DEMONSTRATION PLANTS: ARE THEY NEEDED?

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Keywords: Demonstration of technology; Coal conversion systems for environmental control

INTRODUCTION

In the evolution of new technologies that demonstrate and challenge existing practice, the concept of a demonstration plant is used to bring the process of research, development and demonstration to conclusion. The incorporation of a demonstration plant in the strategy of realizing commercial application of a new technology was a new step introduced by the availability of support from federal agencies that provided the necessary funds required for large plant scale-up and sustained operation.

A. Commercial Plant Following Bench Scale or Pilot Plant Tests

In the chemical industry commercial plants are often constructed based on small scale (less than 1 ton/day) continuous pilot plant trials where there is a large incentive to realize commercial production of a product that is produced at lower cost or that has improved quality over competing routes. Often the commercial plant is built based on kinetic and yield information from limited pilot plant data (10-50 lbs/day).

In these instances homogeneous phase systems are scaled up to commercial sized plants. Engineering usually does not represent a significant change from existing practice that is in existence. Examples of new technology usually include improvements in reactor design (contacting) and/or in catalyst formulation, representing the primary new steps being proven or modified. Adjustments and plant modifications are made at the time of commercial plant "breakin" and startup. An extra allowance is provided for the "first of a kind" commercial plant which usually is 5-25% of the capital cost of the plant. The advantage of this approach is rapid commercial application that takes advantage of an economic incentive that is significantly large.

B. Modification of An Existing Commercial Plant

In some cases an existing commercial plant can be modified to incorporate new features of a technology. For example, an improved high capacity gasifier may easily be incorporated into an existing coal gasification commercial plant. This strategy is often used to avoid the cost of installing the raw materials receiving, feed preparation, and product recovery steps which may be relatively unchanged and that may need no modification. Thus, a new technology such as a high capacity reactor can be demonstrated at relatively modest cost at an existing commercial plant. The new gasifier may represent 10-15% of the total capital requirements.

Projects that are demonstrating sorbent absorption of sulfur dioxide in the hot gas path of an existing power plant are examples of this approach. In the petroleum industry new more selective or aging resistant catalysts are incorporated into an existing plant. This approach is usually a low cost approach to bring a new technological advance to commercial realization.

C. <u>Utilization of Large Pilot Plant</u>

For the situation where there is a change in phase a step wise series of continuous bench scale and pilot plants are used to:

(1) provide scientific information on kinetics, selectivity, product characteristics, yields, etc. Often this information is emperical. The chemistry and mechanisms are not very well understood.

(2) provide engineering data on equipment size requirements, maintenance, materials information, engineering design and safety data, and design of special equipment and subsystems. Catalyst life data are defined based on sustained "steady state" operations performed.

On the basis of the continuous pilot plant trials at increased capacity scale up uncertainties are also defined. In the largest pilot plants operated the smallest commercial size equipment from vendors are used to minimize risk of equipment scale up at a pioneer commercial plant. Table 1 shows the features of a pioneer commercial plant. It should be noted that an integrated program requires various size pilot plants to be operated simultaneously. Thus, the program often requires small and large pilot plants to be operated on feed materials used in a commercial plant. The objective of the integrated program is to obtain the engineering equipment design data and yield and product quality information that permits the pioneer plant to be constructed with ordinary financial risk. Trained operations personnel from the large pilot plant serve as a cadre of experience specialists for the pioneer plant.

D. <u>Demonstration Plant</u>

In the development of new technology in which solid feeds (coal or shale) are converted the concept of a Demonstration Plant has been introduced. It usually represents a single full scale train (1000-5000 Tons/day) of a

TABLE 1.
Pioneer Plant Objectives

- Commercial pretested equipment used to prove the technology in full scale module.
- Establish firm basis for investment, operating procedures, costs of commercial plants.
- Establish permitting procedure for plant, transportation of product, utilization by customers
- Complete testing, and handling procedures and health effects in markets
- Ability to expand pioneer plant to full sized commercial plant.

commercial plant that represents an engineering proof of the information from large pilot plants (100-500 tons/day). An important aspect of such plants is the culmination as a technical spectacular.

Such spectaculars, which challenge existing practice, represent step outs that are important "first of a kind" culminations concluding research that may have taken 10 years or more to accomplish. Being first is always an exciting challenge for scientists and engineers.

A demonstration plant has many purposes and objectives including the challenge of using expert knowledge and organizing and managing the skills necessary to achieve technical innovations. Recent demonstration plant experience that featured solid feeds to (coal and shale) indicates that a minimum of 3 years and more appropriately 5 years or more of operations are required to obtain robust information on maintainability and reliability from a utility industry perspective.

Table 2 shows the features of a demonstration plant and its objectives. For a conservative industry like the electric power industry, that must be prudent and is not used to accepting significant financial risk, the added comfort of robust cost, design, reliability and maintenance practice information is an important aspect favoring demonstration plants that represent technological innovations for generating electricity.

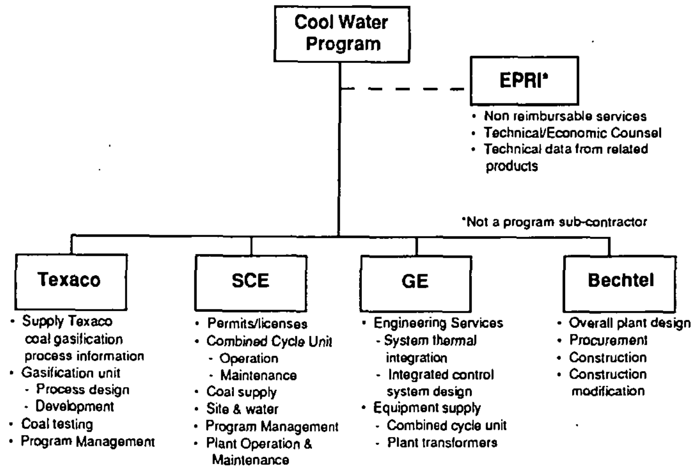

FIGURE 1. Responsibilities of Program Participants

TABLE 2.

Objectives of Demonstration Plant

- Save time to commercial production of products, introduction of new technology
- Complete engineering development from small equipment
- Confirm scaleup parameters, establish sources of commercial equipment
- Operate integrated flow sheet, obtain operating experience, confirm design
- Confirm economics of commercial plant and expand demonstration plant if warranted
- Produce large samples of products for test by customers

While the cost for a demonstration plant is high, new technology acceptance will depend on their outcome. The learnings from demonstration plants guarantee efficient smooth start up and operation of subsequent commercial plants that can reliably proceed with low financial risk.

While there are many advantages for a demonstration plant a major shortcoming is its cost. In the case of the Cool Water program about $300 million was required to build and achieve reliable operations over the course of the 5 year operating program.

Figure 1 shows the responsibilities that were defined for each of the major participants that supplied funds for the Cool Water Program. At the conclusion of the program the demonstration plant was shut down. It is imperative to carefully define the scope of each organizations responsibility at the programs inception.

E. The Cool Water Program

Figure 2 shows a block diagram of the Cool Water plant.

Cool Water is a nominal 120-MW IGCC power plant that uses the Texaco Coal Gasification Process to produce a medium-Btu fuel gas. The gas is combusted in the combined cycle portion of the plant to produce electricity. The plant is designed to process up to 1000 tons of coal per day mixed with water, however, rates as high as 1200 tons per day were achieved. The coal-water slurry is gasified with oxygen at a pressure of approximately 600 psig and a temperature of between 2100 °F and 2500 °F. The raw syngas from the gasifier is first cooled in radiant and convective coolers that generates steam for use in

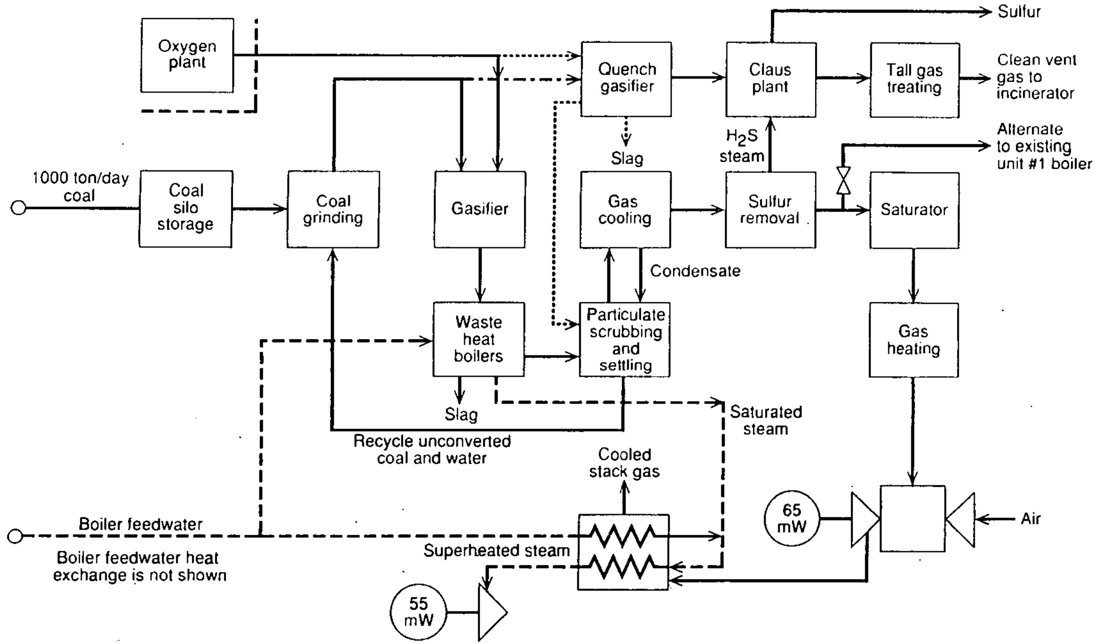

FIGURE 2. Block Flow Diagram of the Cool Water Coal Gasification Plant

power production. The slag solidifies during its fall through the radiant cooler and collects in a water sump at the bottom of the cooler, where it is removed periodically using a lockhopper system.

After leaving the radiant and convective syngas exchangers, the cooled synthesis gas enters a water scrubber where any entrained particulate is removed. After the scrubber, low level heat is recovered from the gas in a series of exchangers, and then air and cooling water trim coolers reduce the gas temperature to appoximately 100 ^oF. Next, sulfur is removed, primarily in the form of hydrogen sulfide, in a Selexol absorber. A sulfur-rich acid gas is stripped from the Selexol solution and routed through a SCOT/Claus sulfur recovery unit to produce an elemental sulfur product. Following sulfur removal, water is added to the desulfurized gas in a syngas saturator to suppress NO_x formation during combustion.

Subsequently the synthesis gas is fired in a GE MS7001E gas turbine to produce electricity. The exhaust gas from the combustion turbine passes through a Heat Recovery Steam Generator (HRSG) where saturated steam formed in the syngas coolers, and in the middle section of the HRSG, is superheated. After superheating, the steam is utilized in a steam turbine for additional electricity production.

F. Definition of Incentives

The Coolwater Program was started in the late 1970's. A major incentive was the control of emissions of an IGCC plant compared to a pulverized coal plant as shown in figure 3. Demonstration of these environmental features was considered an important incentive for the project.

In addition economic analyses showed that electricity from IGCC plants would be cost competitive with conventional coal plants and offer higher efficiency routes to electric power.

At the time of the start of the program oil an gas prices were expected to escalate in real terms. By the last year of the operating period economic dispatch of the facility on the Southern California Edison Co. system was projected. Projections of oil prices of $40 a barrel or higher were expected.

At the conclusion of the program the plant was not competitive with low cost natural gas in conventional generation plants that produce electric power at a cost of about 3-4¢/Kw-hr, or about 50% of the cost of electricity from the Cool Water plant.

Environmental Trade-offs for Coal-Based Technologies

Flue gas desulfurization (FGD) units and fluidized-bed combustion—both atmospheric (AFBC) and pressurized (PFBC)—have been effective in reducing emissions of SO_2 and NO_x from coal-fired plants, but at the cost of producing substantial volumes of solid waste. Gasification-based generation options (IGCC, IGHAT, and IGMCFC) have the potential to cut those airborne emissions further and minimize solid waste without imposing an efficiency penalty on the overall system.

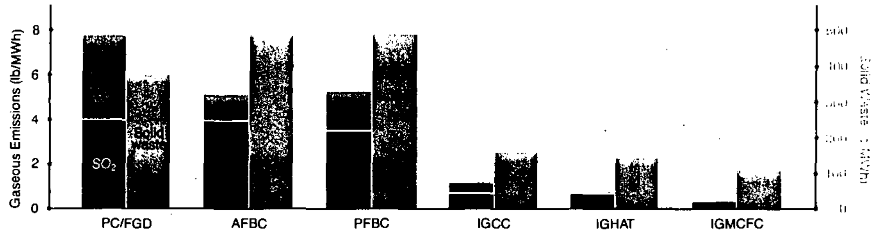

FIGURE 3. Environmental Trade-offs for Coal-Based Technologies

Table 3 shows a summary of the results from the Cool Water program which represented the "know how" produced

TABLE 3.
Major Information From
Demonstration Plants

Management

- Firm basis for capital and operating costs
- Firm basis for plant performance as base load or load following
- Definition of management structure
- Plant reliability as a variable for design
- System integration and performance
- Environmental data for commercial plant licensing

Technical

- Design and equipment requirements
- Performance of equipment from sustained operations on a variety of coals
- Comprehensive information on materials of construction, components, subsystems
- Comprehensive details on environmental impacts and equipment alternatives
- Health and safety information
- Staffing requirements
- Training of future users of the technology, simulator

CONCLUSIONS

Currently a large number of demonstration projects are being performed in the U.S. with funding from federal and private sponsors. The Cool Water Program was a technical success in that all of its objectives were met or exceeded during the 5 year operating period. It's major achievement was to launch a new technological option for the world wide electricity industry--the IGCC plant- which is a clean use of coal.

Of prime importance is agreement by the sponsors on its, objectives and participation by organizations who take the information forward to commercial projects that follow.