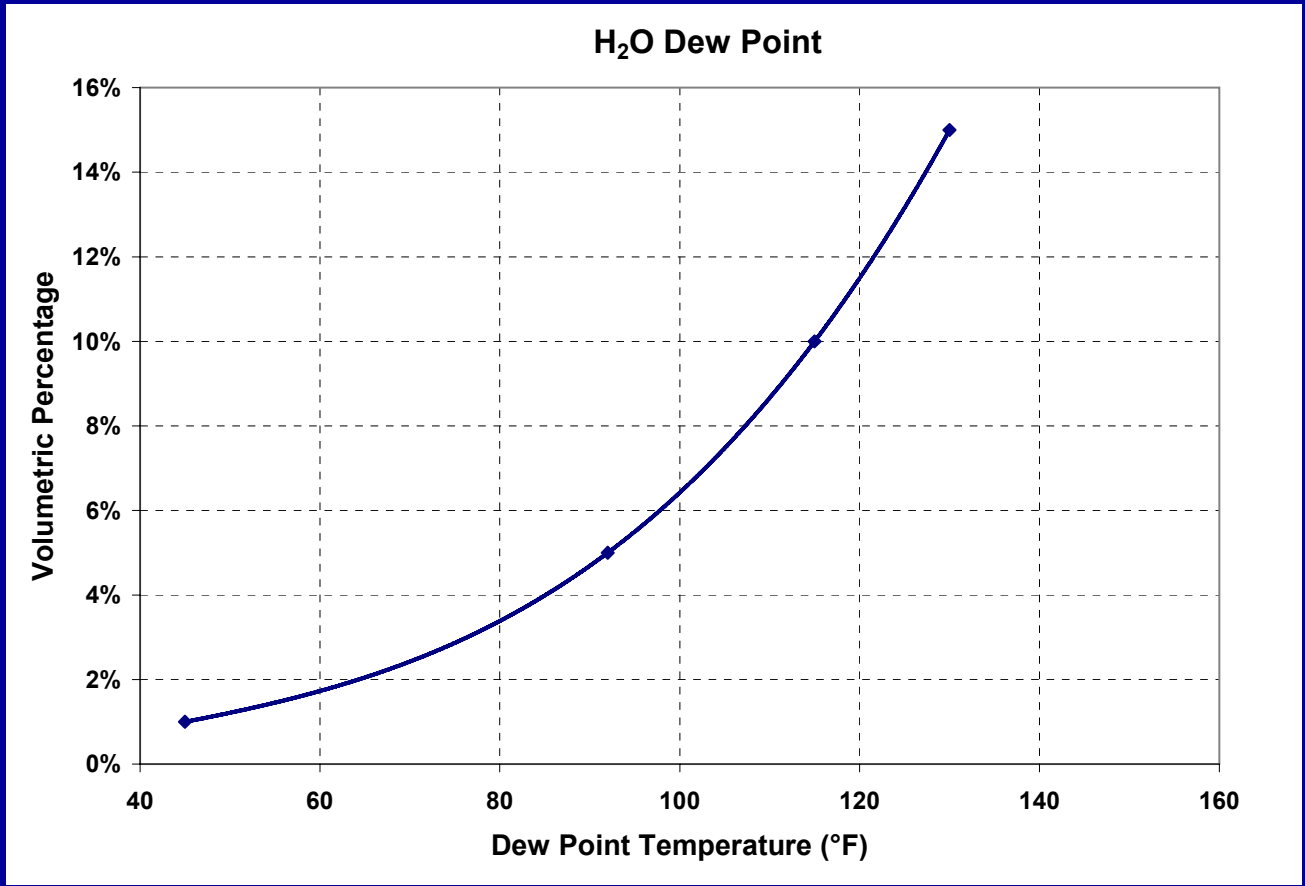
APPROACH

Use Condensing Heat Exchangers to Separate H_2O From Flue Gas



Condensing Heat Exchanger System Located Downstream of ESP

DEW POINTS



Dew Point of Water as Function of Volumetric Percentage of Water in Flue Gas

FLUE GAS ALSO CONTAINS H_2SO_4, HCl AND HNO_3 VAPORS

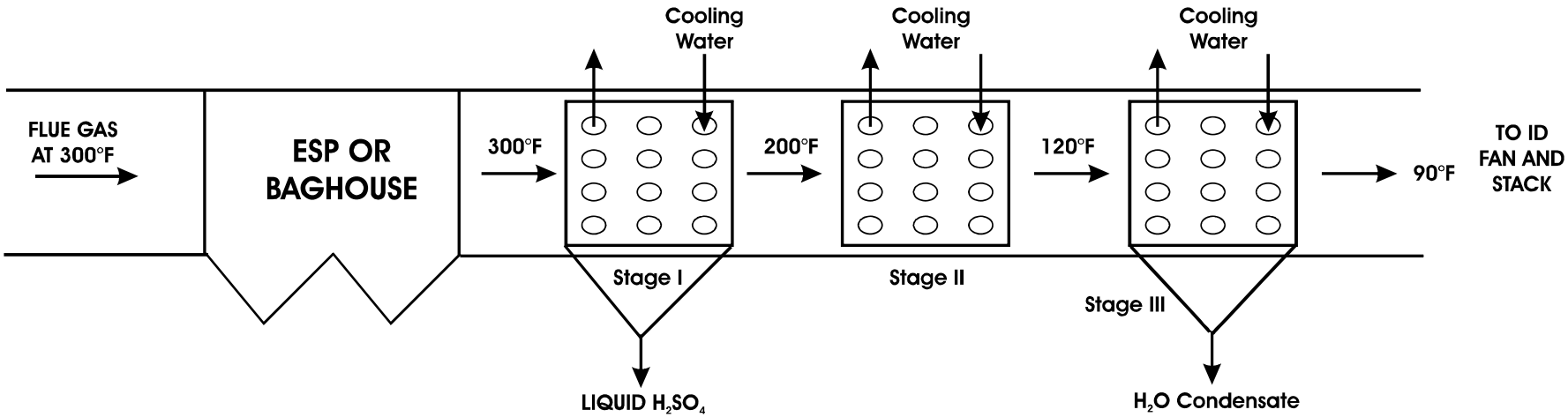
H_2SO_4 Condenses 200 to 320°F

HCl Condenses 80 to 130°F

HNO_3 Condenses 50 to 120°F

PROCESS DESCRIPTION

- Multistage Heat Exchangers Separately Condense H_2SO_4, H_2O and HCl From Flue Gas



BENEFITS

- Multistage Approach Minimizes Overall Cost of Heat Exchanger System
- Recovered Water Will Supply Up to 25% (for PRB) to 37% (for lignite) of Cooling Tower Makeup Water

HEAT RATE IMPROVEMENT

Boiler Efficiency Calculation – Heat Loss Method

	Stack Temperature	
	300°F	90°F
Heat Loss Due to Dry Gas (%)	6.00	0.60
Heat Loss Due to Moisture in Fuel (%)	0.37	0.15
Heat Loss Due to H_2O From Fuel Hydrogen (%)	3.81	1.80
Heat Loss Due to Unburned Carbon (%)	0.26	0.26
Radiation Loss (%)	0.16	0.16
TOTAL LOSSES	10.60	2.97
Boiler Efficiency (%)	89.40	97.03

$$\text{UNIT HEAT RATE} = \frac{HR_{CYCLE} \times P_g}{\eta_{BOILER}\left(P_g - P_{ss}\right)}$$

- Increased Boiler Efficiency Yields Reduced Heat Rate

CO-BENEFITS

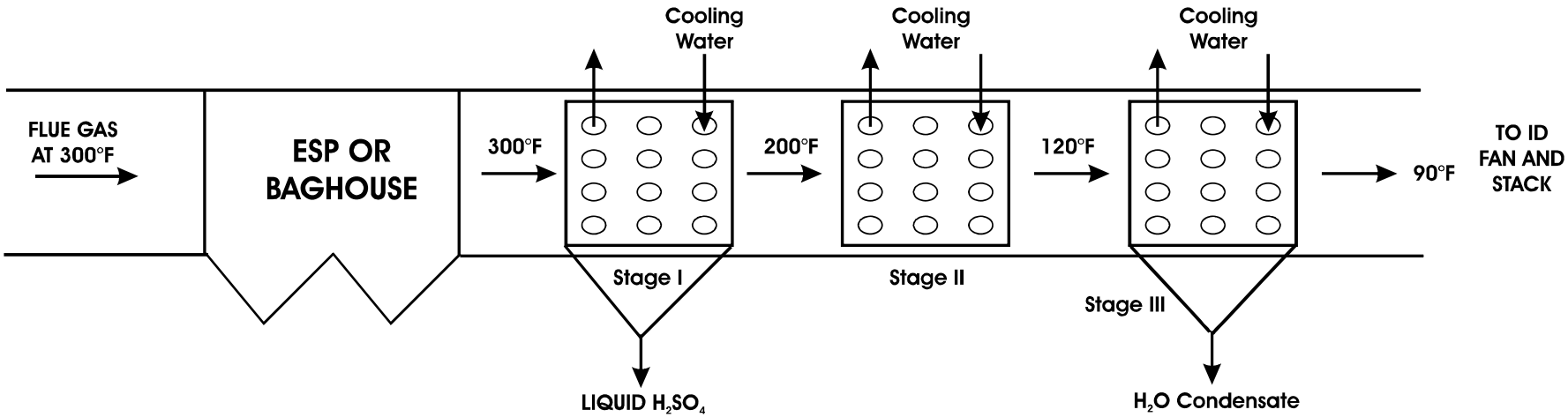
- Unit Heat Rate Reduced By Up to 7% By Recovering Sensible and Latent Heat
- Lower Heat Rate Results in Reductions of CO_2, NO_x, SO_2, and Hg Emissions
- Process Eliminates Acid Plume Problem

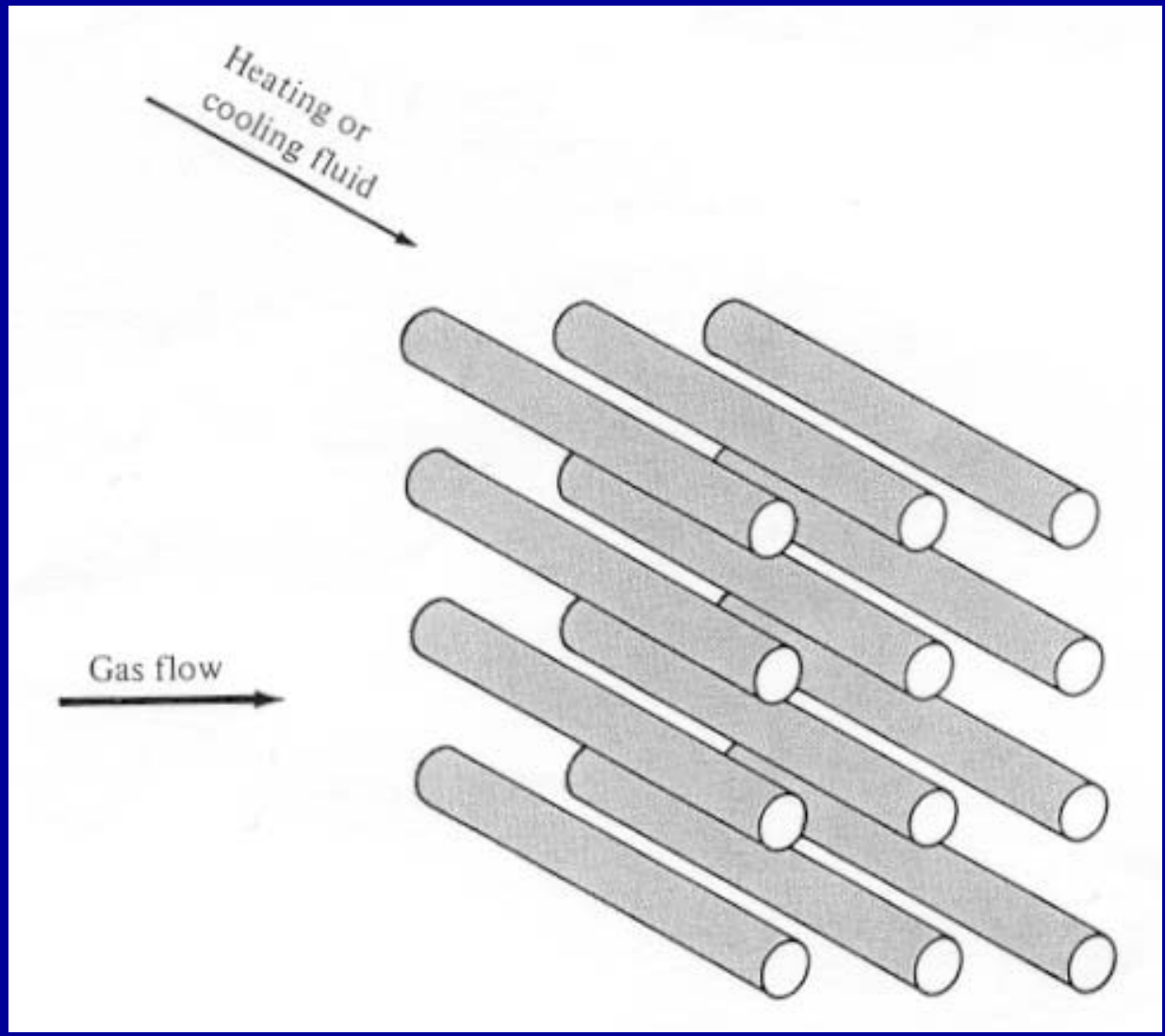
PROJECT OBJECTIVES

- Determine the Extent to Which Removal of Acid Vapors From Flue Gas and Condensation of H_2O Vapor Can Be Achieved in Separate Heat Transfer Sections
- Estimate Potential Heat Rate Reduction

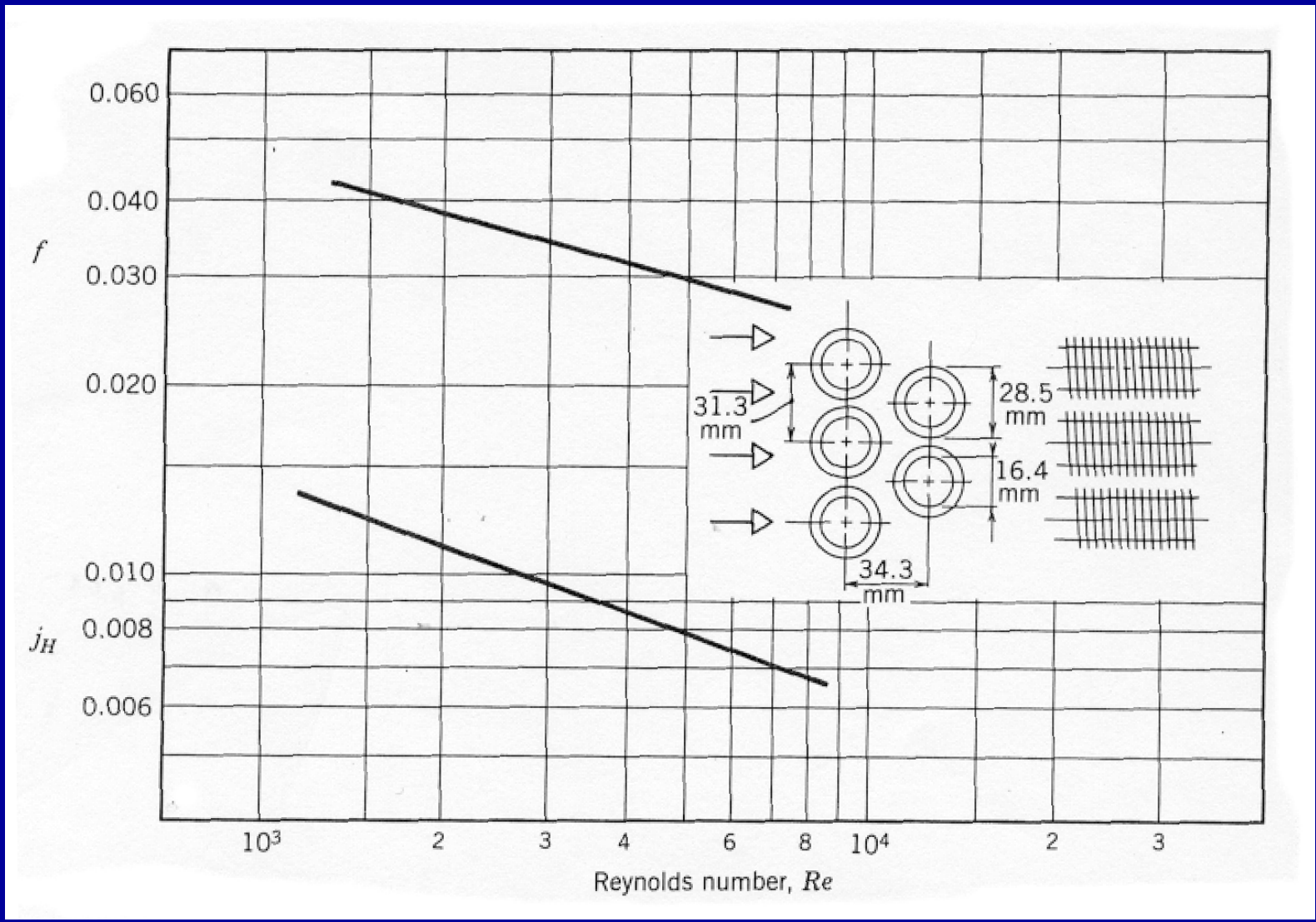
PROCESS DESCRIPTION

- Multistage Heat Exchangers Separately Condense H_2SO_4, H_2O and HCl From Flue Gas

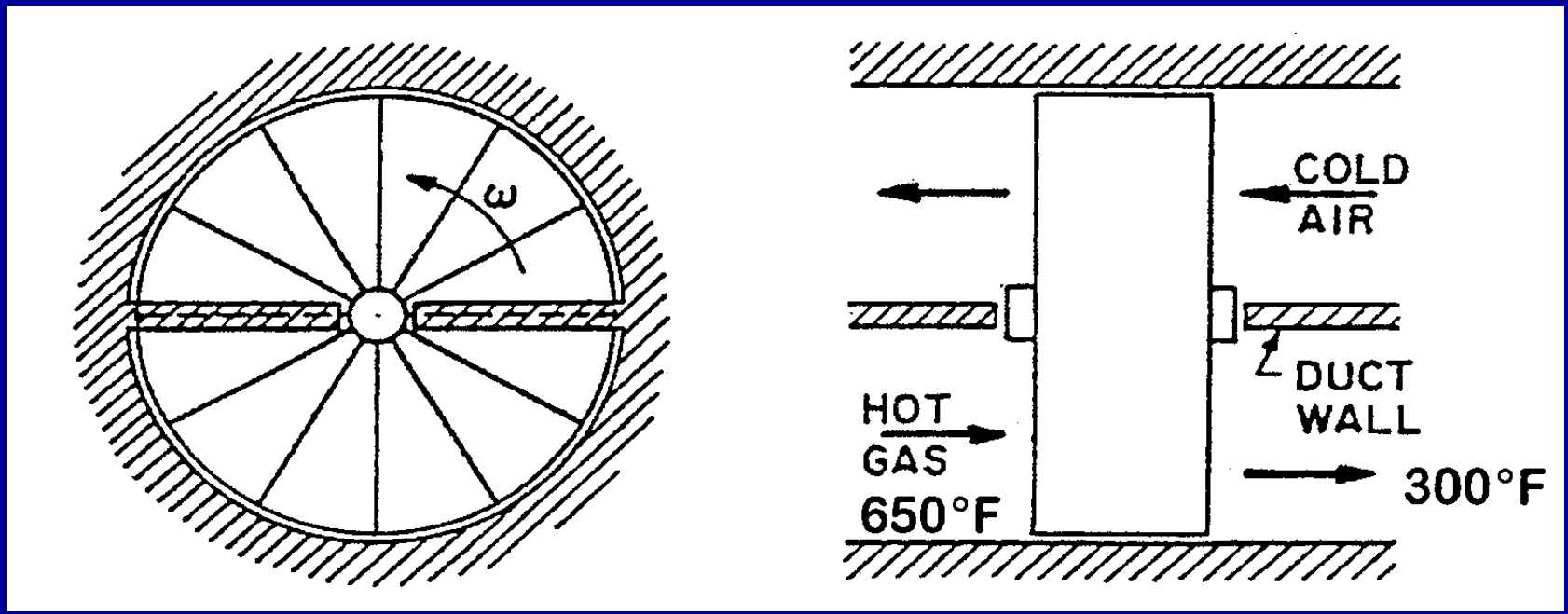




Array of Smooth Wall Circular Tubes in Cross-Flow



Data From Kays and London Showing Heat Transfer and Friction Factors for a Bundle of Circular Tubes with Circular Fins



A Ljungstrum Air Preheater Transfers Heat From Hot Flue Gas to Cool Incoming Air By Way of a Rotating Metal Matrix.

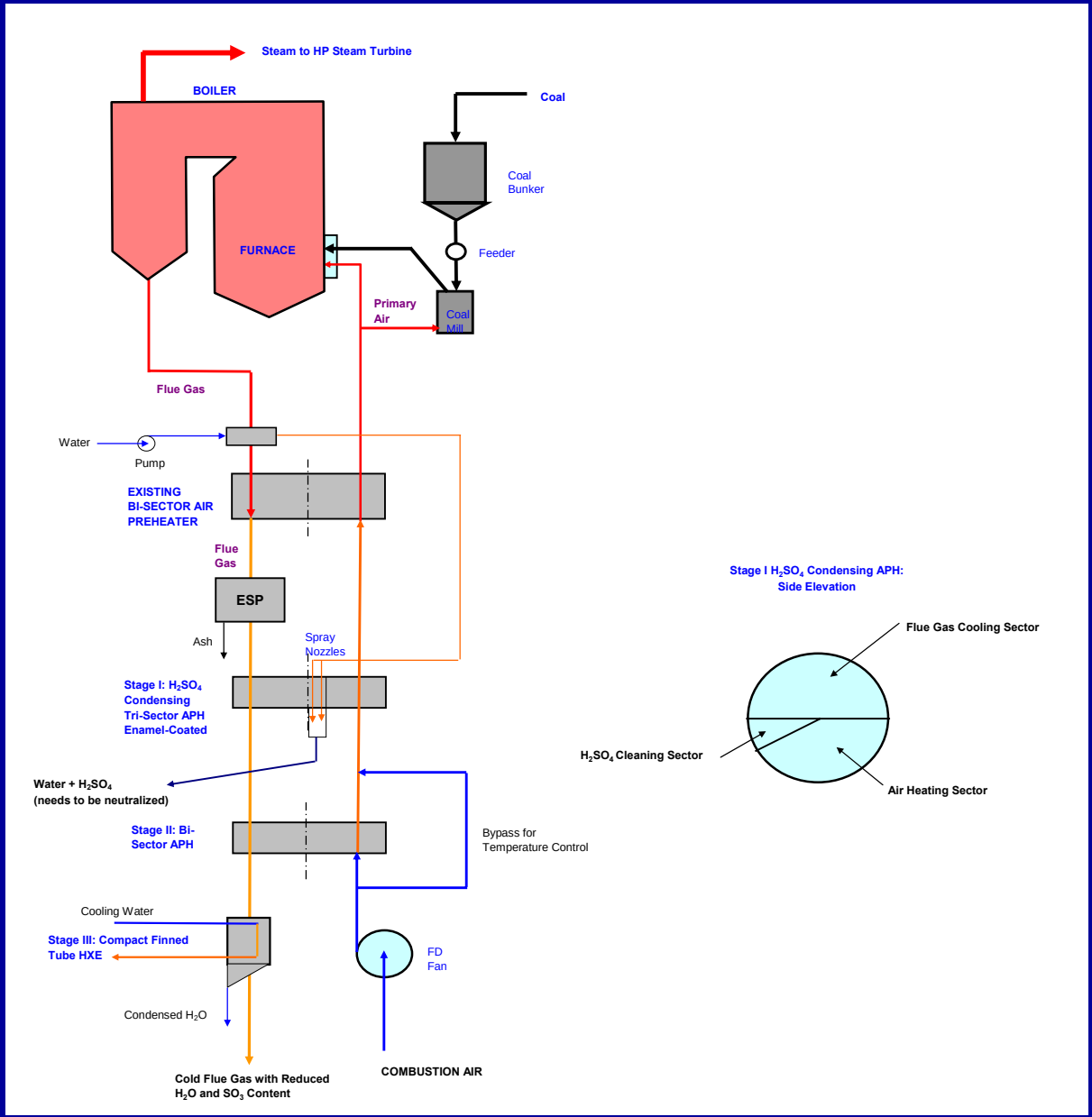
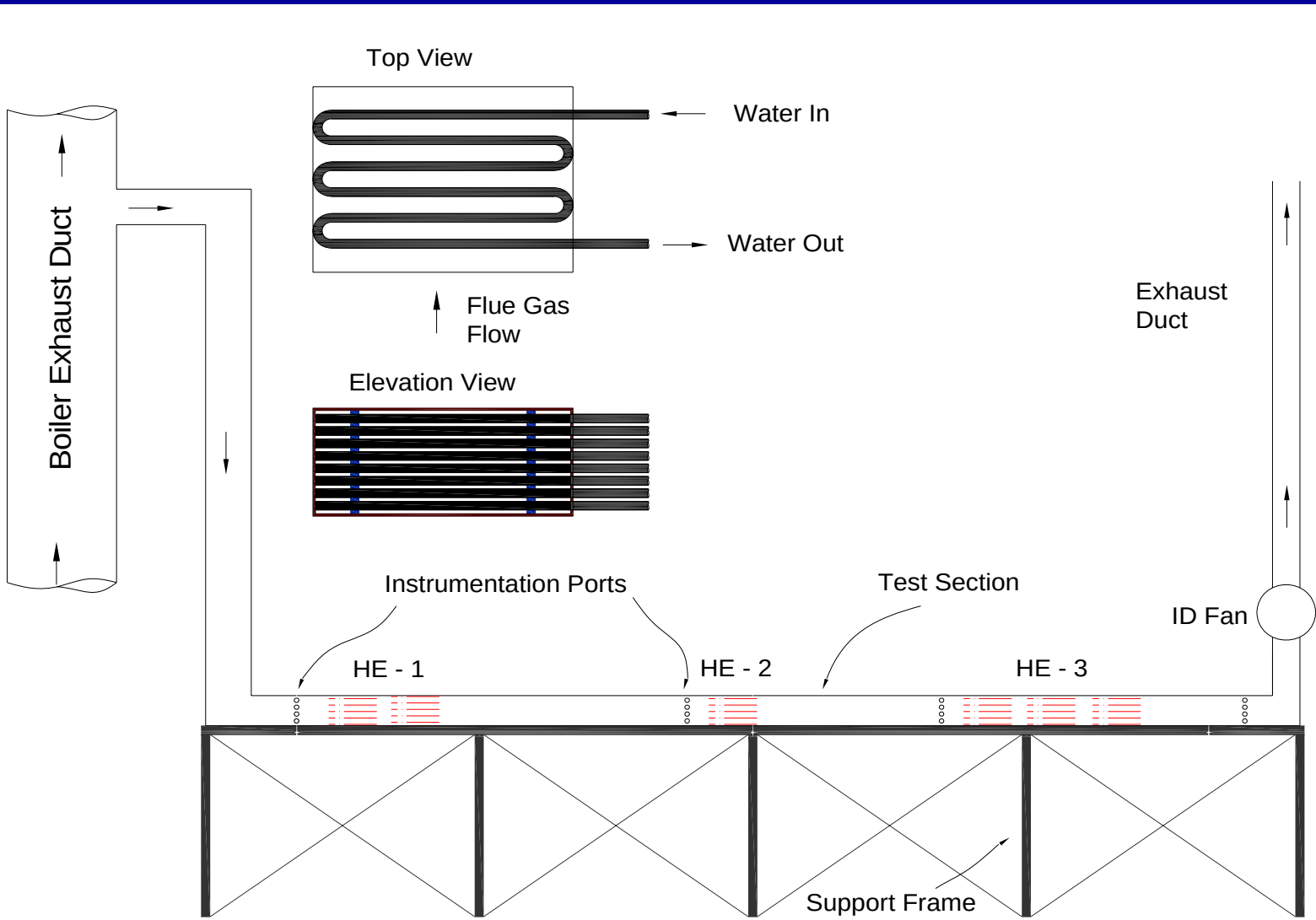


Diagram Showing Ljungstrum Heat Exchanger for Stages I and II

TASKS

1. Design, Fabricate and Assemble Heat Transfer Test Apparatus
2. Experiments at an Oil-Fired Boiler
3. Experiments at a Coal-Fired Boiler
4. Perform Cycle Analyses of Heat Rate Impacts

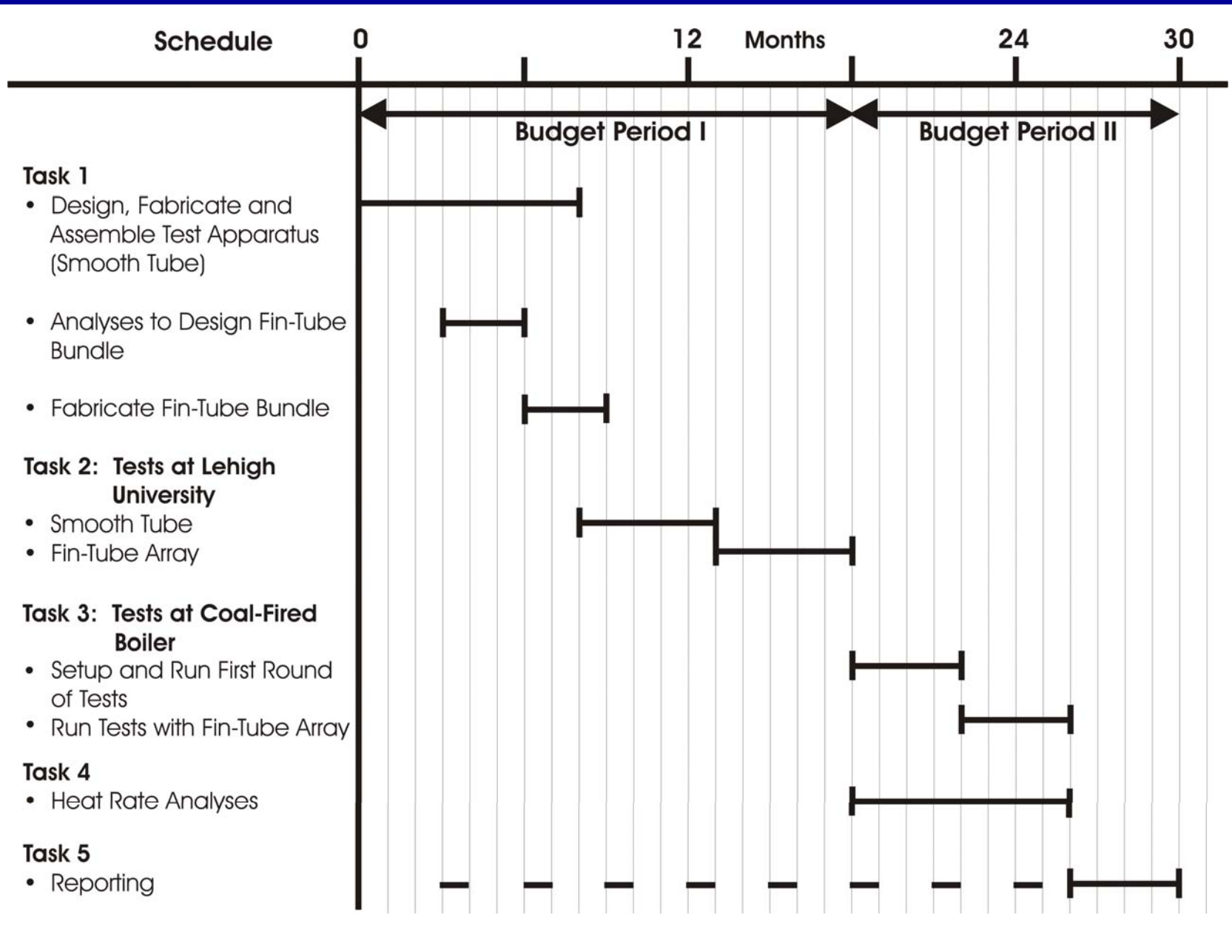

Top View
Water In
Water Out
Flue Gas
Flow
Elevation View
Boiler Exhaust Duct
Exhaust
Duct
Instrumentation Ports
Test Section
ID Fan
HE - 1
HE - 2
HE - 3
Support Frame

INSTRUMENTATION

- Flue Gas Flow Rate (S-Probe Traverses)
- Cooling Water Flow Rates (Rotameters)
- Water and Flue Gas Inlet and Outlet Temperatures (Thermocouples)
- Tube Wall Temperature (Thermocouple)
- Moisture Condensation Rate (Bucket, Stopwatch and Scale)
- H_2SO_4 and HCl Gas-Phase Concentrations (Controlled Condensation)
- Sulfate, Chloride and Nitrate Concentrations in Water

PILOT PLANT FACILITIES

- Oil-Fired Boiler at Lehigh University in Bethlehem, Pennsylvania
- Coal-Fired Boiler at Alstom Power in Windsor, Connecticut


Schedule
0
12
Months
24
30
Budget Period I
Budget Period II
Task 1
• Design, Fabricate and Assemble Test Apparatus (Smooth Tube)
• Analyses to Design Fin-Tube Bundle
• Fabricate Fin-Tube Bundle
Task 2: Tests at Lehigh University
• Smooth Tube
• Fin-Tube Array
Task 3: Tests at Coal-Fired Boiler
• Setup and Run First Round of Tests
• Run Tests with Fin-Tube Array
Task 4
• Heat Rate Analyses
Task 5
• Reporting

PROGRESS TO DATE

- Completed Design of Multi-Stage Heat Exchanger Using Smooth Wall Tube Bundles
- Solicited Bids for Fabrication of System Components
- Beginning to Issue PO's
- Begin Design and Analysis Work on a Finned-Tube Bundle for Low Temperature Heat Exchanger
- Expect to Connect to Boiler and Begin Testing in September 2006

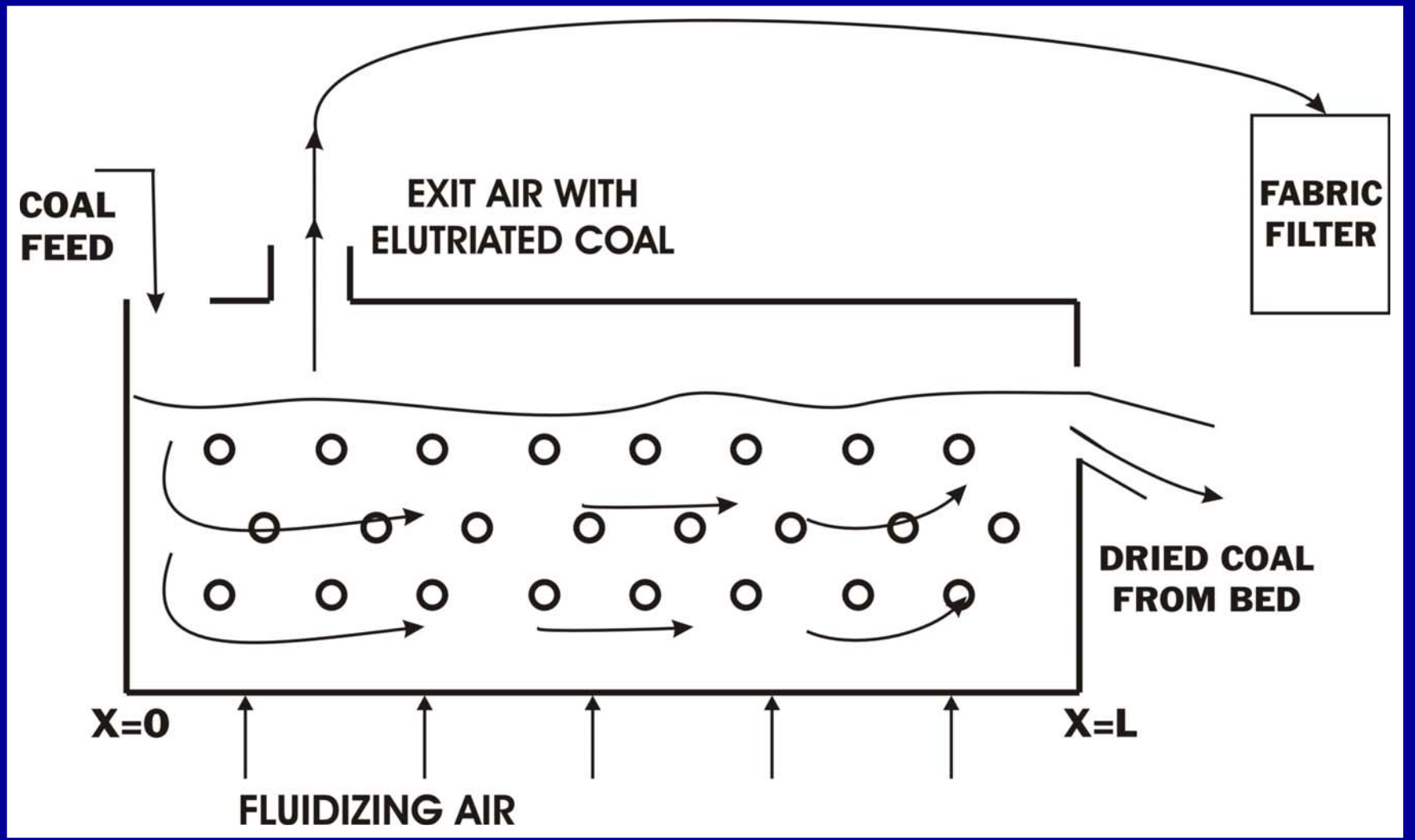
PROJECT TEAM

- Lehigh University, Energy Research Center
- Alstom Power Company

SOME OTHER APPLICATIONS OF CONDENSING HEAT EXCHANGERS

- Oxygen-Fired Coal Combustors – Separate H_2O From CO_2
- IGCC With Oxygen Blown Gasifier – Separate H_2O From CO_2
- Recover H_2O From Moist Air Streams From Coal Dryers

COAL CREEK STATION



Sketch of Continuous Flow Dryer

EVAPORATED COAL MOISTURE DISCHARGED INTO THE ATMOSPHERE

QUESTIONS?