N79-27599

USING COAL INSIDE CALIFORNIA FOR NONELECTRIC APPLICATIONS

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ABSTRACT

An analysis of nonelectric applications for coal will include a review of present energy consumption patterns in the manufacturing, transportation, and residential sectors. The properties of coal that affect its substitution into these market sectors will be discussed. Specific needs and concerns of Californians will be delineated. Present nonelectric consumptive uses of coal in California will be outlined. Current world-wide progress concerning increased industrial use of coal will then be shown. An overview will be given of the options to protect the environment from the direct use of coal, especially from the standpoint of sulfur control; and a time frame for commercialization will be projected. Finally, possible desired changes in energy use patterns over the next fifty years will be proposed.

ENERGY FLOW PATTERNS IN CALIFORNIA

I first would like to review the present energy flow patterns in California to put the nonelectric uses of coal into perspective. Table 1 shows the various energy delivery forms for the period July 1976 to June 1977. Petroleum is obviously the most important resource, with natural gas a close second. What may not be so well known is the fact that coal is in third place, just slightly ahead of hydroelectricity and twice the importance of nuclear. In terms of changes, nuclear increased the most last year, but coal was second in increased percentage. In terms of absolutes the use of natural gas has significantly decreased. Oil continues to dominate the scene; in fact, California increased the import of oil last year by almost 50 percent. Something else will have to happen in the future, and one of the something elses may be the extensive use of coal in this state.

Table 1. Forms of energy delivery for California July 1976 – June 1977

Energy Form	10^{15} Btu's	Annual Change
Natural Gas	1.85	-5%
Petroleum	3.88	+14%
Coal	0.15	+21%
Hydroelectricity	0.14	-38%
Nuclear	0.07	+43%
Geothermal	0.08	-9%
Total	6.18	+5%

Source: Rodman, E. D., California ERCDC.

The users of the various energy resources shown in the first slide are highlighted in Table 2. Please notice that roughly 20 percent of the fuel consumption in California was simply to process fuel itself, i.e., 20 percent was lost for the production and processing of energy before any energy ever got to the consumer. This is also the fastest growing use of energy, i.e., wasted energy is growing four times as fast as total energy use. Fuel for transportation, perhaps not surprisingly, is the major energy benefactor, or problem, depending on one's view of society.

Table 2. Energy usage in California July 1976 – June 1977

Energy Usage	10^{15} Btu's	Annual Change
Production and Processing	1.33	+19%
Gas HCAC	1.54	-1%
Transportation	2.78	+5%
Electricity Sales	0.52	+3%
Total	6.17	+5%

Source: Rodman, E. D., California FRCDC.

If these requirements continue, then California must eventually do what the rest of the world does, and that is to use more coal. Nuclear, by itself, cannot possibly fill the gap in the near future, and there is fear that it never will. Solar will help, but unless or until we change our life style, it cannot do the job we have come to expect. We slip out of bed in the morning in an air-conditioned room to the sound of the electric alarm clock, turn on the light, flush the toilet, shower, shave, and put on nice clean clothes – all before we enter the kitchen expecting the refrigerator, stove, toaster, and so forth, to provide us with what we want. It's considerably later in the morning that we finally press the starter in our car and really start destroying the world's natural juices at a staggering rate. If we keep this up, the only natural fuel that we will have left is coal.

WHAT'S WRONG WITH COAL?

So why don't we go ahead and simply use more coal? Well, first of all, coal can be dirty.

Table 3 shows the ultimate composition range of various coals used to generate steam in the U.S. These elements make up almost entirely the organic portion of coal, although some of the sulfur actually occurs combined with the constituents reported as ash. The ash represents the mineral matter in coal and consists mainly of silicon, aluminum, iron, and calcium oxides, along with traces of most of the other elements in the periodic table. Some of these, e.g., mercury, lead, cadmium, may be environmental problems in themselves. Moisture contents can obviously fluctuate widely depending upon mining and storage conditions.

Table 3. Composition of U.S. coals used for power production

Moisture and Ash Free:	
Carbon	69-94
Oxygen	2.2-24
Hydrogen	2.2-6.0
Sulfur	0.5-6.3
Nitrogen	0.8-2.5
As-Received:	
Moisture	1-43
Ash	3-30

Sulfur, the component of coal under most attack by environmentalists, is not thought to be normally present in the elemental state in coal, but is almost always found combined in three different types of sulfur compounds. The three types are classified as organic, pyritic, and sulfate sulfur. The organic sulfur is bonded into the cross-linked carbon-oxygen-sulfur-nitrogen chains which make up coal. It cannot be easily removed by any coal-cleaning available process today. To remove most of the organic sulfur, we must either completely gasify or liquefy the coal first, or remove it during or after combustion with a sulfur capture agent such as limestone. The pyritic and sulfate sulfur usually occur in the form of occlusions imbedded in the organic mass and are included in the generic term ash. The pyritic and sulfate sulfur can thus be quite concentrated in localized accumulations and can frequently be removed by physical techniques, and easily removed by chemical cleaning techniques.

Nitrogen is normally considered to be bound into the organic portion of coal, and upon combustion can be converted to the oxides of nitrogen which may be considerably more harmful than the oxides of sulfur. If coal is burned at high temperatures, it can also cause the "fixation" of the nitrogen in the combustion air into nitrogen oxides. Particulate emissions can occur from suspended ash particles or unburned coal, or from coal blown around during transport or handling, or from polyaromatic organic by-products, which perhaps are the most insidious of all, and may be exceedingly harmful to health.

Despite the technical jargon in the past about producing clean fuels from coal - that's a technically difficult and expensive way to proceed. Some "cleaned coal" may be more of an environmental problem than the original coal. Fuels based on coal will not be clean unless we are willing to pay a rather considerable premium and energy penalty to cleanse them. One might argue that the real advantage in the production and use of electricity is that it is the most highly developed delivery system known today to provide clean energy from coal. The thermal and economic penalties, of course, are substantial, but many environmentalists claim we should do even more.

So that's what's wrong with coal. On the other hand, coal is stable, does not emit vapors if stored properly, is not particularly radioactive, will not leak, will last for another 200 to 400 years, and there are ample domestic supplies nearby. It has also been the principal fuel in use throughout the world since the industrial revolution. The industrial revolution demanded low-cost energy as a substitute for the energy output of human labor, and coal was the first choice. Coal also may be our last choice.

LARGE-SCALE USE OF COAL

The most energy-intensive industries in the United States at present are shown in Table 4. These industries command approximately three-fourths of all the energy used in manufacturing. They therefore represent the primary opportunities for the expanded use of coal. Since they use lots of fuel and electricity, they are also targeted industries for cogeneration of more on-site electricity and process heat. I would like to discuss each of these industries from the standpoint of coal use.

The chemical industry can, and in some places does, use coal for process heat needs now. Kerr-McGee Corporation, for instance, has a coal-fired boiler for process steam at Trona. The chemical industry will probably eventually shift back toward the use of coal as a feedstock as well. This may not be as difficult as one might think at first glance. Until the advent of cheap petroleum, the world's organic chemical industry was originally based almost entirely on the pyrolysis of coal, as it is still practiced today in the coke ovens of steel plants. However, the price of these organic chemicals will rise if we institute the widespread use of a less convenient raw materials such as coal for petroleum as a feedstock. This is another one of those difficult choices. If we want to continue to use our natural petroleum liquids as fuel our automobiles, then we will force up the cost of organic chemical products now made from petroleum, such as plastic dinnerware, rugs and carpets, blankets, clothing, automobile components, and now even most of our furniture, to noncompetitive price levels from a world standpoint. These chemical products will be increasingly produced at lower cost in the Middle East, with subsequent continued erosion of United States jobs, and even worse balance of payments problems.

Table 4. The six largest industrial users of energy

Industry	Percentage of Total Industrial Purchased Energy		
	Purch. Fuels	Purch. Elec.	Total Energy
Chemicals and Allied Products	21.5	19.4	20.8
Primary Metals Industries	17.9	23.8	19.8
Petroleum and Coal Products	13.3	4.6	10.5
Paper and Allied Products	10.5	6.8	9.3
Stone, Clay, and Glass Products	10.8	4.8	8.8
Food and Kindred Products	8.0	6.9	7.7

Source: NASA-JPL, Technology Briefing on Cogeneration, Washington, D.C., September 15-16, 1977.

The alternative to pyrolysis or direct liquefaction of coal is the gasification of coal and then reforming, as desired, to the products as shown in Figure 1. If we want to pay the price, we can produce low-Btu or intermediate-Btu gas (sometimes called fuel gas) for our industrial furnaces, high-Btu gas (also called synthetic natural gas) for our homes, ammonia as fertilizer for our farms, chemicals for plastics, and methanol for relatively small energy uses such as irrigation pumps and turbines. These will not be cheap products, however. Coal competes with oil and gas on a Btu-basis for direct combustion. If we now convert coal into a gas or liquid by a relatively complicated chemical process, the cost of the synthetic product is probably going to be more than that of natural petroleum-based material it is designed to replace.

If we reexamine Table 4 concerning industrial energy users, the paper industry, which uses wood almost exclusively as its raw material, and is the fourth largest industrial user of energy, could obviously use coal for energy, as it does in many states already. However, this might be unwise in the long run. Perhaps the paper industry should simply be encouraged to use no other fuel than wood itself. It certainly is in a better position than anybody else to use wood, a fuel which we are trying to encourage others to use.

The food products industry in California has substantial needs for fuel. The problem with the use of coal here is the seasonal nature of the demand. If the costs of environmental control technology must be written off over a relatively small fraction of the year, the use of coal may prove to be uncomfortably expensive. The food industry therefore represents a potential market for the so-called cleaned coal, or solvent-refined coal, if regulations could be judiciously written to permit the intelligent use of this technology. Whenever possible, of course, the wastes from these agricultural operations should be used for fuel.

Perhaps the most immediate substitution possibility is the use of coal in the petroleum industry. Figure 2 shows a photograph of a Union Oil steam-flooding operation at Guadalupe. These units generate steam by the combustion of oil, the steam is then injected into the ground to force up additional oil. The flue gas from the boiler is scrubbed with caustic. Perhaps surprising to many of you, California has more SO_2 scrubbers in use than any other state in the nation. That should bring a smile of satisfaction from Frank Princiotta. A close-up of a Chevron steam generator at the Kern River reservoir near Bakersfield is shown in Figure 3. The oil furnace is the horizontal cylindrical device, and the caustic scrubber is the vertical box-like structure between the boiler and the flue. Coal could be substituted here for steam generation to save more oil for our automobiles, but more manpower would be required to operate the units, and then there is the problem and cost of ash disposal. The cost of gasoline would therefore rise, but perhaps that's good, and certainly the oil reservoir would last a little longer, which is what we are trying to accomplish from both a national and a state standpoint.

The last two of these six most energy-intensive industries already use substantial amounts of coal in California. The Kaiser Steel Mill at Fontana now consumes 7000 to 8000 tons of coal per day. The coal is brought in by train from the Sunnyside mine in Utah and the York Canyon mine in New Mexico. The underground mine at Sunnyside is shown in Figure 4. The coal is brought to the surface and transferred to unit trains. You will hear more about these unit train shipments later in the program. The coal is charged to coke ovens like that shown in Figure 5. This is a photograph of a slot oven. The coal is ground, mixed, and rammed into the open slot, allowed to cook or stew to drive out the volatile by-products and to cement the residual coke into massive chunks suitable for charging to the blast furnace. In the blast furnace, iron ore is reduced to molten iron, at extremely high temperatures by the coke. A photograph of the molten iron running out of the bottom of the blast furnace at the Fontana works is shown in Figure 6. From here, the iron is refined to steel to be used as the raw material for numerous products, the most important of which is our friend the automobile, but also for cans for food processing, supports for our buildings, and conduits to bring water, gas, electricity, and coal into our homes. Steel is also used as structural components in bridges and highways, which are again needed by our faithful automobile.

The other significant industrial use of coal at present in California is in the cement industry. A photograph of the Amcord cement plant just outside Riverside is shown in Figure 7. The five long tube-like affairs at the upper right are the coal-fired rotary kilns. The coal pile at center left is shown in close-up in Figure 8. The natural deposit of limestone, also used in the production of cement, is the natural mound of material sticking up behind the coal pile. Coal is pulverized and fed to the kilns to supply the heat necessary to produce the cement. The ash and sulfur can be incorporated with the limestone into the cement, which solves most of the pollution problem. Figure 9 shows a close-up of the baghouse which filters the effluent gases from the kiln. As may be noted, baghouses do a very effective job of removing fly ash and kiln dust. One of the principal uses of cement is in roads for automobiles.

SMALL-SCALE USES OF COAL

Since there is very little use of coal for heating, cooling, and air conditioning applications in California, I am going to use some slides showing photographs of the use of coal in Ohio for illustrative purposes.

Battelle provides research services for roughly 2500 people in Columbus, Ohio, and our power plant is shown in Figure 10. We have three boilers, one of which was converted to coal two years ago. Our coal pile is shown to the right. The feed hopper is the tall, vertical, cylindrical, cement block structure on the left. These boilers help to supply heating in the winter and cooling in summer, as well as process steam to operate our experimental equipment, and the like, throughout the year. During the gas shortage of two years ago, when the entire school system in Ohio was shut down for three weeks because of lack of gas, we opened our doors to approximately 2000 school children in Columbus so that educational programs could be continued in our facilities. We felt quite secure with our coal pile. We also use coal-generated steam to run our 90-ton/hr chiller, which cools our 600-seat auditorium. This chiller is based on a lithium bromide cooling cycle, which employs steam for regeneration.

There is at least one facility in Ohio which uses a scrubber on the power plant, and a photograph of such a unit on a nearby air force base is shown in Figure 11. Sludge disposal is a problem here and the technique used for sludge disposal is simple impoundment. A view of the 2 1/2 acre pond is shown in the foreground. This pond has sufficient volume to store the sludge which will be accumulated during the next five to ten years. After that, presumably we will have to dig another pond.

I would now like to show a photograph of a house in my neighborhood which still employs a coal-fired stoker in the basement for heating in the fall, winter, and spring. A view of the house from the front is shown to the left in Figure 12. The previous night the temperature dropped down to about 32°F, and the furnace was on when this photograph was taken. No emissions from the chimney could be observed. A view inside the basement is shown in Figure 13, and you will notice a nice warm fire in the hearth. The ashes and clinkers must be withdrawn periodically, and the tubs containing previous withdrawals, waiting to be carried out, are shown on the floor in front of the furnace. The last photograph in this series, Figure 14, shows the coal bin and clean clothes hanging in storage to the right of the coal bin. A much cleaner arrangement than my own basement, which contains a coal fired furnace that was converted to gas several decades ago.

THE FUTURE OF COAL IN CALIFORNIA

Coal should be used in California with discretion. The larger the boiler or industrial furnace, the more attractive its use will become. Coal should probably have first priority for the process needs, and especially the high-temperature process needs of industry. Its use in smaller scale applications such as for space heating and cooling in residential, military, hospital, commercial, or light industrial complexes should be accelerated.

Research work going on in California which may be of help in the future is shown in the next two figures. Figure 15 is a view of the TRW Capistrano pilot plant on a new process to clean coal. As indicated earlier, however, if the coal contains large amounts of organic sulfur, it cannot be of great help. Figure 16 shows a view of the Weyerhaeuser 7-1/2-foot diameter fluidized-bed combustor and its associated 1-MW gas turbine located at the Combustion Power Company's Menlo Park facility. The fluidized bed shows promise as an alternative to flue gas desulfurization in that it will capture sulfur during combustion, hopefully at lower cost. Other pertinent work is going on right here at JPL, by Occidental, Stanford Research Institute, and many other organizations.

However, the massive socioeconomic change which is facing not only Californians, but the nation, as well as most of the world, is the problem of the automobile. In terms of the long-range future, it seems that the transportation system based on the personal automobile(s), as we have come to know it, will have to change.

Electricity may be the preferred source of power in the future for most personal transportation, including the automobile, the light truck, the railroads, and mass transportation. This electricity could be produced primarily from coal in large, relatively efficient plants. Cleaned coal, or the so-called clean fuels from coal, could then be used for individual residences and for light manufacturing. Heavy industry will continue to use coal as it has in the past. I am sorry to report that energy for all such uses will no longer be cheap. If the federal government wants to force the technology of synthetic fuel from coal into the industrial marketplace, I believe the most expedient route to do so would be for the government to become the purchaser of such fuels, and to use such synthetic fuel for governmental purposes. The state governments could then join in such federal endeavors as they think prudent.

We must decide for ourselves, and decide relatively soon, what price and sacrifices we are willing to accept for the continued exploitation of energy. Coal should be utilized where appropriate, but it should only be used with discretion. It cannot be both clean and cheap, no matter how much we want it to be otherwise.

ACKNOWLEDGMENTS

I would like to acknowledge the help of Dr. Don Peterson with the California Energy Commission for background information on California's energy needs. Help with respect to visual material was provided by Dr. Henry Wigton of Weyerhaeuser and Dr. Bob Meyers of TRW concerning photographs of their pilot plants in California; by Harvey Rosenberg of Battelle for the photographs of the scrubbers at Rickenbacker, Bakersfield, and Guadalupe; and by Dave Ball of Battelle for the photographs of the baghouse and coal pile at the cement plant in Riverside. The aerial photographs of the Armcord cement plant, and all photographs of the operations associated with the Fontana Steel Works were reproduced from annual reports of the Kaiser Steel Corporation and Amcord, Inc. Finally, I would also like to thank our neighbors, Mr. and Mrs. John S. Motil, for permission to photograph their lovely home.

Process	Product
Air Blown Producer	Low-Btu Fuel Gas
Oxygen Blown Producer	Medium-Btu Fuel Gas
Methanation	Synthetic Natural Gas
Haber	Ammonia Fertilizer
Fischer-Tropsch	Olefins and Paraffins
Oxo-type	Alcohols and Aldehyde

Fig. 1. Chemical products by the gasification of coal

Fig. 2. Union Oil steam flooding operation at Guadalupe

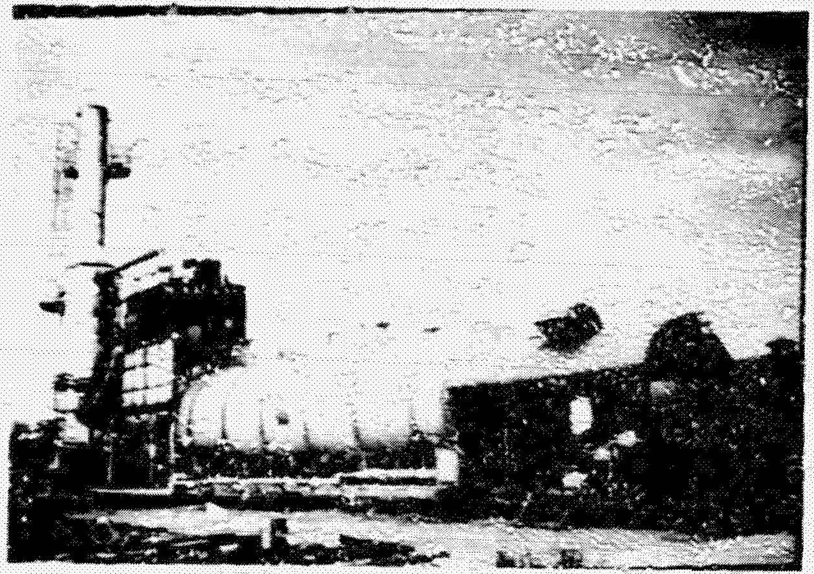

Fig. 3. Chevron steam generator with scrubber near Bakersfield

Fig. 4. Photograph of Longwall mining operation at Sunnyside

Fig. 5. Slot ovens for coke production at Fontana

Fig. 6. Discharge of molten iron from the blast furnace

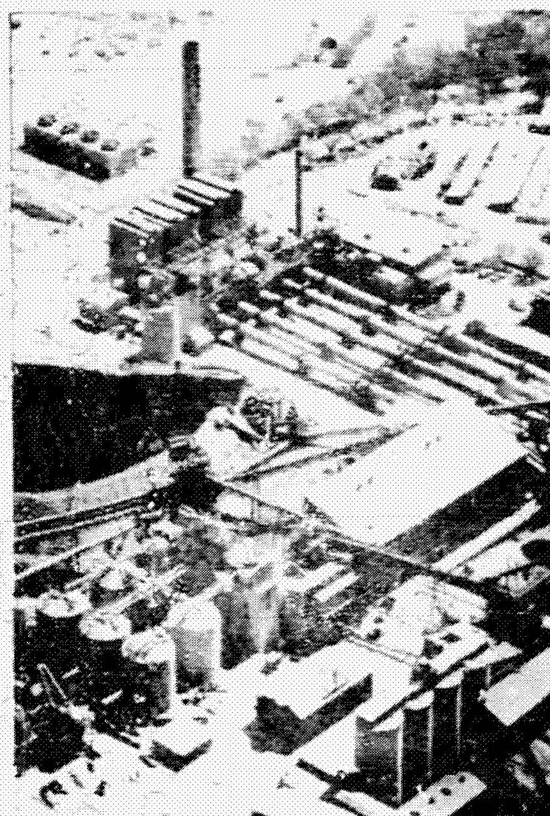

Fig. 7. Amcord cement plant at Riverside

Fig. 8. Storage pile for coal for cement production

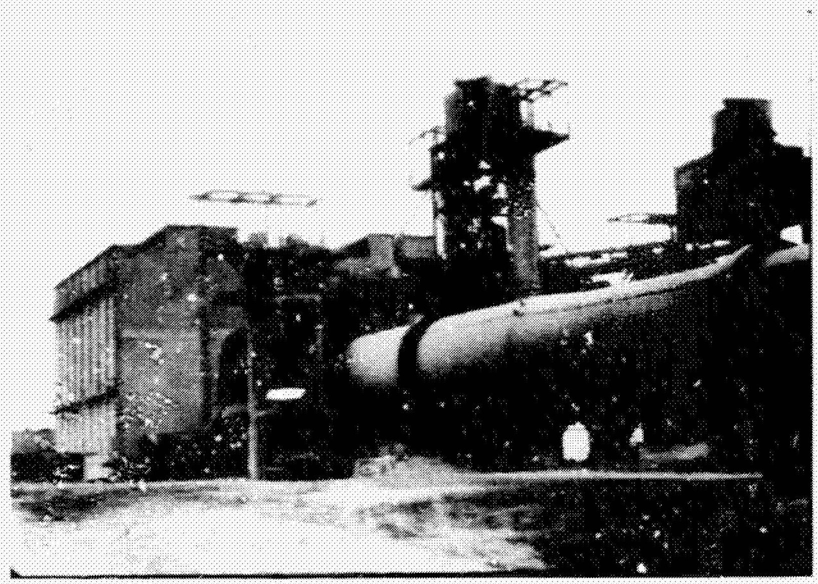

Fig. 9. Baghouse for dust control at Amcord plant

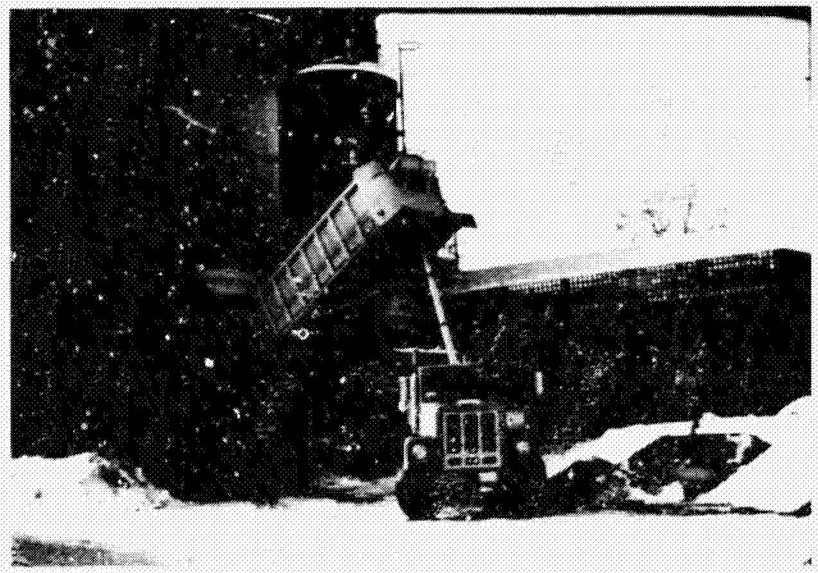

Fig. 10. Power plant at Battelle-Columbus

Fig. 11. Sludge pond for scrubber at Rickenbacher Air Force Base

Fig. 12. Photograph of home with coal-fired furnace

Fig. 13. Stoker furnace in neighbor-
hood basement

Fig. 14. Storage areas for coal
and clean clothes

Fig. 15. TRW pilot plant for coal cleaning at Capistrano

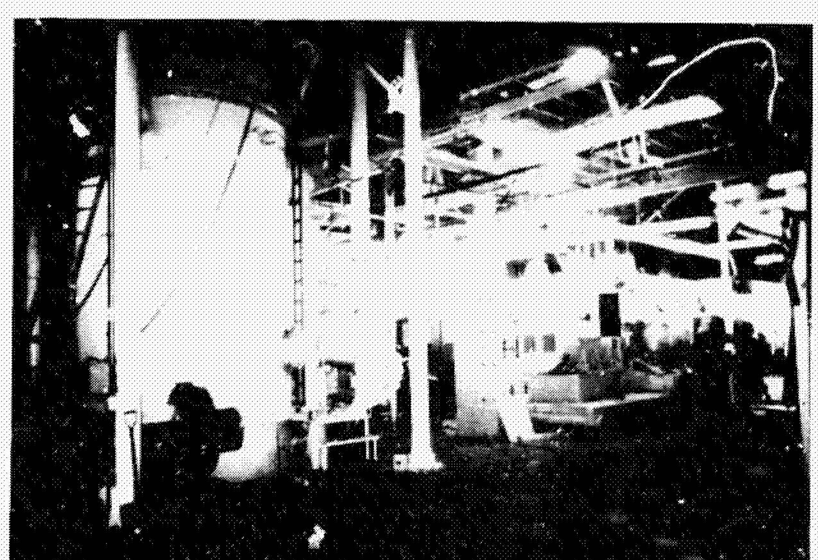

Fig. 16. Weyerhaeuser's fluidized bed combustor at Menlo Park