# FUTURE NEED AND IMPACT ON THE PARTICULATE CONTROL EQUIPMENT INDUSTRY DUE TO SYNTHETIC FUELS

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*Abstract*

*The growing demand for coal conversion processes requires a concurrent assessment of the equipment and systems needed for the control of discharge pollutants entering the environment. The particulate control equipment industry will be affected by the increased coal consumption, by the advanced processes being developed, and by the limitations of existing collection systems. This paper presents an extrapolation of the total energy growth in the United States, its impact for coal consumption, and the need for particulate control in each process. Process control conditions are examined to show whether existing equipment designs are adequate and to show where new and developing designs are needed. The future presents a continuing demand for particulate control with greater emphasis on fine particulate collection and with new control conditions for the advanced coal processes that are expected to be commercialized by 1985.*

## INTRODUCTION

Energy consumption within the United States has been increasing at a rapid growth rate, and is expected to continue in the near future at the same pace. By the year 2000, following this extrapolated growth rate, the total energy consumption[1] will be double that amount presently used during 1976 (Table 1). This increase in energy demand can only be met through increased coal production and through construction of nuclear energy plants. The coal production required for a doubling of energy will be a three-fold level above current production, increasing from 13.5 quadrillion Btu to a new level of 52 quadrillion Btu in 2000. This production and use of coal could result in substantial environmental damage, unless control technology is developed and applied now for each developing coal process.

**TABLE 1**

**ENERGY USE BY SOURCE ($10^{15}$ Btu)(1)**

| | 1976 | 2000 |
|---|---|---|
| Petroleum | 34.9 | 55 |
| Natural Gas | 20.2 | |
| Coal | 13.6 | 52 |
| Nuclear | 2.1 | 34 |
| Hydro | 3.0 | 3 |
| Other | --- | 6 |
| TOTAL | 73.8 | 150 |

Coal conversion processes are being directed along three major routes: (1) combustion to produce heat and electricity; (2) gasification which can result in either a high Btu synthetic natural gas or in a low Btu producer gas for nearby industrial use or for combined cycle electrical generating; and (3) liquefaction to produce oil and chemical feedstocks as a supplement to diminishing supplies of petroleum resources. Immediate production will emphasize combustion systems using available burners and boiler systems. Following technical development and environmental assessment through 1985, advanced combustion systems will be built, with a lesser impact due to the gasification and liquefaction processes. All of these processes will require particulate emission control and gaseous emission control, with the degree of control specified by each individual conversion process and operating conditions.

For any process the selection of a control system must be based first on feasibility and finally on economics. This selection procedure (Figure 1) has three steps: (1) knowledge of regulated emission levels and the amount and type of pollutants present to be controlled; (2) a description of all process streams with total characterization of gas and particulate; and (3) design choice alternatives for each particulate control system. The emission standards are established by Federal and State regulatory agencies based on possible health and ecological effects in the environment for each

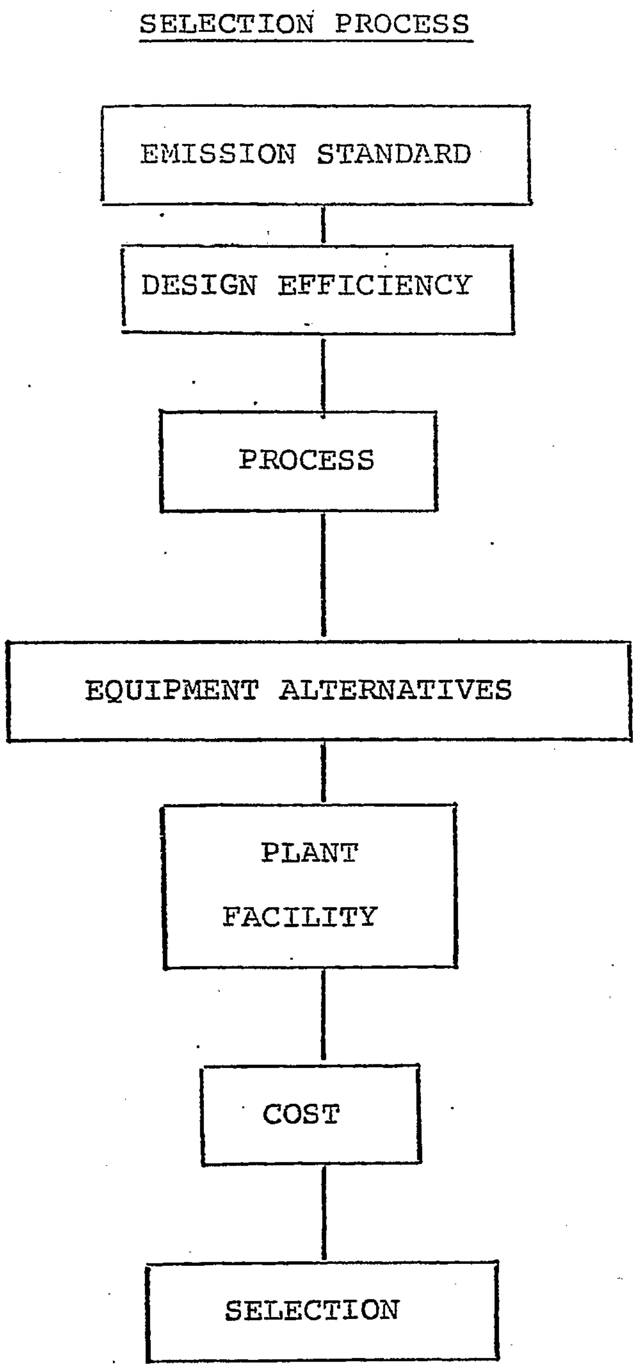


Figure 1. Particulate control equipment selection procedure.

individual pollutant. Each coal conversion process has different designs, different operating characteristics and different control locations depending on downstream process equipment and products. In each stream the gas and particulate need to be characterized for their physical and chemical properties—a partial listing is included in Table 2—that can affect collection mechanisms and design specifications for a control system.

Using the detailed characterizations, each alternative control system can be evaluated, first, for a practical operating design, second, for plant facility limitations of heat recovery, waste treatment, space, water availability, product recovery, and third for total costs based on capital expenditures, power costs, maintenance, and waste disposal. Using these final costs a comparison of each control alternative and a final selection can be made.

## COAL CONVERSION PROCESSES

Looking now at the individual processes, the particulate control operating conditions and design requirements can be evaluated for those ranges where existing designs may be sufficient and those where new designs must be developed. Coal combustion has three major process systems (Figure 2A): (1) direct combustion of pulverized coal in a conventional utility or industrial boiler; (2) atmospheric fluidized bed combustion; and (3) pressurized fluidized bed combustion. The utility and industrial boiler designs are commercially available and use "conventional" stack-gas cleaning systems. Particulate control systems have operated at gas conditions ranging between 250° F and 800° F to collect fly ash particulate. Temperature varies with the location in the process stream. Major design changes reflect increased requirements for "fine" particulate removal and for cost reductions. Atmospheric fluidized bed combustion produces higher heat transfer coefficients for steam generation and provides for $SO_2$ removal in the reactor bed. Particulate removal will occur in a stack gas clean-up system, similar to that used for pulverized coal boilers. Emphasis for design requirements is placed on the different particulate characterization. Pressurized fluidized bed combustion is being developed for combined cycle power generation utilizing a gas turbine on the outlet gases. In this process, which is expected for commercialization after 1985, particulate collection must occur ahead of the gas turbine, thus protecting the blades from erosion by large particulate and from attack by the higher alkali content of the fine particulate. Operating conditions for particulate removal will occur between 1500° F and 2200° F at pressures above 10 atmospheres. This is a new process operating range and will require extensive development of control technology as the process advances towards commercialization.

**TABLE 2**

| PARTICULATE CHARACTERISTICS | |
|---|---|
| Ignition Point | Grain Loading |
| Size Distribution | Density |
| Abrasiveness | Shape |
| Hygroscopic Nature | Physical Properties |
| Electrical Properties | Explosiveness |

| GAS STREAM CHARACTERISTICS | |
|---|---|
| Volume | Odor |
| Temperature | Explosiveness |
| Pressure | Viscosity |
| Moisture | Ionic Mobility |
| Corrosiveness | Thermal Conductivity |
| Composition | |

Gasification of coal (Figure 2B) is needed to produce a clean fuel gas. The high Btu processes manufacture a synthetic natural gas that will be piped via the existing natural gas pipeline to individual customers. In this process with the gas at a pressure of 1000 psi, particulate removal will occur prior to the catalytic steps ugrading the gas. Operating temperature are currently planned between 200° F and 800° F for particulate removal, with the higher temperatures above 500° F preferred for solid char removal and the lower temperatures 200-500° F required for tar mist removal. The development of catalysts and acid-gas removal systems that could operate at higher temperatures would change the temperature level required for particulate removal. Commercial high Btu gasification will not make a major

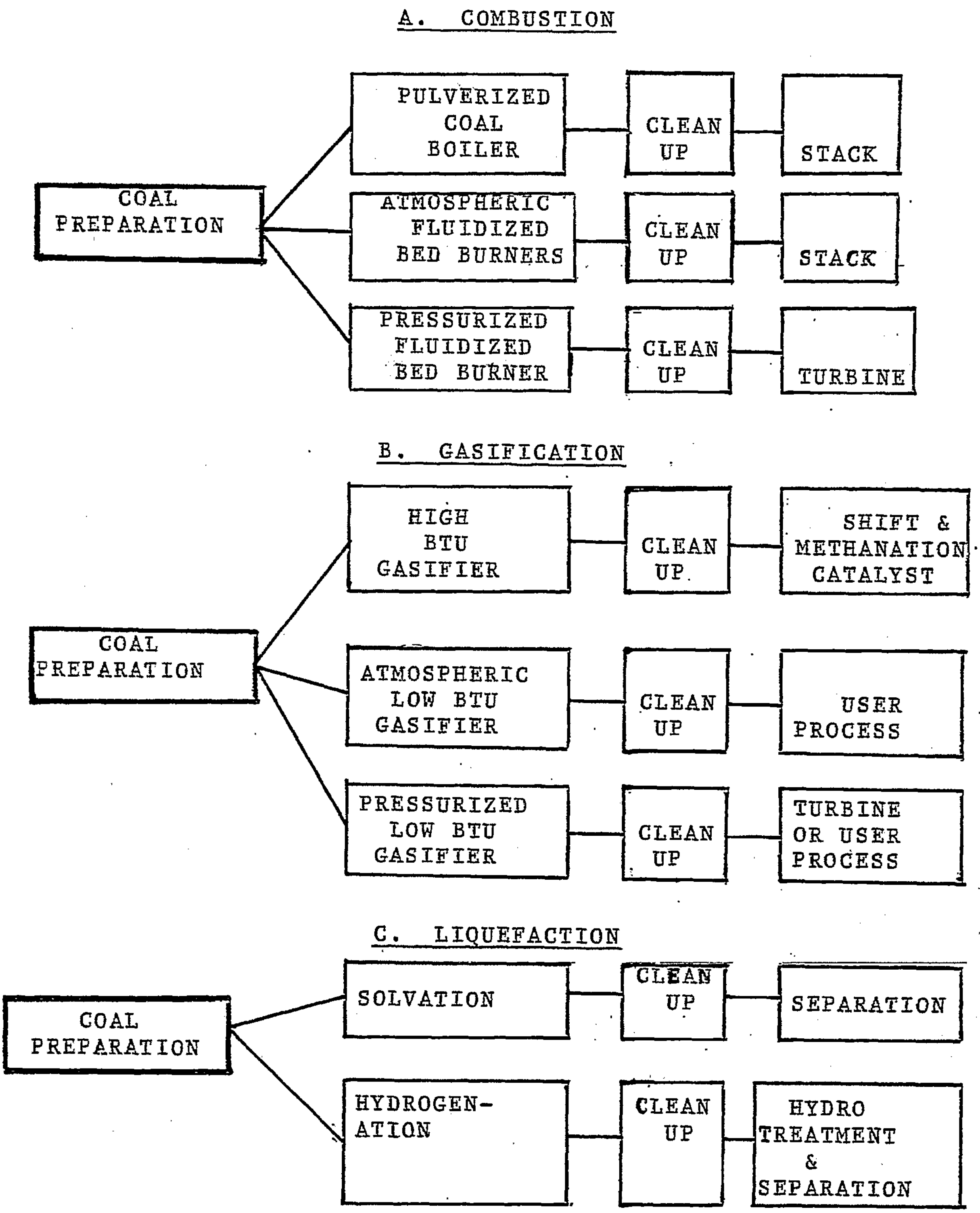


Figure 2. Coal conversion processes.

impact before 1984. Atmospheric low Btu gasification, a second process type, is expected to develop more rapidly, with some commercial designs already in use in Europe and Africa. For this process the gas is cleaned and sent to a nearby industrial process or boiler, with the degree of clean-up determined from the end use requirements. Temperatures for clean-up will range from 200-500° F for tar droplets to 500-1100° F for char removal. Particulate collection systems are commercially available for the low temperature range and can be extended to the higher temperatures with advanced material selection. Pressurized low Btu gasification will be used (1) to either supply more distant industrial users in a local pipeline network or (2) in combined cycle power generation. For the former end use, particulate clean-up will occur at pressures from 10 to 30 atmospheres and for a temperature range between 100° F and 600° F. For the combined cycle system entering a combuster and gas turbine, particulate removal under the same high pressure must be performed at higher temperatures above 1200° F. The maximum temperature will be controlled by the combustor inlet conditions to prevent auto-ignition.

Coal liquefaction (Figure 2C) follows two processes: (1) solvent extraction and (2) catalytic hydrogenation. In the former, a hydrogen donor solvent extracts the smaller coal molecules producing a variety of tars, oils, and gases and leaves a residue of char and minerals. The gases, tars, and oils must be separated and cleaned, usually under pressure and at temperatures below 400° F. In the second hydrogenation reaction, the larger coal molecules are split into smaller molecules producing a higher concentration of lighter oils. Purification and separation again occurs under pressure at low temperatures.

In all of the above processes, particulate collection is required in the main gas stream. In addition, secondary streams from residue combustion, regeneration processes, and coal preparation steps will require particulate control. Conditions found in the secondary streams are generally similar to the established process conditions with some variation in temperatures or pressures. Commercially available equipment with extended temperature limits and improved performance designs will meet the requirements for atmospheric pressure coal systems currently preparing for commercialization. New designs and development are needed for the higher temperature (500 to 2000° F) and pressure (10-70 atm) collection requirements found with pressurized fluidized bed combustion, pressurized low Btu gasification, and high Btu gasification processes that are expected to be ready for commercialization by ~ 1985.

## PARTICLE CONTROL EQUIPMENT

Having examined the general operating characteristics of the coal conversion processes, the particulate equipment to meet these conditions can now be described. Particulate control equipment choices fall into four major classes (Figure 3): mechanical collectors, wet collectors, filters, and electrostatic precipitators. Each of these classes have existing commercial designs and developing designs to meet the coal conversion process requirements. New designs combining mechanical, wet scrubbing, and electrostatic mechanisms are being studied for fine particulate collection and evaluated to reduce size and cost of an individual system.

Mechanical collectors usually consist of cyclones or centrifuges which can be connected in a series arrangement to attain higher efficiencies. This class of collectors is limited to the collection of particles larger than 5

**MECHANICAL COLLECTORS**

**CYCLONES**
**CENTRIFUGES**

**WET COLLECTORS**

**SCRUBBERS**

**FILTERS**

**BAGHOUSES**
**GRANULAR BED FILTERS**

**ELECTROSTATIC PRECIPITATORS**

**Figure 3. Particulate control equipment alternatives.**

microns, and is generally used for a first stage as a precollector of large particulate. Mechanical collectors can be designed for essentially all of the temperatures and pressures found in coal conversion.

Wet collectors such as scrubbers or wet electrostatic precipitators can effectively collect particulate at low temperatures. Both scrubbers and precipitators have been applied at high pressures to 60 atmospheres in past commercial designs. Consideration must be given to the need and cost of additional waste water treatment when applying these systems. Temperature is a limiting factor for the liquid being used as the spray or scrubbing media, in that the gas must be saturated for efficient operation with condensing droplets.

Filters operate by particulate collection on fibers or granular beds. Baghouses consisting of woven fabrics have operated at essentially atmospheric pressure with temperatures ranging to 550° F on industrial boilers and recently on utilities. Material bag life is presently limited in use to the temperatures below 600° F. Granular bed filters and panel bed filters are new designs developed primarily for high temperature and pressure applications. These filters collect fine particulate by building a "filter cake" from the collected particulate onto the granular bed. High pressure drops have usually been found with these systems.

Electrostatic precipitators (wet or dry) have long been in use for efficient collection of tar and various types of dust in both industrial and utility applications. New designs being funded by industry, EPA, and utilities are aimed at improving performance and reducing costs—both capital and operational. Past experiences in precipitation have found applications for atmospheric systems from 200 to 900° F and for high pressure systems from 1 to 60 atm at temperatures generally below 300° F.

Operating data is limited for each of the above classes at the combined high temperature and pressure needed for the developing coal process conditions that exceed existing control ranges. Several companies under contract to EPA and ERDA are developing new designs and concepts for high temperature and pressure particulate removal. Consolidated Coal Company and Mechanical Technology, Inc., are developing high efficiency cyclones using a high pressure drop that collects particulate above 5 microns. Series of three to four cyclones are expected to be required to attain high collection performance. Gravel bed or panel bed systems are being developed and evaluated by Rexnord, Inc., Duccon (used at Exxon's miniplant), Air Pollution Technology, Inc., and Combustion Power Company. Acurex Corporation/Aerortherm is developing a ceramic bag filter for use at high temperature and pressure. Westinghouse is evaluating a ceramic membrane filter under similar conditions. Air Pollution Technology is evaluating a scrubber to be used at high pressures and moderately high temperatures. Research-Cottrell is developing high temperature and pressure electrostatic precipitators for use under all expected operating conditions. Each developing control system is being evaluated under laboratory and pilot operation. Currently, performance predictions and design criteria are poor or lacking at these high temperatures and pressures. Both gaseous and particulate characteristics are essentially unknown. Pilot and demonstration scale systems are needed to provide reliable design data and material selection for long life on all new particulate equipment. At high temperatures, the efficiency of all control equipment for any given size can be expected to decrease due to the increasing value of the gas viscosity; however, electrostatic precipitators are unique in their collection mechanism in that the migration velocity and thus efficiency increases with an increasing applied voltage. Research-Cottrell is conducting a precipitator program evaluating conditions to 500 psi and to 2000° F in air, combustion gas, and a simulated fuel gas. These results have found precipitation to be very favorable for the higher gas densities found with high pressures that maintain substantially higher applied voltages. These higher voltages are capable of increasing precipitator efficiency and reducing its size and cost. Corona current was stable in all gas mixtures evaluated.

## FUTURE IMPACT

Advanced designs and future control requirements are evolving towards a higher collection efficiency of fine particulate, minimal energy consumption, control ranges at a variety of temperatures and pressures, and the capability of handling changing particulate properties due to variations in chemical composition and operating conditions. Catalytic steps and turbine operation require clean-up locations at the higher temperatures and pressures leaving the coal conversion reactor.

Comparative performance evaluation combined with capital investment, operating costs, and maintenance will ultimately determine a final control choice for any one process. The varying process conditions will result in control equipment systems being designed for specific operating conditions, based on economics and collection mechanisms.

In summary, coal conversion processes will continue to require particulate removal, with the particulate control equipment industry growing at approximately the same pace as coal use. Advanced developments requiring high temperature and pressure particulate removal will become commercialized around 1985. Atmospheric combustion processes in utilities and industry will continue to grow prior to that time. Each new design concept will be required to efficiently remove fine particulate under the given process conditions. New design and process optimization between control system and conversion process will be required to minimize costs and improve performance. Particulate control development must occur now with the developing advanced coal conversion processes if commercialization is to be achieved at a minimal cost by 1985.

## REFERENCES


1. S. B. Alpert, "Commercialization of Technology," Presented at 4th Annual Conference on Coal Gasification, Liquefaction, and Conversion to Electricity, August, 1977.
2. Bush, Feldman, Robinson—"High Temperature, High Pressure Electrosatic Precipitation"—to be published.
3. J. M. Marchello, *Control of Air Pollution Sources*, Marcel-Dekker, Inc., (1976).
4. W. Straus, *Air Pollution Control, Part I*, Wiley-Interscience, 1971.
5. A. B. Walker, "Electrostatic Precipitators and Fabric Filters—Changing Needs and Solutions," June, 1977.