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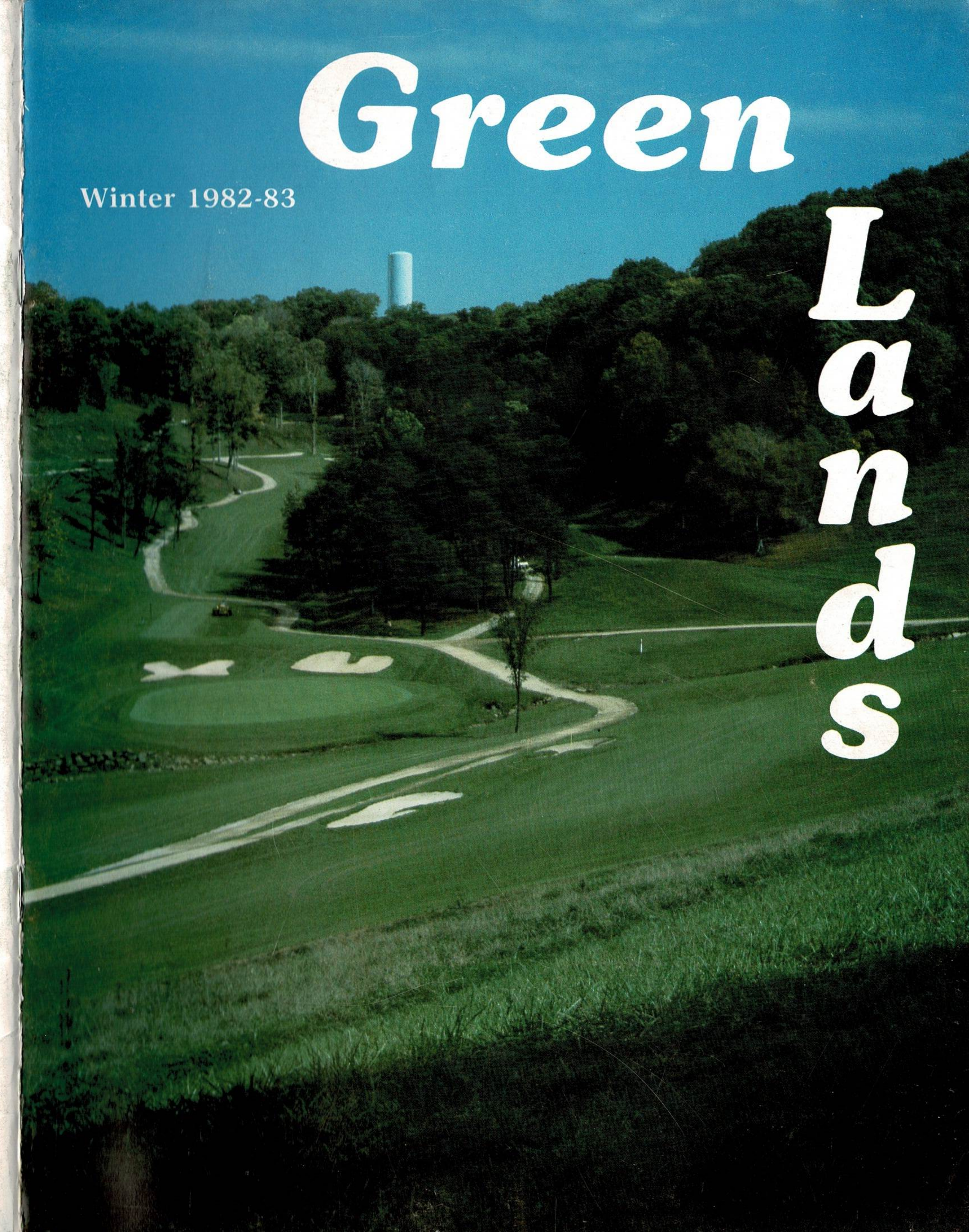

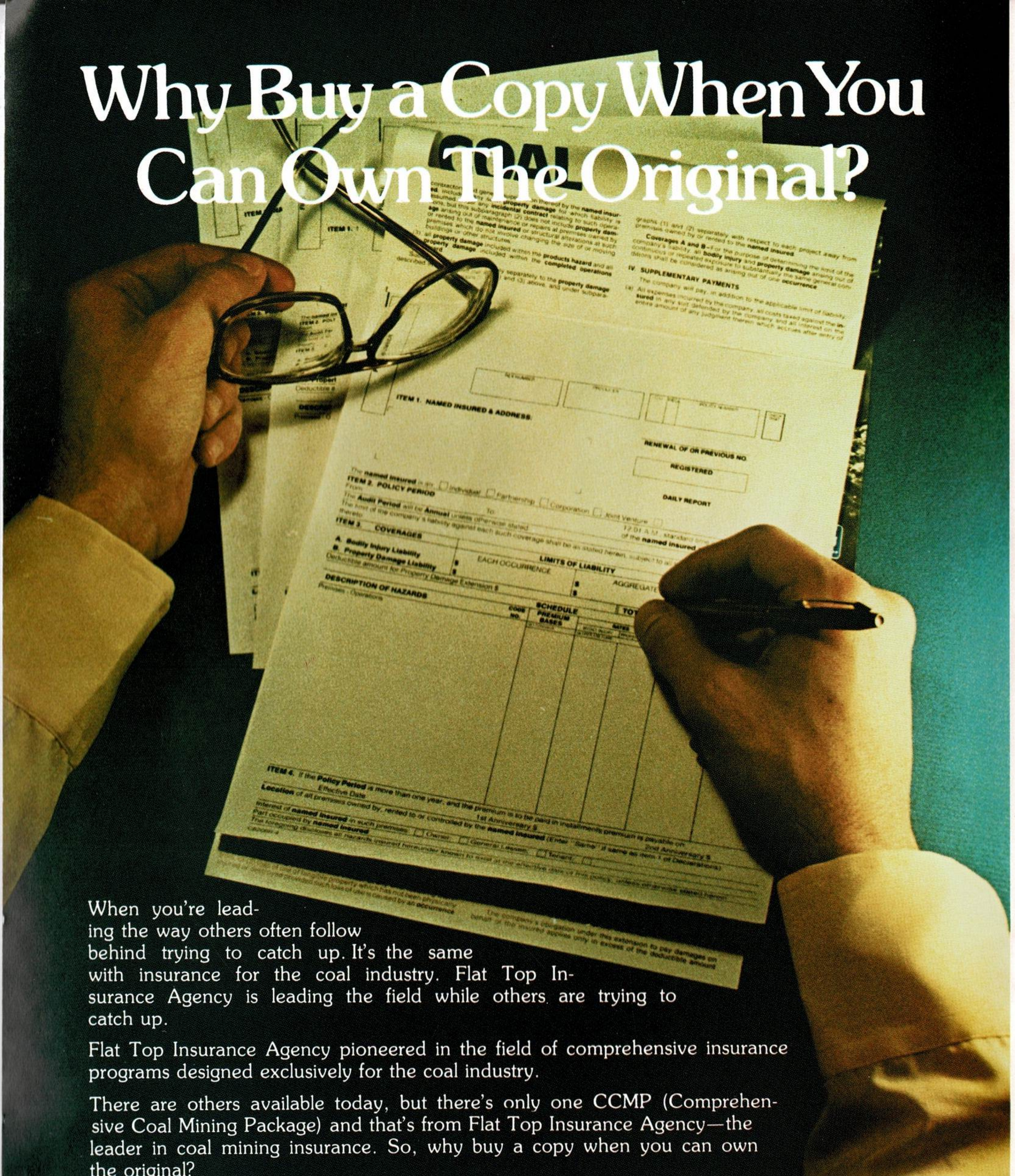

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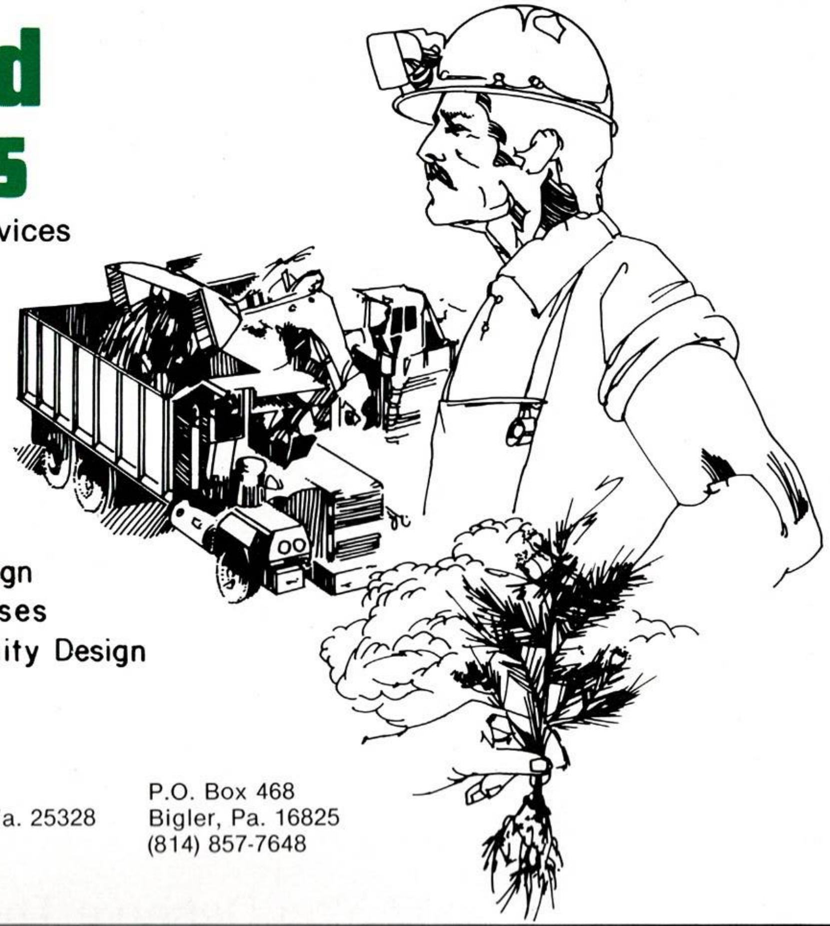

Index to Advertisers

Green Lands

Volume 12 number 4

Cover—Early implementation of modern mining laws have kept West Virginia at the top in the reclamation industry. However, early day reclamation jobs weren't all bad either. Our cover photo is from the beautiful Scarlet Oaks Country Club in Putnam County. The course was built on and around a mine site from the 1950's. In the interim, the acreage served as a dairy farm. Far more on post mining land use, see our cover story on page 9.

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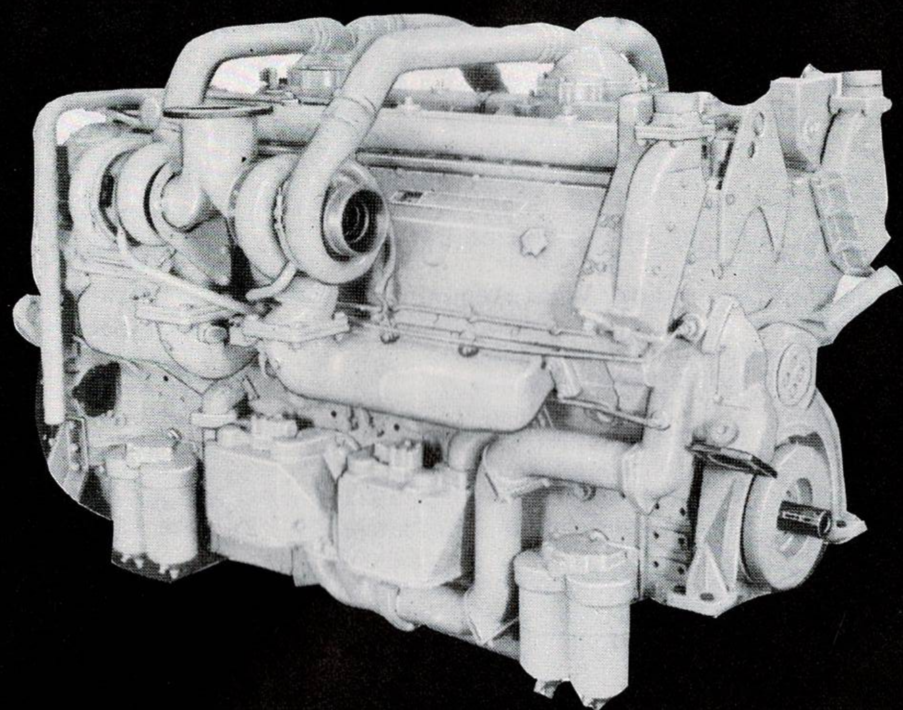

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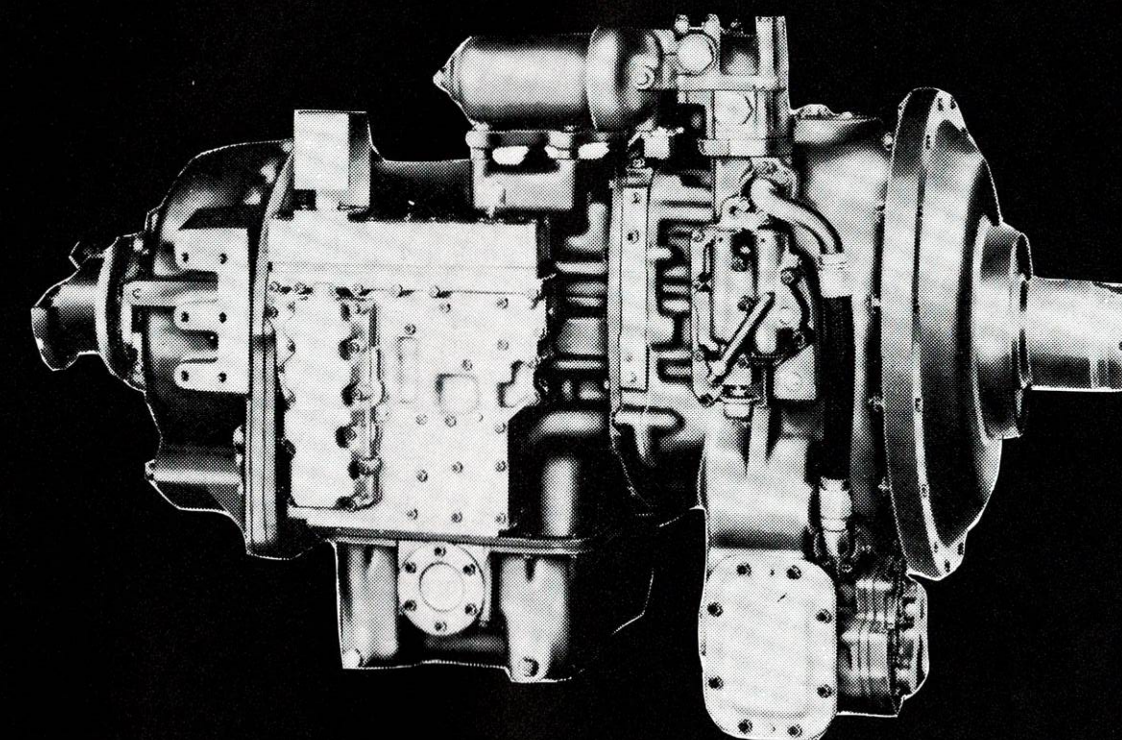

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An interview with Don Donell

Editor's note: Don Donell is president of Starvaggi Industries, Inc., and current chairman of the Board of Directors of the West Virginia Surface Mining and Reclamation Association.

GL: *What are the Association's priorities for 1983?*

Donell: "To get West Virginia coal moving again, period."

GL: *What should the Legislature be doing for the coal industry?*

Donell: "Without beating to death what's already been said, I think it's the job of the Legislature to lead the state out of its economic difficulty. The time has passed us by when we can afford to resort to regressive taxation as an economic solution. I don't believe the current problem is cyclical in nature, but rather the result of worldwide economic problems to which government should offer innovative solutions. Government can do this by encouraging productivity and increased revenue. By this I mean, work and productivity incentives should be built into our tax system, in the same way that business provides those incentives to its work force. After all business, through taxation, is the work force of government.

"I simply don't accept that any legislative body can overcome its constituent's revenue problems just by passing another tax measure. Corporations, hospitals, educational institutions – any entity must make adjustments to difficult economic times. Government is no different. Allowing economy to be ruled by politics is generally a fatal blow to the entire economic system.

"There's no better example of that than the Soviet Union, which can't even feed itself. Or, for an example closer to home for West Virginians, look at the Polish coal industry, which is in a shambles.

"The prevailing relationship between politics and economics is a basic problem that must be faced by government. Legislators are doing a disservice to their constituents if they ignore it. In our economic system, free enterprise must be encouraged, not subjugated.

"Beyond taxation, I think the Legislature specifically needs to work on correcting some problems created by our State Supreme Court. Mandolidis would probably top this list. (Editor's note – "Mandolidis" refers to a 1981 Court decision which leaves employers open to unlimited litigation for work related injuries.) We had a workable system which was wiped out by the Court's interpretation of a specific case. In effect, it has created a flaw in the law. This needs to be corrected.

"The Legislature also needs to work on workmen's compensation and unemployment compensation reform. Despite the burden placed on employers (1% surtax), we are going deeper and deeper into debt to the federal government with unemployment compensation. We simply must bring about a balance between income and payments. I believe this can be accomplished by restoring the incentive to return to work in those cases where it is possible.

"There is also work remaining to be done in streamlining the permitting process. Progress has been made in this area, but we still experience a waste of time and money in obtaining permits for a mining operation, with no corresponding environmental benefit.

"Finally, and I realize that this is a touchy area, we need to make safety regulations more realistic. Many people don't seem to realize that management has a bona fide interest in safety, financially as well as morally. But we have some regulations on the books now, again mostly through the judicial process, which just do not make sense. After the couple of years we've had to work with these in the field, it's time we cleared away the deadwood regulations and refine those that have some meaning and benefits."

GL: *Has the Reagan administration been good for coal?*

Donell: "Yes and no. In terms of actually helping and promoting coal, I can't see that the Reagan administration has done anything for coal, and I'm very disappointed with that. For instance, the synfuels program has gone nowhere with this administration. Synfuels, in addition to being a major boost to American coal, was also an important hedge against our dependence on foreign energy. I shudder at the thought of any degree of dependence on foreign fuel sources, and I think the federal government should do everything in its power to keep that from coming about.

"On the other hand, this administration can be credited with removal of some of the regulatory roadblocks to coal production. Certainly, the regulatory approach of agencies like OSM and EPA is much more realistic than was the case four years ago."

GL: *How far have we come in eliminating wasteful regulation? How far do we have yet to go?*

Donell: "As I indicated before, we have made progress, but we still have a long way to go. I think the whole concept of federal regulation was one of overkill. Certainly, the way in which the Surface Mining Act of 1977 was implemented has hamstrung the states in doing their own regulatory work. I have also noticed a disturbing hesitancy on the part of individual states to aggressively attack the federal government for its mistakes.

"On the state level, in West Virginia, my comment would be that there must be a simpler way to approve a surface mining permit. Despite some recent streamlining, it is still easier to permit a $50 million highway than it is for a 150-acre surface mine. In West Virginia, you know, the permit application starts with the local inspector and works its way up. I think its fine for the inspector to have full imput, but why can't that be concurrent with the process in Charleston? That alone would mean a tremendous savings."

GL: *How do you see the effects of the West Virginia Coal Development Authority and the Coal Commission?*

Donell: "I think the CDA is to be commended for attempting, within existing constraints, to sell and promote West Virginia coal, and I think its been effective to a point. However, their problems in selling coal are the same as ours, and they're tough to overcome.

"As to the Coal Commission, I would say that if nothing else, it has gotten a cross section of the industry to sit down together and discuss the problems intelligently – and that's good."

GL: *What have been the effects of the fall advertising campaign in which the coal industry criticized West Virginia's business climate?*

Donell: "I think its been very good. The comments we've received, both pro and con, tell me that our message is getting across. The things we said in those commercials have drawn rebuttals from some of the people responsible for the problems. They've tried to justify the situation, and I think their justifications have been shown to be shallow, and full of political rhetoric. I sincerely believe that the majority of the people who followed the controversy would agree with that assessment. At the very least, we've gotten a lot of people thinking about what the problems are, and we certainly welcome that. It is a good start for a permanent solution."

Scarlet Oaks is acknowledged as one of West Virginia's outstanding golf courses.

Strip mine? What strip mine?

Much has been made of the West Virginia record in modern reclamation. Indeed, the West Virginia Surface Mining and Reclamation Association has been at the forefront in pointing to the amazing results produced by technological leaps and bounds over the last two decades.

West Virginia was the first state, for instance, to mandate the total elimination of highwalls, a requirement later reflected in federal law. West Virginia was also the birthplace of steep slope haulback, and of mountaintop removal, or flat top mining.

These innovative techniques offered multi-dimensional advantages. Mineral recovery increased; disturbed acreage decreased. Equipment utility became more efficient. Aesthetic qualities of the final reclamation product were enhanced.

By the time the federal government inflicted its version of uniform surface mining regulation of the states, West Virginia was the acknowledged reclamation leader, a model in many ways for other states to emulate.

Any discussion of "old reclamation" generally conjures images of denuded hillsides, piles of refuse, and eroded landscapes. But many responsible mining operations were carried out during the "highwall days." With a little assist, Mother Nature has taken good care of many of the older mine sites.

Such a case is the current site of the Scarlet Oaks Country Club, in Putnam County.

Scarlet Oaks is acknowledged to be a beautiful golf course. It is the scene each year of a celebrity benefit tournament, and is generally accepted as one of the outstanding courses in West Virginia.

Popular myth has it that Scarlet Oaks is a converted dairy farm, and that's true as far as it goes. But in the 1950's, the lush fairways yielded coal.

The trained eye can still detect signs of a former surface mine site. There are small highwalls here and there. But the works of early day reclamation people and latter day golf course architects have blended beautifully, as the pictures on these pages will attest.

In north central West Virginia, at two rural sites about 60 country road miles apart, faith in reclamation takes

Reminders of the land's surface mining past are present, but difficult to detect. The lower photo, for instance, includes a highwall.

An old sediment pond is now home for fish, ducks, migrating geese, and Art Sandy when he feels like fishing.

a slightly different form. Here, two men thought enough of modern mining and reclamation to make their homes on the reclaimed mine sites.

Art Sandy, longtime president of Barbour Coal Co., retired to his mountain. "We originally bought an old farm near here," he says, "just to use on' weekends. My intention was to build a nicer place someday, but still just for use on weekends and maybe vacations. But the further we got along, the more involved it became, and we finally just decided to move up here altogether."

The Sandy home, about seven miles outside of Bridgeport, in Harrison County, sits on an undisturbed point in the middle of several miles of twice mined farm land. "This was a remining project," he recounts. "It was good farmland when the mining started and it's good farmland today."

Art Sandy's home is rural – there are no other houses in sight – but it's by no means rustic. He and his wife have just about all the comforts of their urban counterparts, plus a few that aren't available in the city. "The grandchildren just love it up here," he says proudly. "There's plenty of room for sled riding, or just walking, or about anything you might want to do."

He also enjoys his own fish and duck pond, a converted sediment control structure from the mining days. "We have to plan our trips to town more carefully, like other folks in the country," Art Sandy concluded, "but we wouldn't give this place up for anything."

Mike Jenkins didn't wait to retire to the mountaintop. He moved right in as soon as reclamation was completed and his house could be built. "We more or less built this mountainside," Mike says of the Mary Ruth Corporation operation where he works with his Dad, Milford. "This was mostly just piles of rock," he says, gesturing to what must be one of the biggest front yards in the state.

Like Art Sandy's grandchildren, Mike Jenkins's boys have plenty of room to roam. The Jenkinses also enjoy a spectacular view from their rear deck. The house is situated about ten miles from Kingwood, the county seat of mountainous Preston County. On a clear day, you can see to Maryland. Other days you can look down on the clouds.

Country living may not be for everyone, but skeptics who believe that nothing ever comes of plans for post mining land use, should go ask Art Sandy or Mike Jenkins, two men who have made their beds, and are quite content to lie in them.

Art Sandy's house sits on an undisturbed point in the middle of the old mining operation. Reclamation, and a little homeowner's landscaping, have placed the Sandy home in a very picturesque setting.

Mike Jenkins lives on top of the world, at least on top of the West Virginia part of it. The Jenkins home site features a front yard that no kid could knock a ball out of, and a back yard view of the surrounding Preston County countryside.

An alternative to oil

Burning coal with gas

by A. E. S. Green

Biography

A. E. S. Green is a graduate research professor of physics and nuclear engineering at the University of Florida, Gainesville. He is the director of the University's Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences (ICAAS). As a graduate research professor, he has taught in the departments of electrical engineering, mechanical engineering, engineering sciences, and astronomy.

In Brief

Research and economic analysis which has been performed at the University of Florida indicates that boilers originally designed to burn oil can be converted to burn mixtures of pulverized coal and natural gas, with no increase in criteria air emissions or substantial derating at a modest conversion cost and considerable cost savings, compared to remaining on oil. It is estimated that $2.5 billion per year (1980 dollars) in total annualized costs could be saved by converting suitable oil-fired Florida electric generation plants to gas-coal burning. Nationally, the savings are estimated at $12.5 billion annually in power plants alone.

This article summarizes a recently published book, *An Alternative to Oil: Burning Coal with Gas.* The book, prepared under the auspices of the Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences (ICAAS) of the University of Florida, was edited by A. E. S. Green with contributions by J. R. Jones, Jr.; M. J. Ellerbrock; J. M. Schwartz; S. J. Kuntz; and B. Zeiler. Copies may be ordered from the University Presses of Florida, 15 N.W. 15th St., Gainesville, FL 32603.

Background

Recently, the Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences (ICAAS) at the University of Florida completed two broad interdisciplinary studies relative to coal burning. The first, "Coal Burning Issues" (ICAAS 1980a, to be referred to as CBI), was a monograph written in a national context reporting the results of the scoping phase of an interdisciplinary assessment of the impact of the increased use of coal. The second report entitled, "The Impact of Increased Coal Use on Florida (IICUF)" (ICAAS 1980b), was a study to determine major economic, social, environmental and technological issues to be considered in reference to increased coal burning in Florida and a projection of options available to the state attendant to each issue. The major conclusion of both studies was that the nation and particularly the State of Florida, must quickly reduce their large reliance on foreign oil; and that conservation measures and increased reliance on the abundant national supply of coal were the major alternatives available to the public in the next few decades.

More recently, increased estimates of the economically recoverable natural gas reserves in the United States prompted the study, "Gas-Coal Burning Options" (Green and Jones 1981), which concluded that the State of Florida, and with it the United States, should broaden the options in its transitional energy plan to include the development and utilization of flexible combinations of gas-coal fuels for industrial and utility boilers. The coherence of this last study with economic analyses favoring select gas use with coal (American Gas Association 1981, Schlesinger 1980), led to a grant by A.G.A. to ICAAS to study economic and related technical aspects of converting Florida's electric utility oil boilers to gas-coal burning.

Abstract of Report to American Gas Association (August 26, 1981) on the Conversion of Utility Oil Boilers in Florida to Gas and Coal Burning

"Natural gas production levels in the United States now appear sustainable to the year 2000 at 20 trillion cubic feet (Tcf) or greater. Thus, natural gas need not be phased out of utility and industrial applications as originally specified by the 1978 Power Plant and Industrial Fuel Use Act. This study evaluates the use of gas with coal in Florida to replace residual oil in utility steam boilers originally designed for oil burning. The conversion costs (in dollars per kilowatt) are estimated for various oil-backout options: (a) coal-oil mixtures; (b) dual coal or oil use; (c) new coal-fired boiler; (d) gas-coal; (e) water-coal; and (f) water-gas-coal. Simplified economic comparisons based upon the annual costs of a 200-

megawatt unit favor the gas-coal option. A more refined and detailed economic analysis of the conversion to gas-coal of 12,678 megawatts of suitable oil boiler capacity in Florida is carried out, which allows for fuel and general inflation rates and economies of scale. The results indicate a savings of 2.5 billion dollars per year in annualized electric generation cost (1980 dollars) over the 1980-95 period, and a reduction of about 50% in the annualized power production cost.

"The most important factor that influences our economic projections is the price difference between oil and coal energy. Gas energy, which plays only a 30% role, is not very influential upon costs. The air quality impact of conversion from oil to gas-coal is examined. It is shown to be possible to maintain or improve upon current emission standards. Oil use in Florida's 10-year electrical generation expansion plan would be substantially reduced if gas-coal conversions were implemented."

Whether gas and coal can displace the much larger proportion of oil used in electrical generation in Florida (50%), as compared to the USA as a whole (15%), was the underlying question of our Florida study.

State of the Gas-Coal Burning Literature

About the same time as the initiation of the Green-Jones (1981) study, an experimental study of natural gas-pulverized coal burning was started using a burner in the 0.5 million BTU per-hour range. This field program was influenced by two years of exploratory thinking and discussion (Green and Green 1980, 1981) on the use of coal to displace propane burning by a production pottery kiln. Shortly thereafter, a laboratory study of gas-coal flames was initiated using a burner in the 10,000 BTU per-hour range (Horvath, Vaidya and Green 1981). The primary intent here was to carry out gas-coal burning under carefully controlled conditions and to use the observations to help develop a theoretical model of this mixed combustion process. Most of the observations were carried out with the use of middle ultraviolet spectroscopy, since refined instruments were available to utilize this specialty of the editor (Green 1966, 1981). The radiations emitted by various zones of gas-coal flames are being used to obtain information about the chemical, radiative and flow processes taking place in heterogeneous gas-coal flames.

These experimental and theoretical efforts, collateral to the A.G.A.-ICAAS economic study, led to a rapid familiarization with the literatures of pulverized coal combustion and natural gas combustion – two vast technical and scientific literatures. This familiarization revealed a paucity of flame studies of natural gas-pulverized coal mixtures – apparently accounted for by the absence of applications for this fuel combination. While combustion studies have substantially increased in the United States during recent years, most of the new studies have been directed at answering the question of whether we can use our abundant supply of coal to develop alternative fuels to substitute for oil and natural gas. Attempts to answer this question largely derive from the 1978 Power Plant and Industrial Fuel Use Act (PIFUA), which reflected the national concern that the oil and natural gas reserves of the United States were rapidly depleting. The possibility that domestic natural gas supplies are not at a great risk for the next 20 years or so has been raised only recently. If one grants this possibility, then different questions arise: How can we use our abundant reserves of coal and our modest supplies of natural gas to displace oil so as to minimize our imports, a major source of our current economic problems? While addressing this economic question, how can we use natural gas to mitigate the environmental consequences of increased coal burning?

Coal and Natural Gas Supply Considerations

Table 1 summarizes the gas and coal supplies per year needed to displace various levels of oil use. Our current annual coal production is at a rate of about 700 million tons per year, and our production capability is about 800 million tons. From the entries in the table it should be obvious that even a displacement of 3 to 5 million barrels of oil per day could readily be accommodated with only minor or modest increases in our domestic gas and coal production capabilities. With some redistribution of our current gas uses, it should be possible to accommodate even greater levels of oil displacement. Accordingly, the gas-coal-oil displacement approach can be accommodated from a supply standpoint.

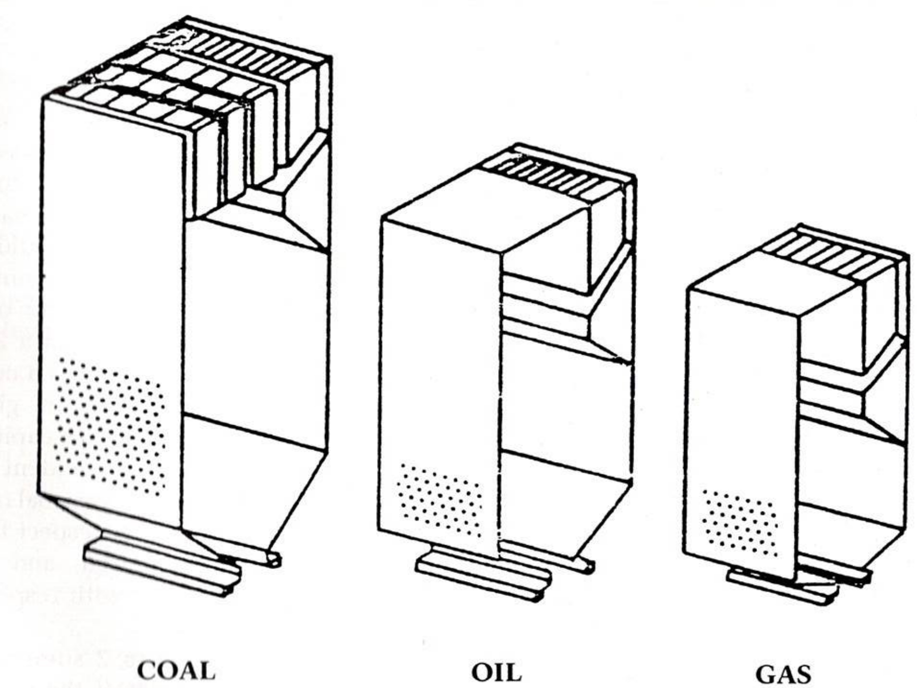
A Summary of the Physical Basis of Gas-Coal Replacement of Oil

This section summarizes various physical reasons in support of the concept that gas and coal can displace oil in utility boilers. These reasons largely rest upon the intermediate nature of various properties of residual oil as compared to gas and coal. Figure 1 (adapted from Ehrlich, Drenker and Manfred 1980) illustrates this intermediate character of oil with a display of the relative sizes and boiler design differences for coal (bituminous), oil (residual) and gas (natural) boilers which produce equal steam power output. Other examples of such properties are summarized in Table 2. Because of the intermediate characteristics, it is reasonable to expect in all matters with the exception of ash problems, that a gas-coal mixture fed into the burning zone of an

Table 1. Gas and Coal Needs for Various Oil Displacements (using a 30/70 by energy gas/coal ratio)

Oil Displaced		Gas Required		Coal Required	
μ	*Quads per yr*	*Tcf per yr*	*% of National Gas Supply (20 Tcf assumed)*	*Million Tons per yr*	*% of National Coal Supply (800 10^6T/yr assumed)*
1	2.2	0.66	3.3	64	8.0
2	4.4	1.31	6.6	128	16.0
3	6.6	1.97	9.8	192	24.0
5	11.0	3.28	16.4	319	39.9
7	15.3	4.60	23.0	447	55.9

μ = million barrels of oil per day = 2.2 quad per yr.
Tcf = trillion cubic feet = 1 quad
Quad = 10^{15} BTU = 41.7 million tons of coal



Source: Ehrlich, S., S. Drenker and R. Manfred, *Coal Use in Boilers Designed for Oil and Gas Firing,* American Power Conference, Chicago, Illinois, April 21-23, 1980

Figure 1. Relative Sizes and Features of Coal, Oil and Gas Boilers

Table 2. Characteristics of Gas, Oil and Coal

	Gas	*Oil*	*Coal*
Relative power density	1.6	1.0	0.73
Calorific value (10^3 BTU 1/8 lbs)	24	18	12
Air/fuel ratio by weight	20:1	17:1	11:1
Hydrogen/Carbon by weight	1:3	1:9	1:20
by atom	4	1.6	0.8
SO_2 emission (lbs/10^6 BTU)	0	0.5-3	1-6
CO_2:H_2O emissions	0.5:1	1.2:1	2.5:1
Burning time	fast	intermediate	slow
Radiation	low	middle	high
State of matter	gas	liquid	solid
Ash levels (percent)	0	0.2-0.5	1-10

oil boiler would burn somewhat like oil. Ash problems such as slagging, fouling, increased corrosion, tube erosion, plugging of air passes and increased particulate emission require more complex measures (Babcock and Wilcox 1978, Combustion Engineering 1981). The particulate emissions problem can be handled by the use of highly-efficient precipitators or bag houses. Means of dealing with the other expected ash problems are just being developed as various approaches to oil boiler retrofitting are now being examined, tested or carried out. These approaches include: (1) conversion to coal oil mixtures such as recently undertaken at the Sanford Station in Florida (Cook 1980); (2) conversion to coal use with the maintenance of oil-firing capability, as recently carried out at the Kwinana power station in Perth, Australia (Kirkwood et al. 1978); (3) the installation of a new coal boiler to be used with the remainder of the electric plant (Philipp 1979, 1980, Ehrlich, Drenker and Manfred 1980); and (4) the use of coal-water slurries (ibid., Glenn 1979). In addition, various types of clean fuels derived from coal using hydroliquefaction processes or chemical coal cleaning or coal gasification have been proposed, but for the most part these will not be available until the 1990s.

No prior literature appears to exist on the use of gas and coal for oil boiler retrofitting; hopefully this monograph will help fill this void. The measures being used for coping with ash handling problems for the first four options described above would also be applicable. In addition, there is the possibility of using a first stage gas-coal combustion chamber, which separates out a large portion of the ash before the hot fuel-rich combustion gases including coal volatiles, CO, and other gases are injected into the boiler for afterburning with natural gas enhancement and secondary and tertiary air.

Economic Analyses

The economic analysis first classified all of Florida's utility oil boilers pertaining to their suitability for coal conversion. These classes are: (a) oil boilers located where existing or projected coal units are available; (b) oil boilers in service approximately 25 years or less with large enough land area or port facilities to accommodate coal and ash handling; (c) oil boilers in service approximately 25 years or less on small sites with no port facilities; (d) all remaining steam turbine oil boilers that have been in service more than 25 years; and (e) all gas turbines which use distillate oil. Classes D and E were not considered for conversion.

A methodology and simple economic analysis developed on retrofitting oil boilers to (a) coal-oil mixtures; (b) dual oil and coal capability with no flue gas desulfurization (FGD); and (c) installation of a new coal boiler was already available (Philipp 1980a,b). This methodology is extended to consider gas-coal, water-coal and gas-coal-water conversions. The total conversion cost per kilowatt for the various back-out options which should be of general applicability is summarized in Table 3. The third column of Table 3 gives annual savings of a 200 megawatt unit following such a conversion, and the fourth column gives the payback period for the capital costs of conversion. It is evident that these results favor the gas-coal option to a large extent with respect to the coal-oil mixture option, and to varying lesser degrees with respect to the other options.

Figure 2 summarizes the essential features of the time dependences incorporated into the study. The large differences anticipated between oil and coal prices account for the major savings attendant to the displacement of oil by gas and coal. The price of gas which only supplies about 30% of the energy does not greatly influence the results.

The principal results of our analyses of the Florida utility system are summarized in Table 4. A savings of 2.5 billion dollars per year is obtained by the conversion of 12,678 megawatts of oil boiler capacity. The reduction in annual oil use by Florida utilities would be about 0.2 million barrels of oil per day.

Air Quality Impacts

Table 5 gives the characteristics of several major fuel groups, along with their energy release, ash and SO_2 emissions. The installation of a flue gas desulfurization (FGD) unit is extremely costly, and there is usually little space to accommodate it in a pre-existing plant. Fortunately, it is possible to achieve acceptable levels of SO_2 by four simple and relatively inexpensive measures. These include:

- the choice of a high quality or moderate quality coal
- the use of physical coal cleaning (PC)
- the burning of coal with natural gas (NG)
- the use of burner or boiler scrubbing (BS).

Figure 3 is a nomogram for calculating the emission levels for any fuel when the percentage sulfur by weight and the calorific values (in 10^3BTU per pound) are specified. The lines illustrate the major fuel groups listed in Table 5. Note that high-sulfur residual oil leads to much greater emissions than two of the coal groups (CAR and W), and also gives emissions comparable to the third group (NA). Thus, while the reduction factors achievable by measures 2, 3 and 4 are moderate, the combined reduction factor can bring a unit without FGD into the range achievable with Best Available Control Technology (BACT), which is usually accepted as 1.2 pounds SO_2 per million BTUs. This is illustrated in Table 6, which shows the effects of the reduction factors R(PC), R(NG), and R(BS) upon the final emission for various coal grades as defined by the normal emissions.

The technology for coping with particulates using precipitators or bag houses and ash handling boiler modifications is quite advanced and the costs of refitting, while large, are tolerable. In addition, it should be possible to minimize ash problems by using a first stage gas-coal combustor designed to remove ash.

National Assessment

The national capacity of utility oil boilers corresponding to the categories in our Florida study constitutes 63,279 megawatts. Proportioning this to the 12,678 Florida oil capacity and the 2.5 billion dollar per year Florida consumer saving, we arrive at a 12.5 billion dollar per year national savings. The 0.2 μ (million barrels of oil per day) saved by Florida extrapolates to 1.0 μ. The value of this savings to the United States as a country is, of course, greater than the consumer savings since we are keeping our dollars for gas and coal at home.

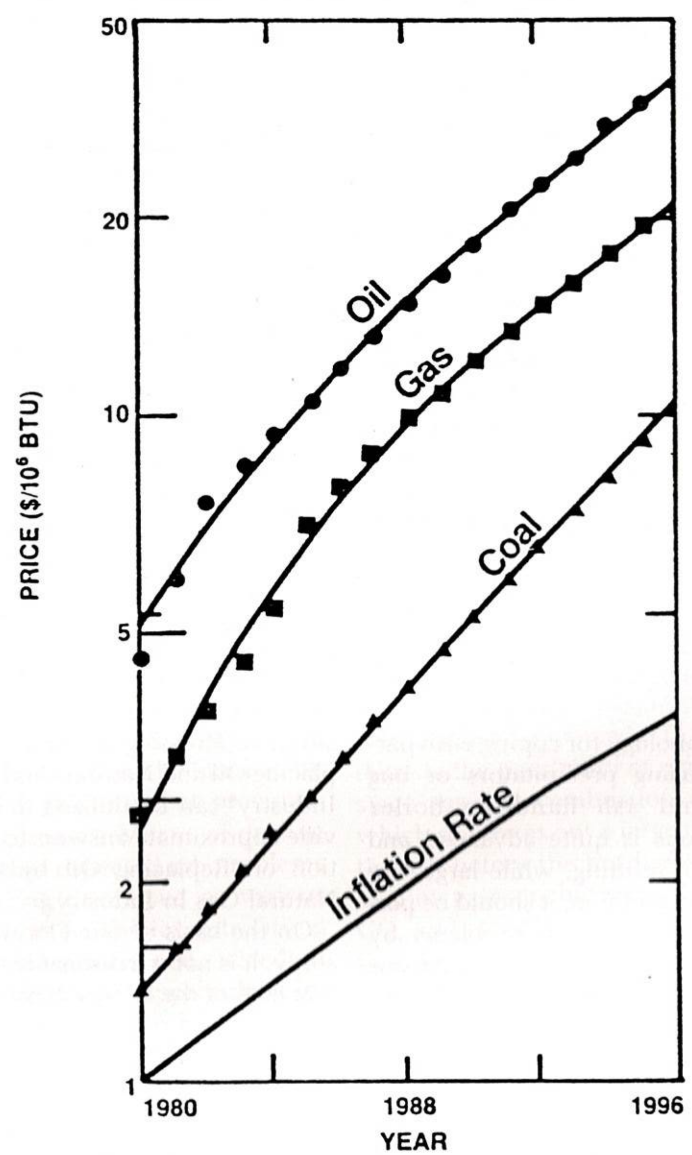
The industrial oil use of 3.4 μ constitutes an even more tempting alternative fuels target. Fortunately, many of the considerations applicable to smaller utility boilers are directly applicable to large industrial boilers. Furthermore, a number of national studies addressing the question of "Replacing Oil and Natural Gas by Coal in Industry" can be utilized to help provide approximate answers to the question of "Replacing Oil by Coal and Natural Gas in Industry."

On the basis of our Florida utilities study, it is not unreasonable to assume that 80% of the energy consumable by

Table 3. Total Conversion Costs for Various Options

	Percent Coal Energy	*Total Conversion Cost $/KW*	*Total Annual Cost $10^6$$/yr*	*Differential Annual Cost $10^6$$/yr*	*Payback Period*
Oil	0	–	46.0	Base	–
COM	30	84	43.9	– 2.1	3.3
Dual NFGD	80	144	29.5	–16.5	1.5
Coal Oil FGD	80	216	34.4	–11.6	2.4
NCFBWFGD†	100	376	36.0	–10.0	3.2
Gas/Coal	70	127	25.8	–20.2	1.2
Coal/Water	100	132	31.3*	–14.7	1.5
Gas-Coal/Water	70	132	29.4*	–16.6	1.4

† denotes new coal-fired boiler with flue gas desulfurization.
*Includes extra energy cost of water evaporation and fine coal grind but not cost of peaking unit to replace lost capacity.



The symbols O, G, and C indicate 1980 prices used in Chapter 8.

Figure 2. Price Projections for Oil, Gas and Coal and Inflation from A.G.A. TERA Model

Table 4. Summary of Economic Gain for Gas-Coal Conversion of Florida Oil Boilers

	Oil Base Case	*Gas-Coal*
Capacity (MW)	12,678	12,678
Conversion Costs (million dollars)		1,429
Annualized Capital Cost (15 yrs @ 11%)		199
Annualized (extra O and M costs)		29
Total Annualized Costs	4,824	2,294
Savings from base case		2,530
Production Cost/KWH	7.2¢	3.4¢

large industrial boilers can be displaced by gas and coal. The smaller boiler question is more difficult. However, using prior studies and taking advantage of the large proportion of natural gas used, and recent developments in stoker-fired fluidized bed combustors and tri-fuel boilers, we show that it should be possible to displace most of the oil used by small industrial boilers.

The prospects for displacing oil in the process heat industrial sector are also quite good. In addition, coal can be used directly as a chemical feedstock in place of oil. Furthermore, biomass (Zaborsky 1981) and botanochemical crops can substitute for the use of many petroleum-derived products (Buchanan and Duke 1981).

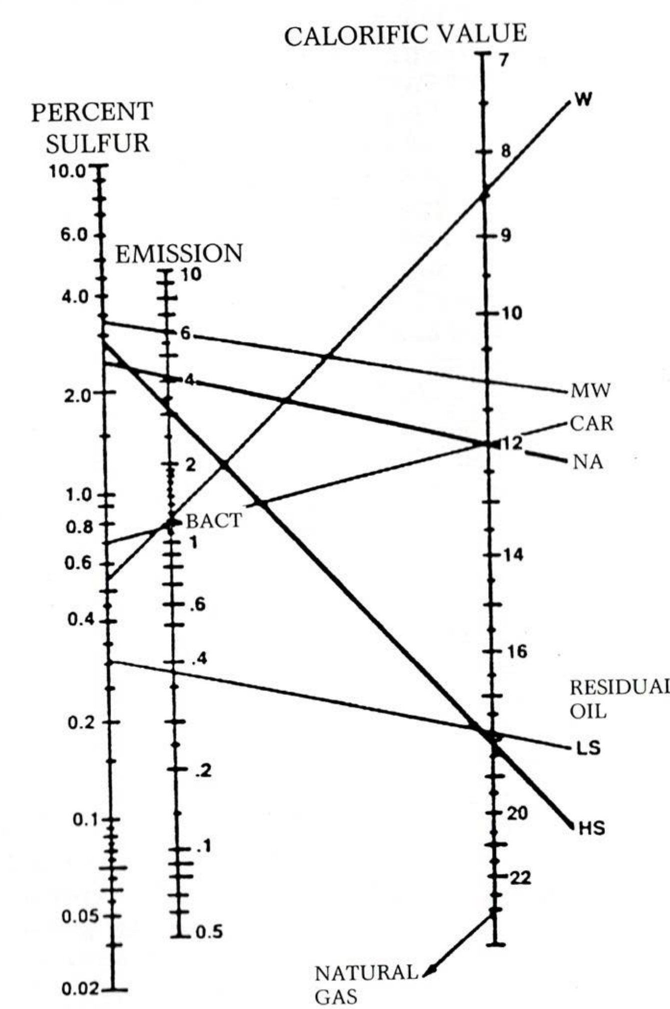
The United States might be able to make substantial inroads into the oil used in the commercial sector and the residential sector (at least for apartment houses and condominiums). Table 7 illustrates the best low and high estimates of oil displacement levels that might be achieved in the utility, industrial, commercial and residential sectors by vigorous programs directed toward gas-coal replacement of oil. Note that if the high estimates were realized we would have practically achieved National Energy Independence, the goal of our nation since 1974.

Finally, we should note that while concern for the United States' flagging economy has been the driving force behind this entire effort, the international aspects of oil displacement by gas and coal should not go unnoticed. Most immediately, Europe appears to be going ahead with a pipeline to draw upon natural gas from the Soviet Uñion. Several countries in Europe also have large coal reserves. Many other countries of the world that are deficient in oil reserves have coal and natural gas. The economic and environmental advantages of gas-coal burning in place of oil would be accessible to such countries as well.

Table 5. Major Fuel Groups Uncontrolled SO_2 and TSP Emission Rates

Fuel	*BTU Content BTU/Unit*	*%S*	*Emission*	*Ash %*	*Emission*
Coal					
Northern Appalachian (NA)	12,000/LB	2.5	4.17 σ	14.0	7.58 π
Central Appalachian & Rockies (CAR)	12,000/LB	0.7	1.17 σ	12.0	6.50 π
Midwestern (MW)	11,000/LB	3.3	6.0 σ	11.0	6.50 π
Western (W(	8,500/LB	0.5	1.18 σ	9.0	6.88 π
Residual Oil					
High Sulfur (HS)	150,560/GAL	3.0	3.14 σ	–	0.053 π
Low Sulfur (LS(	146,430/GAL	0.3	0.31 σ	–	0.055 π
Natural Gas (NG)	1,027/FT³	–	0.006 σ	–	< 0.015 π

σ denotes lbs. $SO_2/10^6$BTU. π denotes lbs. particulates /10⁶ BTU.
Adapted from ICF, Inc. Boilers System Cost Estimates, Table II-3, 1978.



Adapted from EPA-600 9-77-0171. Emission levels are in σ / 1 lb. SO_2/10 BTU Calorific values are in 10¹ BTU lb²

Figure 3. Nomogram for Calculating Emission Levels

Research and Development Needs

Recently, a general recognition has developed of a near-term need to rely upon our abundant supply of coal (National Academy of Sciences, 1980; Landsberg, et al. 1980; ICAAS, CBI, 1980). A program to restore to coal use, boilers originally designed for coal but converted to oil, has for the most part been carried out. Conventional wisdom did not favor retrofitting to coal use boilers originally designed for oil or natural gas. However, with the retrofitting of two utility oil boilers at Kwinana in Australia to dual coal-oil capability, a more flexible view has developed and studies of various options for such oil to coal conversions are beginning. The favored order of research and development priorities for the displacement of oil in the United States appears to be coal-oil mixtures and after that, coal-water mixtures. Gas-coal is not yet under serious consideration.

Since the analyses reported in this article suggest that the displacement of oil-burning coal with gas warrants serious consideration, we devote this section to a sketch of a Research and Development Program which would enable this country to implement this option quickly.

To provide a focus, we describe three conceptual approaches to oil boiler conversion to gas-coal burning.

Table 6. Emissions (in lbs. $SO_2/10^6$ BTU) for Various Coals, Physical Cleanings, Natural Gas and Burner Scrubbing

R(PC)	R(NG)	R(BS)	A(1.2 σ)	B(2.4 σ)	C(4.2 σ)	D(6.0 σ)
1.0	1.0	1.0	1.2	2.4	4.2	6.0
		.6	0.72	1.44	2.52	3.6
	.75	1.0	0.9	1.8	3.15	4.5
		.6	0.54	1.08	1.89	2.7
	.60	1.0	0.72	1.44	2.52	3.6
		.6	0.43	0.86	1.51	2.16
	.50	1.0	0.6	1.2	2.1	3.0
		.6	0.36	0.72	1.26	1.8
.6	1.0	1.0	0.72	1.44	2.52	3.6
		.6	0.43	0.86	1.51	2.16
	.75	1.0	0.54	1.08	1.89	2.7
		.6	0.32	0.65	1.13	1.62
	.60	1.0	0.43	0.86	1.51	2.6
		.6	0.26	0.52	0.91	1.18
	.50	1.0	0.36	0.72	1.26	1.8
		.6	0.22	0.43	0.76	1.08

σ denotes lbs. $SO_2/10^6$ BTU.
Adapted from ICF, Inc. Boilers System Cost Estimates, Table II-3, 1978.

Table 7. National Potential for Oil Displacement in Million Barrels of Oil per Day

	Current Use	Best Estimate	Low	High
Utilities	1.4	1.0	0.8	1.2
Industry	3.4	2.0	1.6	2.6
Commercial	1.4	0.8	0.5	1.0
Residential	1.6	0.6	0.4	0.7
	7.8	4.4	3.3	5.5

The first approach, direct gas-coal firing, retrofits the oil boiler to take the technical characteristics of coal boiler. However, unlike the Australian Kwinana solution, natural gas is used instead of the retention of oil boiler capability as a means of overcoming the derating to 60% of design capacity experienced with coal use alone.

The second approach introduces a first stage combustion chamber which has a multiple purpose: (1) to provide a combustible gas for afterburning in the boiler itself when augmented by natural gas; (2) to separate out most of the coal ash before the hot combustion products are injected into the boiler; (3) to provide for first stage SO_x and NO_x suppression; and (4) to make the ash commercially useful.

The third configuration considers mixing gas with a coal-water slurry. Again, a first stage combustion chamber is used to serve the functions defined in the second configuration and to facilitate the direct use of the larger particle sizes being considered for coal-water slurry pipelines.

These three configurations help define areas of uncertainty which should be resolved by a research program. These include studies of: (1) the ash formation process in interacting gas-coal flames; (2) the characteristics of afterburning flames produced by various gas-coal primary flames; (3) the influence of additives in the primary stage upon the production of SO_x, NO_x, and the possible commercial applications of the ash; and (4) the influence of the water in the gas-coal-water approach upon the ash formation process, the characteristics of the after burning flame, and the influence of additives. Also included in this section is a list of the principal research recommendations recently formulated by an American Physical Society Study Group on Research and Planning for Coal Utilization and Synthetic Fuel Production (Cooper et al. 1981).

Using knowledge generated in the large coal-gasification program – by experience with cyclone burners and recent combustion studies on NO_x control – the immediate development of first stage gas-coal combustion chambers with ash separation and SO_x, and NO_x suppression capability could be launched while basic and applied research are underway – a parallel rather than series approach.

Final Summary

This effort began in January 1981 shortly after the completion of two interdisciplinary assessments, *Coal Burning Issues* and *Impact of Increased Coal Burning on Florida (ICAAS 1980a, b.)*. It was motivated by a strong concern that we had overlooked the possibility that natural gas production rates could be sustained at a level of 20 Tcf for the next two decades or so. As we looked into this question (Green and Jones, 1981), we became convinced that this possibility was appreciable. In February 1981, we initiated a small development program and in March, a scientific program. In June, we initiated an economic analyses of oil boiler conversion in Florida which was completed in August. The economic benefits indicated in the third endeavor (see Chapters 5-8 of this monograph) were far beyond our expectations, and together with knowledge gained during the development and scientific programs, these projected benefits convinced us that the gas-coal approach could and should openly stand as a contender with the coal-oil mixture, dual coal-oil, a new coal boiler and coal-water mixture approaches to oil boiler retrofitting. The pay-off for the United States from oil boiler retrofitting is very large and we show in Chapter 10 that the displacement of four or so million barrels of oil per day seems quite feasible. This level of reduction would bring the United States within the range of a normal trade balance with the OPEC nations.

We must acknowledge that there are unusual obstacles to the implementation of the gas-coal approach. In the first place, the Power Plant and Industrial Fuel Use Act of 1978, which assumed that gas production rates would decline precipitously by the year 2000, provides legal obstacles despite the fact that it is now being interpreted with very great flexibility. In the second place, none of the agencies which would naturally support oil-backout research and development endeavors such as the Department of Energy, the Environmental Protection Acency, the Electric Power Research Institute, the Gas Research Institute or the National Coal Association, has a pre-existing program to pursue the gas-coal option. In days of very tight research and development budgets it is difficult to establish a new program. In the third place, to implement the gas-coal approach would require an unusual degree of cooperation by diverse groups, including the electric utility industry, the boiler manufacturers, the gas and coal producing and distributing industries, and the federal and state regulatory agencies that are concerned with energy-environmental problems.

Despite these serious obstacles, we still believe after a year of intensive involvement with scientific, technological, economic and environmental aspects of burning coal with gas, that the approach warrants serious consideration by the United States. Not only does it offer great promise as a way of backing out of using oil in existing boilers and furnaces, but it also suggests a simple design path for improving the performance of new systems using a variety of solid fuels.

As 1981 draws to a close, we feel that from a broad perspective we are basically close to where ICAAS was a year ago (see CBI and IICUF reports, ICAAS 1980a,b.). To deal with our excessive oil imports problem, we advocated strong conservation measures and increased reliance upon our nation's abundant supply of coal. However, among the ways of utilizing coal as an alternative to oil, we now believe that burning coal with gas is environmentally cleaner than coal alone. Furthermore, it can permit coal use in boilers originally designed to burn oil without substantial derating. We hope that we have put together a reasoned presentation of various aspects of the gas-coal approach that will facilitate its early, or at least eventual, consideration.


Cummins

The Clean Water Act—1983: Time for reassessment

Dr. Donald W. Genson
Science Advisor to Citizens for
Effective Environmental Action Now

Tens of billions of dollars have been spent improving the quality of this nation's waters. To the extent that the effect of this effort can be quantified, we have seen considerable improvement. However, we are at a point in this clean-up project where as a society we have some tough decisions to make.

Because the existing Clean Water Act focuses only on technology-based effluent standards and not on its impact on water quality, no reliable data on national water quality exists.

Locally, however, definite improvements have been identified throughout the United States. During the 1960's, pollution of the Neches River tidal area in Texas left the water black. Today, industrial water intake pipes are often plugged by shrimp, and commercial crabbers have returned. Detroit's River Rouge and Ohio's Cuyahoga River are two examples that can be highlighted as part of the success story that needs to be told. The U.S. Environmental Protection Agency (EPA) has reported to Congress that there are 70 other areas showing similar improvement.

Right here in West Virginia the Ohio River is showing a dramatic turnaround as a result of past clean-up efforts. Desirable game fish have returned from the tributaries to many portions of the river, and even fish thought to be non-existent have become abundant again.

While this program has been significant, it has not come without a price tag. According to the Department of Commerce, *$112 billion* was spent on water quality from 1972 through 1979—about $14 billion each year. The U.S. taxpayers paid directly for 42% of that bill, including costs for community waste treatment plants throughout our nation. Realistically, the taxpayer also paid for the remaining 58% because when industry pays, the public gets higher prices and lost job opportunities.

Presently scheduled more stringent controls and national programs for municipalities will greatly increase the current costs. The Council on Environmental Quality estimated that by 1988 water quality costs for industry and public combined will rise to at least $24 billion each year—a number considerably larger than the national budget of several small European countries. If the EPA begins an active program of regulating the diffuse non-point source discharges, this amount could well double or triple.

If all of our money had been wisely spent, it would be difficult to quarrel with the expense. Unfortunately, the clean-up effort called for by the Act has been marred by poor science, unnecessary rules, and costly regulatory schemes. Yet, a number of the Act's provisions and many billions of tax dollars have had little, if any, impact on the discharge of pollutants in this country's waterways.

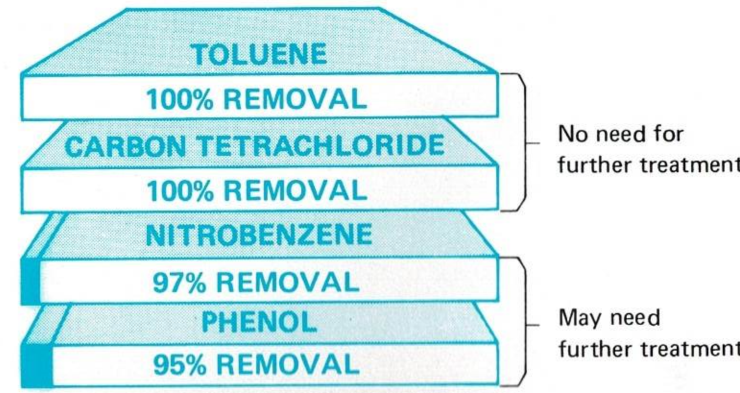
For instance, more than half of the 2,000 municipal waste treatment plants completed under EPA's $30 billion construction grants program are not working well. The *Washington Post* series, "Dirty Water: A Federal Failure," cites the causes of these problems as poor design, operation and maintenance. Such are the troubles with the *largest* public works program in this country's recent history.

Additionally, the House of Representatives' Subcommittee on Oversight and Review reported in December of 1980 that although "thousands of dischargers have moved to comply with the requirements contained in their permits" because they are technology-based effluents requirements, "federal officials are hard pressed to say just how much has actually been accomplished." The report continues to say that while "significant clean-up is undoubtedly taking place," the inability to qualify where we are leaves us as ignorant today as we were ten years ago when the Act first took shape.

The lesson here is obvious: we must understand the nature and dimensions of America's pollution problems before we declare war on them and regulate. Yesterday, our booming economy and realization of a need for clean-up allowed us to attack water quality problems before we understood them. The results were predictable; industry and municipalities hamstrung with red tape and regulations that did not contribute to water quality, and taxpayers paying the bill for multi-million dollar facilities that do not function well, and in some instances, were unnecessary.

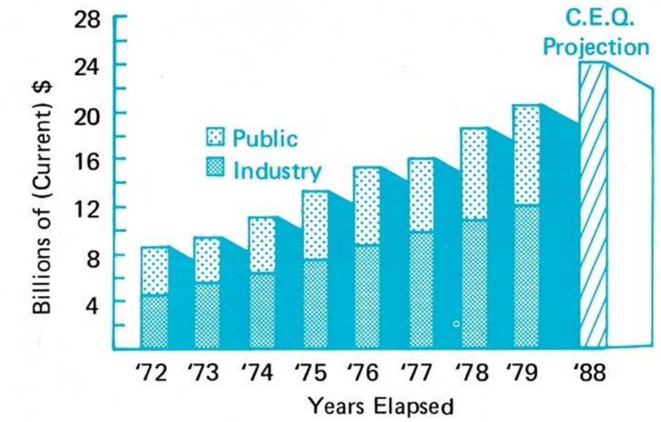
We can no longer afford to spend first and think later. In the 1960's, our economic vitality made it seem that dollars wasted by poor decision-making were not a public concern. Today, we are paying for excesses of the past. We can no longer accept the economic burden of trying to smother problems with the mindless application of dollars. At the very least, after spending $112 billion, we must request that the scope of the problem be

EFFECTIVENESS OF BIOLOGICAL TREATMENT AGAINST TOXIC WATER POLLUTANTS



These four pollutants are representative of the three categories of "toxic" pollutants dealt with in the EPA-CMA five plant study.

POLLUTION ABATEMENT EXPENDITURES FOR WATER
(Source: Dept. of Commerce & Council on Environmental Quality 11th Annual Report)



evaluated in order to decide what is left to be done and how best to do it. The present legislation must be improved based on our hard-earned experience and best data available today.

The existing treatment standards, originally scheduled to be met by industry and municipal treatment systems alike in 1977, were aimed at conventional pollutants. These included biological-oxygen demand (BOD), total suspended solids (TSS), and oil and grease, among others. This program has had more success thus far with industrial point sources than municipal ones; however, the impact on pollutant discharge has been dramatic. By 1977, the amount of BOD-material discharged by industrial sources had declined to 12% of the total; BOD discharges from municipal sewage systems had fallen to 14%, with diffuse non-point discharges accounting for the remaining 74%.

Another fact that needs to be brought to light about this first-round treatment strategy is that it has been far more successful than anticipated. Because these treatment standards called for biological treatment, which was intended to address conventional pollutants, the prescribed treatment was not expected to have an impact on the so-called "toxic" pollutants. It is this legally, not scientifically, defined set of presumably bad actors for which a separate set of effluent standards will be required in 1984. Yet, the best data available today clearly indicates that a specifically-designed technology to handle these "toxic" pollutants, in most instances, is unnecessary.

Not only is biological treatment much more effective than expected in reducing the amount of "toxics" discharged (see Figure 2), but these "toxics" are far less prevalent and at lower concentrations than originally anticipated.

In other words, the original problem was *overstated* and effectiveness of current treatment badly *understated* as it pertains to "toxics." Therefore, as a nation, we need to rethink the strategy formulated in 1977. We cannot afford to get so caught up in the rules as they stand now that we forget why they were written and what they were intended to do. More stringent effluent standards may be needed for some pollutants and in some specific areas—but clearly, given the data available, those decisions need to be made locally on a case-by-case basis and not mandated nationally.

No one is questioning the need to protect America's water. No one is talking about going backward or sacrificing water quality improvements already accomplished. Where present treatment is not doing the job, better treatment should be added. If present effluent standards are not stringent enough to protect the environment, more stringent limits need to be set. The point is that we ought to get the most benefit out of every pollution control dollar we spend. We should use the hard-earned and expensive knowledge we've gained in during the past decade to continue improving water quality without unnecessary expense.

The amount of clean-up and polishing that our regulations require has to be based on some benefit to the environment. This perspective too often gets lost among hundreds of pages of regulatory language. Unless we keep that goal very clear in our minds, we will find ourselves installing treatment for the sake of treatment—at enormous cost and with no practical benefit to anyone. We have a decade's worth of progress behind us from which to learn. While the task ahead is tough, we must not allow the complexity to make us lose sight of our goal. The clean-up of our nation's waterways is well underway. What remains are refinements and fine-tuning. Protecting our water resources in a practical, economically sensible manner demands a reassessment of our regulatory strategy now. It is a task too important to be left to political rhetoric and emotional appeals, and it is a task far too important to neglect.

The Eastern Wild Turkey use revegetated mine lands for breeding and brood rearing areas in West Virginia. —Photo by James Pack

White-tailed deer benefit from openings in the forest canopy when properly revegetated. —Photograph by Richard Hall

The Fish and Wildlife Alternative

by Roger J. Anderson

The Department of Natural Resources reclamation program now includes technical assistance in fish and wildlife planning. The Reclamation and Wildlife Resources Divisions of the Department of Natural Resources have entered into a cooperative agreement that permits specific Wildlife Resources Division personnel to work with operators and inspectors in designing reclamation plans for enhancement of fish and wildlife habitat on mined lands.

This new "Mining Coordination" program was implemented because of the tremendous potential for establishment of fish and wildlife habitat on mined lands in West Virginia. Wildlife Resources Division Chief Bob Miles stated, "I feel this program will benefit West Virginia's wildlife, sportsmen, and coal industry. Mining removes wildlife habitat from its original productive state. When proper reclamation is complete, mined areas may again be valuable wildlife habitat. Under the guidance of our professional biologists, fish and wildlife habitat will be established and thus benefit every West Virginian."

Many opportunities for fish and wildlife habitat enhancement exist. For example, in a totally forested area with an existing turkey population, suitable areas for raising poults (brood range) may be limited or nonexistent. This lack of brood range will depress the turkey population and restrict possible expansion. A wildlife revegetation plan, featuring specific grassland and forestland vegetation attractive to turkeys and containing the basic components for brood range, will benefit the turkey population. A settling pond may be retained as a bluegill and bass pond, which will provide additional recreation. Each surface mine is different and the mining coordination biologist will consider many factors prior to developing a reclamation plan to feature a selected fish or wildlife species. Such plans may be adapted to meet a landowner's or operator's particular fish or wildlife interest.

Reclamation cost is a major concern to operators. Mining coordination biologists are prepared to estimate revegetation costs. On most developed areas where costs have been documented, wildlife plans are considerably less expensive than other revegetation options. In most cases a mixture of herbaceous and woody plants are recommended rather than the standard one or two species planted at specified spacing. With proper planting schemes, plants that create good wildlife food and cover are less expensive.

The program does not delay the permitting procedure. The mining coordination biologist is contacted by the inspector when the biologist's assistance is needed at a pre-inspection. The biologist attends the pre-inspection and discusses his involvement with the operator (or his representative) and the reclamation inspector. If both the operator and inspector agree, a wildlife revegetation plan will be developed and included in the surface mine permit application (SMA) during the advertising period.

Wildlife Resources mining coordination biologists can provide assistance when:

1. pre and/or post-mining land use is forestland or fish and wildlife habitat;
2. quality streams, critical or sensitive habitats are involved; and,
3. fish and wildlife resources are of concern.

The wildlife revegetation option is not only available for new applications but also for qualifying existing permits. If the post-mining land use on an existing permit is woodland/wildlife, a simple modification of the revegetation plan provide the same advantages available to new applicants. Both the Wildlife Resources and Reclamation Divisions stress that mining coordination biologists have no regulatory power. These five professional wildlife and fishery biologists are stationed at the Department of Natural Resources District offices in Beckley, Elkins, Fairmont, and Milton. These persons are available to the mining industry for reclamation planning pertaining to fish and wildlife restoration. They look forward to meeting and discussing our coordination program with you.

This program provides the Wildlife Resources Division, Reclamation Division, and surface mine operators the opportunity to cooperate in utilizing the reclamation processes to restore valuable fish, wildlife, and forest resources for the future benefit of all West Virginians.

Grouse hunters enjoy older reclaimed areas of Autumn Olive, Honeysuckle and other young hardwoods for the pursuit of their sport. —Photo by Walter Lesser

A job well done by this English Setter, Dawn Shadbush Ted. —Photo by Walter Lesser

Design considerations for valley fills

by Thomas T. Kirk, P.E.,
Hobet Mining and Construction Co., Inc.
George A. Hall, Ph.D., P.E.,
Terra Engineers

A Brief Background

The subject of valley fills is central to the whole issue of surface mining of coal in West Virginia. Regulations concerning the construction of valley fills or head of hollow fills are also a subject that will readily engender emotional arguments ranging from the one extreme of the regulations being far too permissive to the other extreme of their not being needed at all.

Regulators of the West Virginia Surface Mining Industry saw need several years back for controls on valley fills which would function well under a variety of site conditions and under construction procedures which varied widely from one operator to another. The outgrowth of this was a valley fill concept using a vertical rock core or chimney drain along the center of the fill, extending vertically from the original stream bed to the top of the fill. The top of the core was sloped to the head of the hollow with a pocket formed at the upstream end of the core to force surface water to flow through the core. The core was intended to inhibit build up of a high phreatic surface, trap sediment, and reduce erosion of the face of the fill by passing surface runoff downward through the core to original ground. The West Virginia regulations further required that spoil material be hauled down and placed in nearly horizontal lifts not exceeding four feet in thickness.

The West Virginia method has been the industry standard for construction of valley fills in the state for several years, and the method is well suited to the construction of head-of-hollow fills. Yet, huge mountaintop removal operations lead to proportionately large valley fills—a mile long and over a tenth of a mile high is becoming common. Merely the cost of transporting this waste material is gargantuan.

In addition to the cost of hauling the material down to the fill, the safety of miners is also receiving considerable attention. The overburden is hauled downhill over considerable distances, with attendant wear on the braking systems with added cost of maintenance and possibility of failure. Because of safety, cost, and other considerations, operators have sought ways to achieve stable and environmentally acceptable methods of constructing fills by means other than hauling the material down and placing it in lifts.

The interim program regulations have made provision for design on a site specific basis, for example see Section 9E.07 of the West Virginia regulations. In addition, the regulations allow approval of design for single lift construction of durable rock fills when the spoil material consists of at least 80 percent rock or other material that does not slake in water. Recently proposed Office of Surface Mining Regulations also show more design latitude and even more flexibility may appear in the offing.

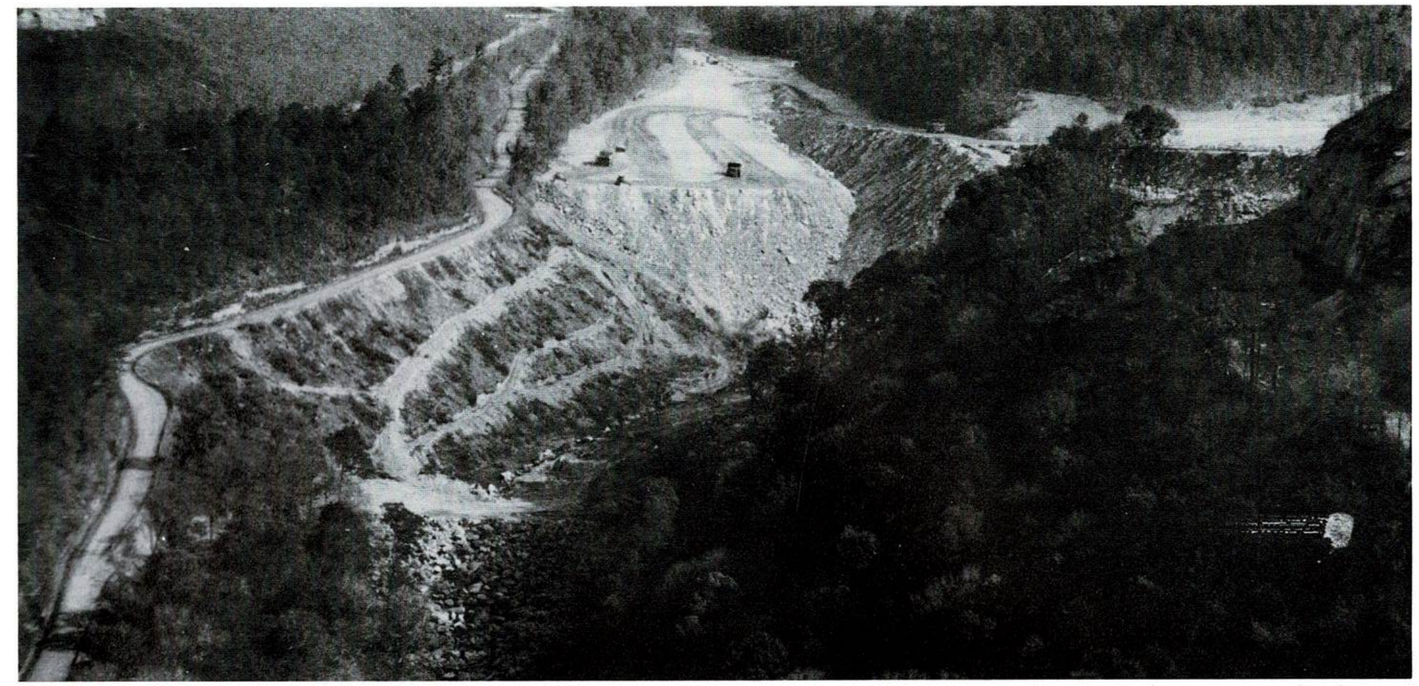
At first thought, the concept of dumping mine spoil into a hollow or valley seems untidy or disorderly to the senses. It also seems contrary to what natural impulse purports to be prudent engineering practice. On further thought, however, why is this not a feasible concept? What problems are generated by dumping that do not exist with a conventional valley fill, and what alternatives are available to solve these problems?

Single Lift Construction Problems and Mechanisms

Materials dumped loosely at the "angle of repose" can develop several problems: slope instability, erosion and downstream sedimentation, and fill settlement immediately come to mind. Inherent in these are surface and subsurface drainage considerations. We need to look at these problems and the mechanism of dumping in order to arrive at a logical approach to solving the problems.

One important mechanism involved in dumping spoil material is "natural segregation." It has been widely publicized in the mining industry that the larger sizes tend to roll to the bottom when random sized materials are dumped over a slope. Natural segregation tends to provide free draining material at the bottom and to develop a gradation which is a "natural filter." Hence, nature lends a helping hand; however, natural segregation is not a panacea for potential problems with dumped valley fills.

If natural segregation leads to coarser material at the bottom of the slope, it follows that the top of the slope contains finer material. It is conceivable that this finer material could



Overview of dump fill. The design and construction of the fill requires coordination with the overall mining plan.

become saturated during heavy or prolonged rainfall. In this event, a landslide or mudflow could cover the toe of the slope. Obviously, such an event would impair the subsurface drainage promoted by natural segregation, and it is equally obvious that a cleanup operation would be most expensive and difficult.

Another mechanism that can be utilized in dumping spoil is "arching." Loosely speaking, arching is the tendency for soil or soil-like materials to form a "bridge" of unsupported or poorly supported material between supported areas. This bridge develops as a result of friction between the better and lesser supported material zones. In the case of a valley fill, the valley bottom and especially the sides act as supports for the fill. Arching can develop both vertically and horizontally between the valley sides to help hold the fill material in place.

If a fill were dumped so as to form a lobe projecting down the center of the valley, there would be little material on the sides to develop horizontal arching between the valley sides. Thus a convex shaped fill face would be less stable than a uniform fill straight across the valley. Further, a concave shaped fill face with material on the sides projecting farther downstream than the center would tend to develop greater horizontal arching. The arching concept in fill material is akin to the behavior of a concrete arch dam.

Even without landslides or mudflows, erosion of the constantly advancing front face of fill material is a problem. Although some sediment control may be provided above the fill area, the quantity of sediment from the fill face which must be caught and retained can be great. This could require a sediment dam of major proportions, and such a dam could be a potential hazard to miners or downstream residents.

The problem of fill settlement also requires attention, and there are at least two considerations. Will settlement affect the post-mining land use, and can settlement adversely influence surface drainage? Mathematically, settlement is a type of "decay" process. This means that it starts with its biggest effect but continually decreases with time. Radioactive decay and depletion of an oil or gas well are other examples of decay processes. A dumped fill, especially one with a lot of particles which will break down with time, could settle perceptibly for several years; however, each year the settlement will become less.

The post-mining land use (e.g., hayland or woodland) may not be influenced by settlement. Yet, one would not want to build a brick home on a dumped fill immediately after the fill is completed. On the other hand, a few years later the same fill may be a good site for a brick home. A program to monitor settlement is advisable for any type of fill, and a necessity for dumped fills, whenever settlement will affect the use of the fill.

A fill will settle most over the center of the valley where the material is thickest. If surface water is intended to drain to the sides of the fill, settlement could create problems when the middle of the fill moves downward relative to the sides. Also, the magnitude of settlement in dumped fills is hard to predict. Hence, the influence of settlement on surface drainage requires careful consideration.

Some Solutions for the Problems

The predominant problems associated with dumped (single lift constructed) valley fills have been discussed briefly. These are not all of the problems that will ever be encountered, and even these problems will vary from site to site. Consequently, solutions to the problems must also be site specific. Nevertheless, we will examine some generalizations which will help provide guidelines.

In summary, we are most concerned with the three S's: stability, sediment, and settlement. The last of these is usually the least important, and we will look at it first. We have said that settlement may adversely affect surface drainage. There are several ways to combat this problem. One obvious way is simply to slope the fill to drain down the middle. Settlement would then improve drainage, but should not be so great as to cause erosion problems.

The problem of sediment control can be handled by a properly designed sediment pond or dam below the toe of the fill. This may necessitate a rather large dam or a series of ponds or smaller dams. Depending on downstream conditions, a large dam or a series of dams could be a potential safety hazard.

A second possibility is to construct the final toe of the fill in advance as a "rock toe dam." Several features may be incorporated into the design of such a dam:

1. The dam can be designed to be safely overtopped by runoff from a large storm.
2. The dam can "leak," so that no significant quantity of water is impounded except during heavy rainfalls (when sediment control is most needed).
3. The dam forms a highly stable and permeable toe for the final fill slope.

A conventional sediment pond is required below the toe dam to capture sediment from the final face.

A rock toe dam will assist stability of the final fill slope – which brings us to that third S. We have briefly discussed how natural segregation improves, but does not always insure, subsurface drainage and how arching can be used to improve stability of the advancing face. But what of stability of the final face? Under current regulations the design of a valley fill must yield a static factor of safety of 1.5. This appears to the writers to be rather conservative when it is considered that normal highway embankments are designed to a factor of safety of about 1.25, and even major dams are normally designed to a factor safety of 1.5.

Engineers have long recognized that stability of any waste fill depends *entirely* on stability of the outer or final face. In fact, in upstream construction of coal waste facilities, it has been demonstrated that a properly designed and constructed "outer shell" of coarse coal refuse can safely hold back massive quantities of fine coal slurry. There are numerous design approaches possible for the many site specific problems which will virtually assure stability. Consequently, the design and construction of the downstream end of a valley fill is of paramount importance. It is also the most difficult aspect of construction.

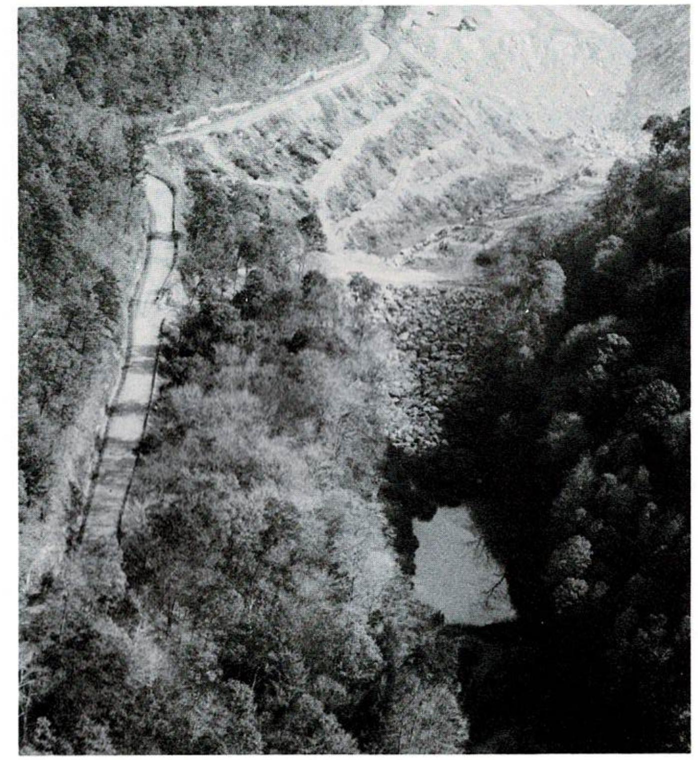
The importance of the design and construction of the downstream end of the valley fill is such that it can preclude consideration of the material dumped upstream. That is, if the lower end of the valley fill is designed and constructed to be stable – which implies consideration of both strength and subsurface drainage – then the valley fill can retain the weakest of materials in the fill above. This means that the requirement for 80 percent durable rock in the entirety of a properly designed and constructed valley fill would be superfluous. This point is only one illustration of the necessity of regulations to provide leeway for innovative engineering design.

Other considerations

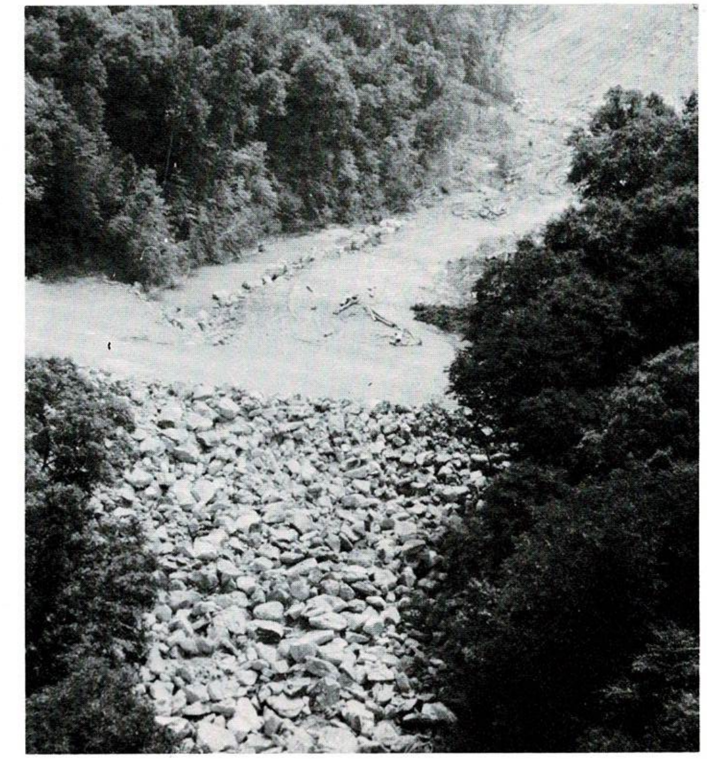
Perhaps the greatest problem to be faced in utilizing dumped valley fills is completion of the final face of the fill. The importance of the final face to stability has already been emphasized. The construction problems involved in progressing from a high slope at the angle of repose to a final, highly stable slope are imposing. To haul material down to complete the fill can be costly and dangerous. Dumping and pushing down with dozers is also costly and dangerous. Solutions to this problem are highly site specific and will require a great deal of future consideration to develop the best techniques.

Another important consideration is the coordination of the mining plan with the valley fill design. Once construction is initiated, it usually is difficult to revise the general approach to the project; for example, it would be very difficult to start hauling material down for conventional construction once dumping has progressed to any appreciable extent. Also, material incorporated into the fill may vary appreciably in size, gradation, and physical appearance because of the methods of blasting handling, compaction, and the extent and nature of weathering to which it is exposed.

Valley fills are unique in several aspects, the principal one being that they are generally massive structures designed and constructed with the specific purpose of using up and storing excess material. Since it frequently is almost impossible to alter the method of construction once it has been started, the design must consider, and regulators must accept, determinations made on insitu material *before construction*. The importance of this concept must be borne in mind for the future success of dumped valley fills.



Toe dam for sediment control and stability of fill. Note the conventional sediment pond below the toe dam.



Toe dam in place. Note the large rock on the face to protect against overtopping.

Initiation of dumping. Note the selective placement with finer material placed at the sides and coarser material in the center.

Coal Calendar

January

10-11 Short course, "Computer Analysis of Slopes," University of Kentucky, Lexington, Ky., contact Mary Lou Johnson, P.O. Box 13015, Lexington, Ky. 40512, (606) 252-5535.

11-12 Seminar, "Mine Management," Hyatt Hotel, Pittsburgh, Pa., contact McGraw-Hill Seminar Center, 331 Madison Ave., Suite 603, New York, N.Y. 10017.

12-13 10th Annual West Virginia Surface Mining Symposium, Marriott Hotel, Charleston, contact Patty Bruce, WVSMRA, 1624 Kanawha Blvd. E, Charleston, WV 25311, (304) 346-5318.

19-20 Seminar, "Successful Coal Export Marketing," Hyatt Hotel, Louisville, Ky., contact McGraw-Hill Seminar Center, 331 Madison Ave., Suite 603, New York, N.Y. 10017.

25-26 Seminar, "Negotiating and Administering Coal Supply Agreements," McGraw-Hill Building, New York, N.Y., contact McGraw-Hill Seminar Center, 331 Madison Ave., Suite 603, New York, N.Y. 10017.

26-30 Semi-Annual Meeting, West Virginia Surface Mining and Reclamation Association, Mountain Shadows Resort, Scottsdale, Ariz., contact Patty Bruce, WVSMRA, 1624 Kanawha Blvd. E, Charleston, WV 25311, (304) 346-5318.

February

17-18 Seminar, "Fundamentals of the Mining Industry," Hyatt Hotel, Pittsburgh, Pa., contact McGraw-Hill Seminar Center, 331 Madison Ave., Suite 603, New York, N.Y. 10017.

Feb. 27-March 1

Seminar, "Coal Transportation and Distribution," Westin Galleria, Houston, Tex., contact Kathy Eichel, National Coal Association, 1130 17th St. NW, Washington, D.C. 20036, (202) 463-2629.

March

16-18 Short Course, "Coal Laboratory Technician Training," University of Kentucky, Lexington, Ky., contact Connie Blakemore, P.O. Box 13015, Lexington, Ky. 40512, (606) 252-5535.

21-23 Sixth Annual Meeting, Mining and Reclamation Council of America, Mayflower Hotel, Washington, D.C., contact Moya Phelleps, MARC, 1575 Eye St. NW, Washington, D.C. 20005, (202) 789-0220.

23-24 Seminar, "Modern Mine Materials Handling," Hyatt Hotel, Pittsburgh, Pa., contact McGraw-Hill Seminar Center, 331 Madison Ave., Suite 603, New York, N.Y. 10017.

West Virginia Coal Bell

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