DIRECT FIRING OF COAL FOR POWER PRODUCTION

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ABSTRACT

The direct combustion of coal to produce electricity in California may require that the emissions from such a plant be less than those experienced with the combustion of low sulfur oil. Such a situation requires the use of new technology and advanced emission control hardware which has never been integrated into a single facility.

In order for various state agencies to accept coal within the state, it may be necessary to demonstrate that this integration will yield the desired results. A conceptual study conducted by Southern California Edison has revealed that it is technically feasible to conduct such a demonstration project on an existing, small 81-MW boiler.

Southern California Edison's studies on the question of trying to utilize coal to a larger extent in our generating mix (both from a capacity and from a fuel point of view) predate the oil embargo of late 1973. In these studies a spectrum of technologies was reviewed, and we came to the conclusion that liquids from coal were the preferred route because they were storable and could be decoupled from the generating unit. The Clean Fuels West project was initiated. In addition to ourselves, EPRI, Conoco, and Mobil participated. The preliminary engineering studies revealed one crucial problem. In looking at the forecasted environmental regulations for the State of California, it became apparent that there was probably no liquid fuel which would meet the projected stringent regulations with the exception of methanol. Methanol, of course, suffered from high projected costs, especially if produced from coal. Nevertheless, Southern California Edison has done a series of combustion tests, principally on oil from shale in conjunction with the Paraho project and others on a small utility boiler. In fact, we developed a new combustion technique for fuel combustion to try to minimize NO_x production. Currently, we, along with EPRI, have planned a methanol combustion test which will be started this summer.

Due to growing restrictions on energy and environmental options, a series of studies were done in-house over the last several years involving a variety of technologies (>40) and a number of departments. The principle results of these studies are given in Figure 1. It is clear that nuclear power is still the preferred economical alternative. Of the remaining technologies, direct combustion of coal, coal gasification integrated with a combined cycle plant, and geothermal were the three most promising alternatives. Coal gasification is the subject of another session, and a commercialization project involving Texaco and Southern California Edison will be discussed then. This paper focuses on the direct combustion of coal. Edison's program in direct combustion has two principle elements: demonstration on an 81 MW boiler at our Cool Water Generating Station, and the planned 1500 MW coal-fired plant in the Eastern California desert.

The direct combustion of coal to raise steam is a well-proven technology. The problem of meeting the extremely stringent air quality regulations in California and the public's perception of coal-fired power plants present the major challenges. Our experience in this area is contrary to the general perception of the impact of coal fired power plants on the environment. As the operator of the Mohave coal-fired power plant in southern Nevada, the data, based on our ambient measurements which have been in progress since 1968, or two years before the plant went operational, reveals that the operation of this plant is barely detectable in terms of annual ambient SO_2 levels using 0.4% sulfur coal. Coal of 0.4% sulfur content adequately meets current New Source Performance Standards (NSPS). The monitoring network extends up to 22 miles from the plant in the direction of the prevailing winds. The plant is equipped with electrostatic precipitators designed for particulate removal, which are adequate to meet current NSPS. Thus the plant meets current NSPS even though it was built prior to the adoption of these standards.

Figure 2 shows the southern California area and is useful in locating the projects mentioned above. First, Mohave is located in the southern tip of Nevada, just north of Needles, California. For the proposed 1500 MW plant, three sites are being considered in the eastern California desert: Rice, southwest of Needles; Vidal, south of Rice; and Cadiz, northwest of Rice. The site for the 81 MW demonstration project is about 10 miles east of Barstow at Southern California Edison's Cool Water Generating Station. The solid lines in Figure 2 are the major railroads in southern California. As can be seen, Rice and Cadiz are quite close to railheads, while two railroads (the Union Pacific from Las Vegas, and the Santa Fe from Arizona) actually border the Cool Water site. This is an important factor in considering this site for the coal demonstration project.

Supplying coal to a site in California, whether by rail or perhaps by slurry pipeline, does not present a great problem. The principle question is the matter of the emissions from a coal-fired plant, since we recognize that regulations have become more stringent and that the public remains apprehensive. The objective of the Cool Water demonstration study was to see if we could design a plant which could burn coal cleaner than oil. Stearns-Roger conducted the study for SCE with this objective in mind. The particular unit which was used for the study is the Cool Water Unit No. 2. Cool Water No. 2 is an 81 MW Combustion Engineering boiler, which went into operation in 1964. One reason it was used in this study is that it was designed for possible conversion to coal. Out of our 9,237 MW of oil and gas-fired units, only a relatively few have that possibility. For example, the forced draft fan is oversized for oil-burning but is the proper size for coal. The air heater is also sized for coal burning. The cooling tower and condenser systems are oversized for oil firing but are sufficient for coal.

The turbine generator combination is sized such that with a small change to the turbine blading the unit will be able to generate enough extra power to satisfy the additional auxiliary power requirements for burning coal, with no reduction in the present electrical output of the unit.

Perhaps the most important aspect is that the boiler design is such that no change will have to be made in the superheater, reheater, or convection pass portions of the boiler because the tube spacing is adequate for coal burning. Also, the boiler foundation and structural steel design is sufficient to support the necessary additional equipment required for coal burning, and provisions were made to accomodate furnace expansion and the installation of the bottom ash handling equipment under the boiler without disturbing the structural foundation.

The original design of Cool Water Unit 2 included consideration of coal burning space requirements. For example, the space required for additional controls and switchgear was provided in the control room and in the electrical room below the main control room. The switchyard was designed so that additional equipment could be added to provide the needed auxiliary power without moving any existing equipment. Also, a concrete room was installed beneath the boiler large enough to accomodate the required extension to the bottom of the boiler, the bottom ash hopper, and the bottom ash handling equipment. Finally the site is large enough to allow space for a long-term ash storage area without interfering with the equipment or facilities.

Figure 3 is an artists rendering of the coal demonstration plant at Cool Water. In the figure, some of the special precautions that will be taken to contain all fugitive dust from coal and ash handling operations are visible. Spray treatment of the rail cars (at the mine) will prevent windborne dust during transportation of the coal to the plant site. During rail car unloading, a dust suppression system will be employed inside a totally enclosed building. The coal will be dumped from the bottom of 95-ton coal cars and any coal dust present in the building will be collected in a filter system. Coal storage at the site will consist of three 2000-ton enclosed silos, each having a dust collection system. There will be no open coal storage during the demonstration test program.

Primary coal crushing will take place in an enclosed building utilizing another dust collection system. Also, all the coal conveyor belts will be enclosed.

The boiler will be converted from a pressurized system to a balanced draft system. Therefore, the boiler will be at a pressure slightly less than atmospheric so that any possible leakage will be into the boiler rather than out of it.

Fly ash handling will utilize a vacuum conveyor to draw the fly ash through pipes into a completely enclosed storage silo. The fly ash will be trucked away in trucks fitted with special dust control features.

Finally, the structures immediately to the left of the boiler in Figure 3 will contain the pollution control system.

The criteria for direct coal-fired technology are shown in Figure 4. In addition to demonstrating emissions less than that which you would have with burning low sulfur oil, it is desirable to have a coal to electricity heat rate of around 10,000 BTU/kWh with capabilities to get even lower heat rates (or improved efficiency). Figure 4 shows that we are considering time dependent targets in these areas. The 1978 data is related to the present state of the art. It is clear that we must be able to translate the information from this demonstration program to the 1500 MW coal-fired plant of the late 1980's.

The problem then is to provide an adequate demonstration of control of particulates, SO_2 and NO_x, while retaining a respectable heat rate. The problem is compounded by the fact that advanced technologies for emissions control have not been operated in series on the same utility boiler.

Particulate, SO_2 and NO_x control technologies are the subject of another session at this conference, so this paper does not dwell on them at any length. However, it is important to place these technologies in perspective relative to Edison's coal development program.

New technology has emerged since the early 1970's for achieving very high levels of pollution control with conventional coal-fired plants. For example, fabric filtration, which involves the use of bag filterhouses, was first successfully demonstrated at a coal-fired plant in 1973. Today, several thousand megawatts of electric generating capacity are being fitted with baghouses for new and existing coal-fired powerplants. Stack sampling conducted by the Electric Power Research Institute, and others, has shown that in excess of 99.5% of the particulate matter resulting from coal combustion can be removed with a baghouse if it is working properly. This requires an air-to-cloth ratio of about 2.0 ACFM per square foot, or less, for conventional reverse air type baghouses. Advancements have been made in the bag materials such that operating temperatures up to 450°F with bag lifetimes of two years have been achieved.

The primary advantage of a baghouse is that there is no visible smoke plume under normal conditions. If there is a visible plume, then one or more of the bags has been damaged or broken. The problem area can then be quickly identified and corrected without shutting down the generating station. This is accomplished by sequentially isolating individual bag compartments until the plume disappears, and then entering the compartment where the problem exists to replace the damaged bags. When the powerplant can operate without a visible smoke plume, there is much more of a tendency for the general public to believe that the insignificant levels of pollution actually are insignificant.

One of the problems with smoke plumes is that the density, or opacity, is more a function of the sun angle and viewing position than any other factor. A smoke plume will always appear more dense when viewed with the observer facing towards the sun than with the sun at the observer's back. One example of this is a car which is being driven in a direction towards the sun, and also happens to be very smoky or on fire. It is very hard for the driver to see any smoke, but all the other drivers behind him cannot avoid seeing billowing clouds of smoke. This is a case which is similar to viewing a smoke plume from a powerplant -- what you may see is not a very strong function of what is actually there. Since it is very difficult to convince people that their eyes can deceive them, it is becoming increasingly attractive to install bag filterhouses on coal-fired powerplants and completely eliminate the problem of a visual smoke plume.

Most of the experience with electrostatic precipitators is with "cold-side" precipitators, that is, precipitators downstream of the air preheater. There is limited experience with hot-side (upstream of the air preheater) precipitators. Although we have chosen a baghouse for the demonstration program it should be pointed out that the final NO_x control configuration may require a reevaluation of our particulate control equipment.

Wet alkaline scrubbers for SO_2 removal have also been developed since the early 1970's. Early experience identified severe problems in the formation of chemical scale inside scrubbers which caused severe operating and maintenance problems. The chemistry of lime and limestone scrubbers is very complex, and basic research is still being conducted on methods of preventing scale formation. However, sufficient engineering know-how has been developed to solve most of the problems encountered with wet scrubbers. Several thousand megawatts of coal-fired generating capacity are currently operating with scrubbers, and a wide variety of commercial systems are available. The choice of a horizontal cross-flow lime scrubber is based on Edison's extensive work done at Mohave including the operation of two large demonstration units.

Some work has been done on various methods for the disposal of flyash and scrubber sludge which is discharged as a consequence of coal-fired powerplant operation. Many types of flyash can be wetted and compacted to form a very hard, impervious landfill. Flyash is sometimes sold as a commercial byproduct used in cement manufacturing or as a road base. Sometimes, the flyash is mixed with the scrubber sludge to promote stabilization of the mixture, with or without other chemical additives. Scrubber sludge resembles plaster of paris, but will not harden by itself. Successful experiments have been conducted to manufacture wallboard from scrubber sludge. It has also been used successfully as a substitute for natural gypsum in the manufacture of Portland cement. Both flyash and scrubber sludge can be used as soil amendment additives and/or crop yield improvement additives, depending on the type of soil, the dosage rate, and the type of crop. Further research to identify suitable end-uses for these products of coal combustion are still in progress.

The most difficult pollution control problem with coal is NO_x. Coal-fired boilers are being offered today which can achieve an NO_x emission level of about 225 ppm (corrected to 3% excess oxygen). This is cleaner than most oil-fired boilers, but has never been demonstrated during long periods of continuous operation on a full-scale powerplant. The Electric Power Research Institute is also developing low NO_x coal burners which may be able to do even better, perhaps down to 150 ppm.

Other technologies exist on a laboratory or pilot plant scale which use ammonia or other chemicals to reduce NO_x emissions. Since ammonia is presently made from natural gas, and is a main ingredient for fertilizer, it is not apparent that it would benefit the nation to divert thousands of tons per day of this resource for the purpose of NO_x control in coal-fired powerplants. The benefits become even less apparent when an emissions inventory for urban areas indicates that automotive NO_x emissions are a much larger percentage of the total -- for example, about eight times more than the total power plant NO_x emissions in the Los Angeles area. Also, it is not clear to what extent any of the emissions, particularly NO_x, will affect ambient air quality.

Thus, although we do not agree necessarily with the regulatory agencies as to the level of control which may be required at Cool Water or for the 1500 MW plant, we are looking at the various alternatives. Figure 5 illustrates the problem with which we are confronted. The data in this figure was supplied by EPRI. First, there are several technologies which have to be evaluated: low NO_x burners, ammonia injection, and ammonia with catalysts. None of these technologies is commercial today, each offers differing possible levels of control, and each is being developed under a different schedule. The problem is compounded by the fact that the particulate control system may be affected by the choice of NO_x control system.

With all of these concerns, the need for adequate pilot and demonstration projects becomes quite apparent. By integrating the EPRI pilot work in NO_x and utility experience in baghouses and scrubbers, a first of a kind demonstration of advanced particulate, NO_x, and SO_2 control systems can be envisioned. A schematic of the possible arrangements is shown in Figure 6. Of course, an ambient air monitoring program will be conducted at Cool Water to measure the plant's impact, if any, on ambient air quality. This then, is the primary purpose of the Cool Water direct coal-fired demonstration project: to take several diverse independently developed technologies and operate them in an integrated fashion with a conventional boiler; to try to do this in a reliable and economic manner, while still demonstrating that it is environmentally acceptable.

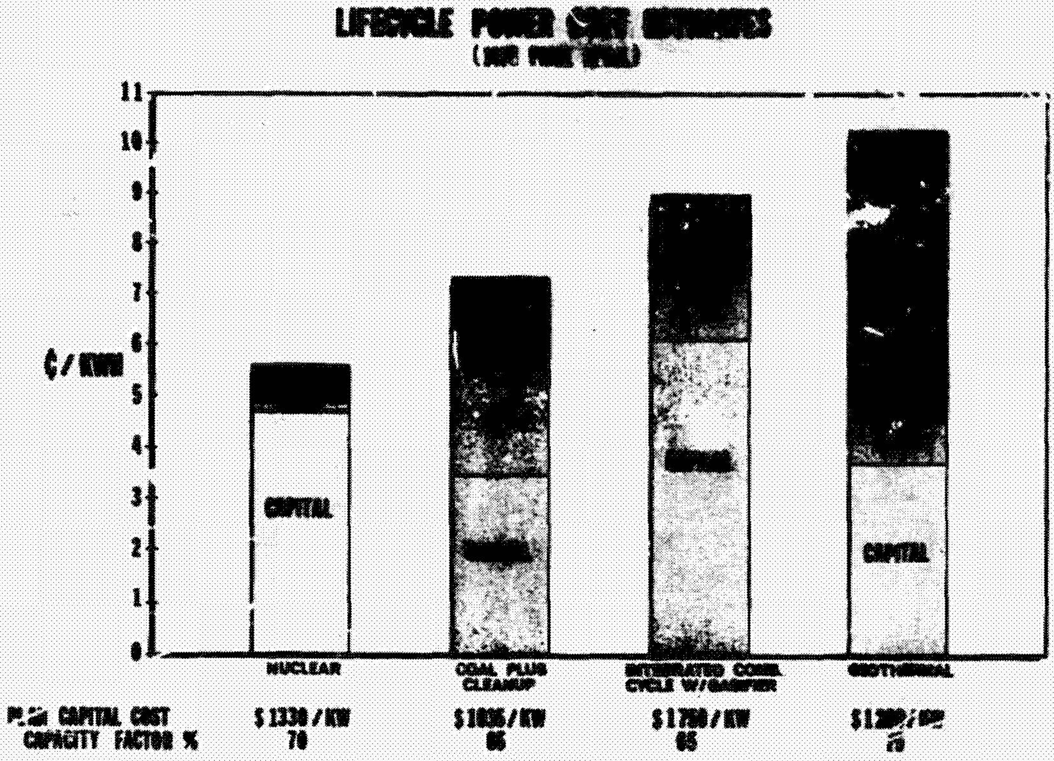

Figure 1 - Economics of Alternate Technologies

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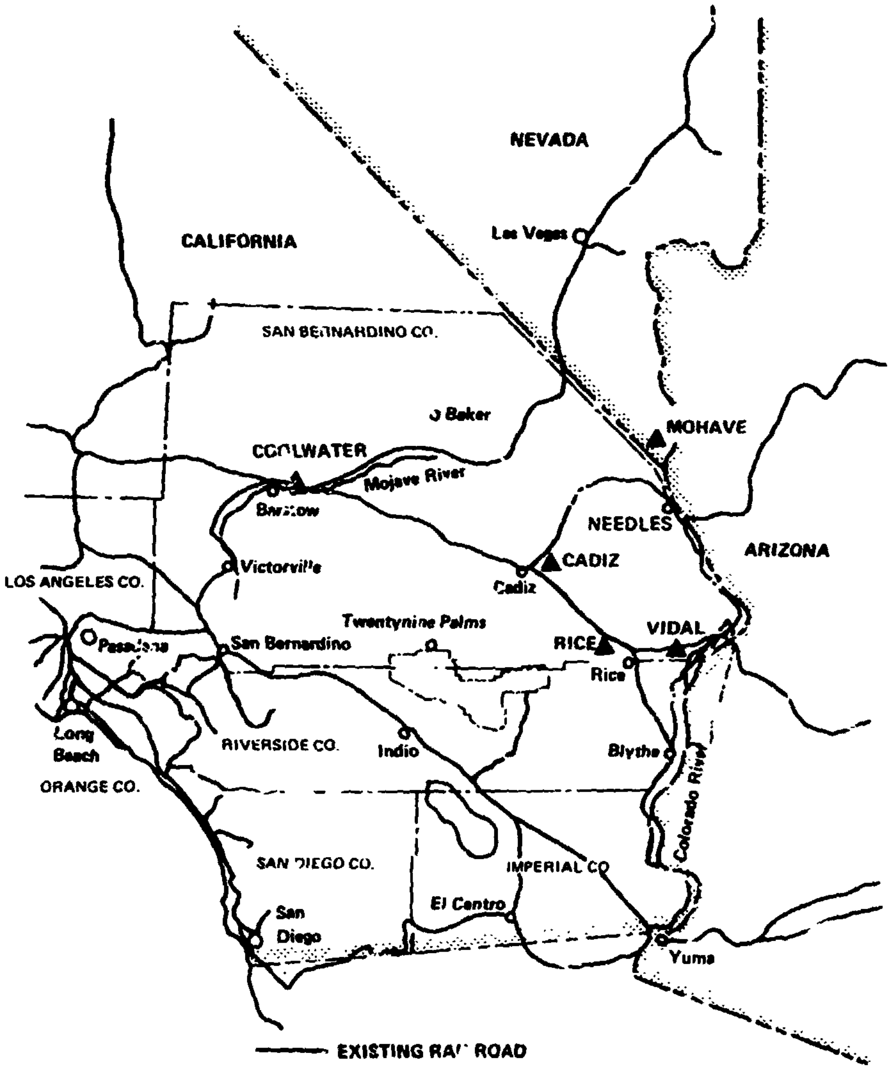

Figure 2 - Southern California Area

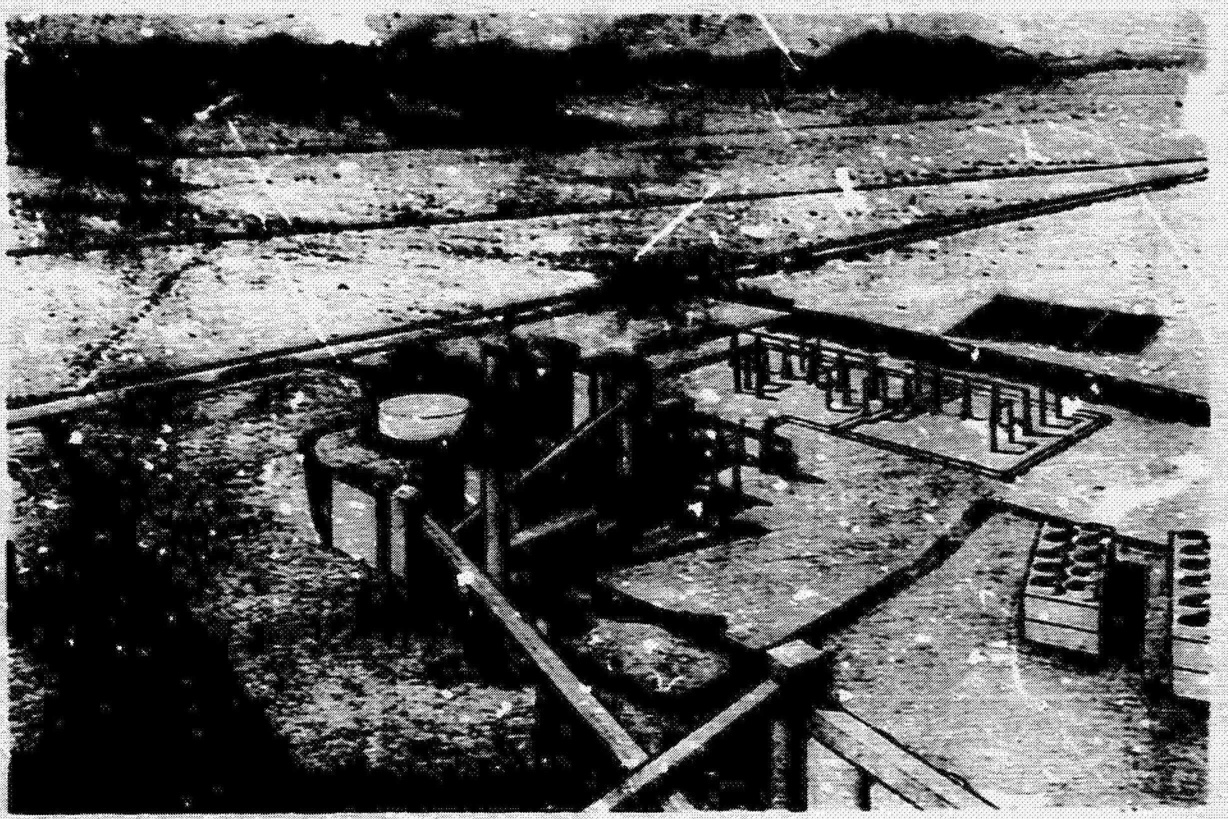

Figure 3 - Coal Demonstration Plant

DIRECT COAL COMBUSTION

	HARDWARE ORDER DATE	PREDICTED RESULTS(ESTIMATES)
Emissions	1978	Particulate (99.80% to 99.98% removal)
	1978	SO_2 (80% to 90% removal)
	1978	NO_x - Advanced combustion (20% to 40% removal)
	1983	NO_x - Advanced combustion plus Catalytic NH_3 injection(80% to ? removal)
	1978	Opacity (smoke plume density) < 1%
Efficiency	1978	Small demonstration plant (80 MW) - 10,600 BTU/KWH
	?	Large new plant (800 MW) 9,300 BTU/KWH
Commercialization	1981-82	Initial demonstration tests completed
	1986-88	Startup of first commercial plant

Figure 4 - Coal Combustion Criteria

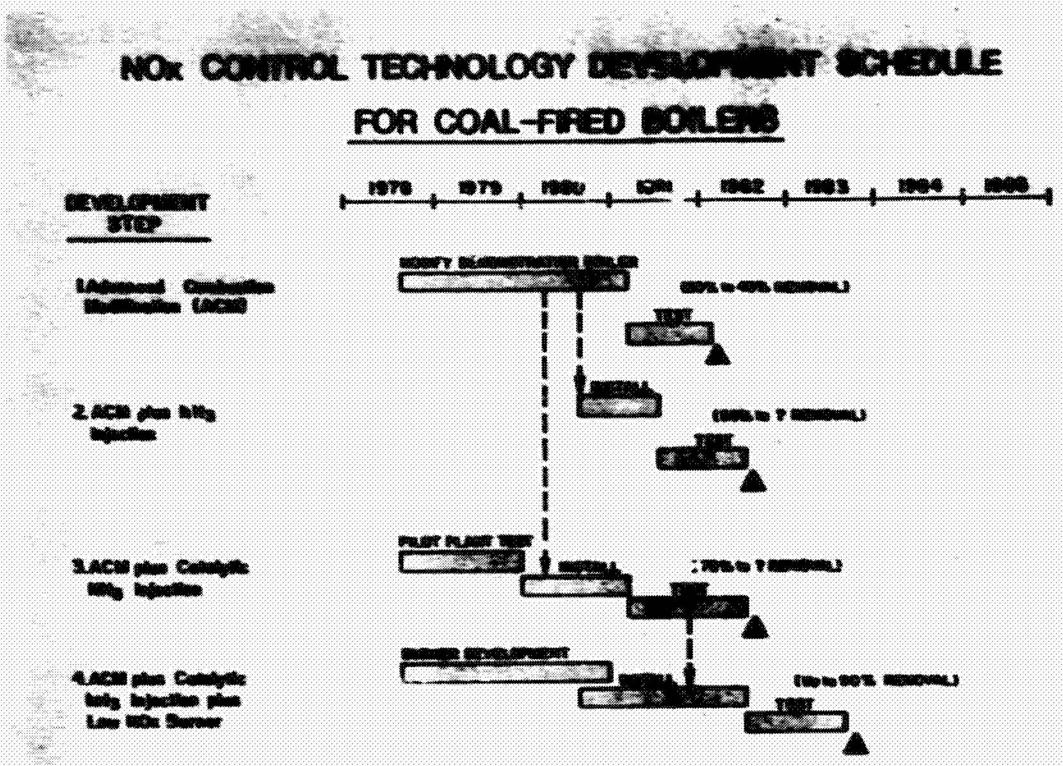

Figure 5 - Coal Boiler Advanced NO_x Control (EPRI)

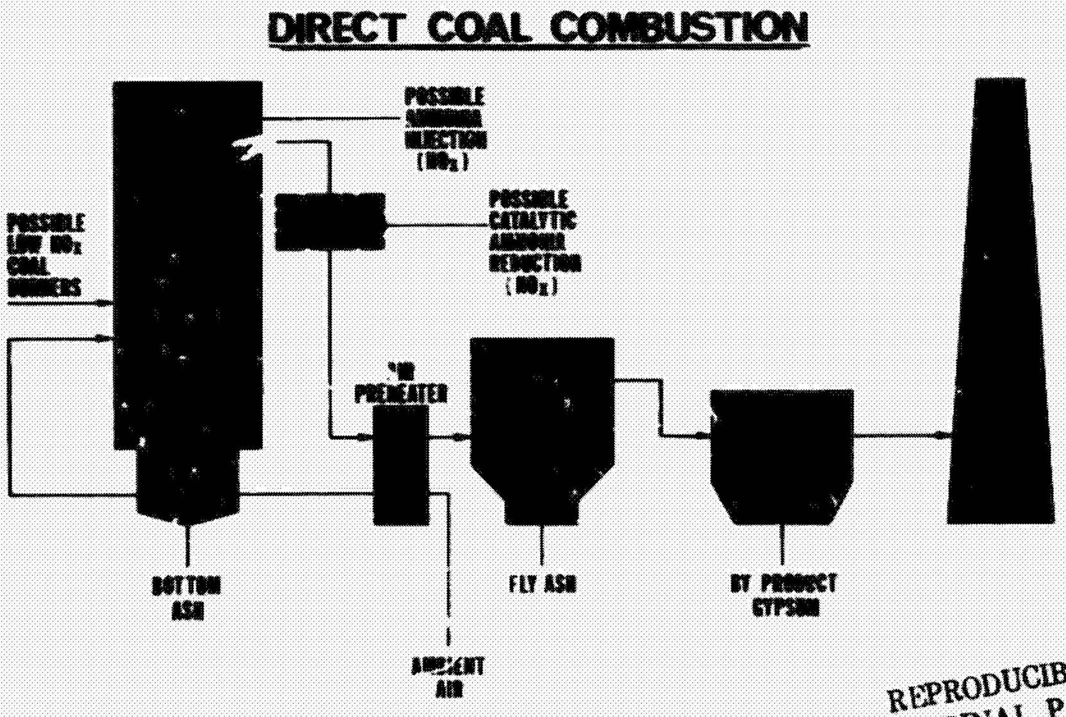

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Figure 6 - Coal Combustion with Integrated Controls