BURNOUT CONTROL AT THE ALBRIGHT COAL WASTE PILE FIRE[1]

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Abstract.--A novel technique for the control of fires in coal waste piles has been developed and tested by the Bureau of Mines. It is an important step in developing a comprehensive approach to solving the technical, environmental, social, and economic problems associated with fires on abandoned coal-mined lands. In the Burnout Control process, a pipe is inserted into the waste pile, and a large suction fan applies a vacuum to the interior of the pile causing ambient air to flow into the pile. The air flows through the porous waste and into the interior fire zones thereby enhancing the burning process. All heat and fumes produced are collected and exhausted through the suction pipe and fan. Burnout Control was tested in a 0.75 acre zone of a 300,000-yd^3 burning coal waste pile near Albright, WV. In this first trial, there was no intent to utilize the heat produced, but simply to test the applicability of the Burnout Control concept to a burning waste bank. Preliminary interpretation of the data indicates that Burnout Control is indeed applicable to burning coal waste fires, and that it can function in an environmentally and economically sound manner.

INTRODUCTION

The Bureau of Mines for several years has been developing an in situ combustion concept and technology called 'Burnout Control' which can be applied to the control of fires in underground coal mines and in coal refuse piles (Chaiken 1980, 1983; Kim et al. 1984). There are several important aspects related to Burnout Control which can become part of a comprehensive approach to solving the technical, environmental, social, and economic problems associated with abandoned coal-mined lands. First, is the extinguishment of the fire by burning the fuel to completion with control of all the heat and fumes produced. Second, is the potential utilization of the heat of combustion for production of electricity. Third, is the production of nonacid-producing coal slag products (red dog) which can fill mine voids and/or be used as a gravel substitute. Fourth, is the possible revenues from sale of heat and electrical energy and ash products which could offset the entire cost of individual reclamation projects. It is believed that this latter aspect - that is, reclamation in which costs are offset through utilization of waste - is essential if a major impact is to be made on the nations' Abandoned Mined Lands problems. This is because that the more conventional reclamation techniques would require the unrecoverable expenditure of many billions of tax dollars.

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At this time, significant progress has been made in developing a Burnout Control system by demonstrating its operation in field trials at a burning abandoned coal mine and a burning abandoned coal waste bank. The Calamity Hollow Mine Fire Project, which was carried out at an underground mine in 1982, has been previously reported in detail (Irani et al. 1983; Dalverny et al. 1984; Chaiken et al. 1984, 1987; Soroka et al. 1986). The field trial at the Albright Waste Bank Fire Project (Chaiken 1987) has been completed only recently, and this paper presents a preliminary report on that work. Detailed reports must await completion of the analyses of the approximatly 150,000 data points and 200 pages of written notes taken during the field operation.

BURNOUT CONTROL PROCESS

Burnout Control, is a method for burning coal wastes in situ involving exhaust ventilation through a pipe inserted into the pile with the amount of suction achievable with available fan systems. Maintaining the waste pile at negative pressure relative to atmospheric induces airflow through the surface of the pile and into the buried fire zones, while at the same time exhausting product heat and fumes through the fan. In essence, the process is like smoking a pipe of tobacco with one long continuous draw. The improved aeration of the pile is expected to lead to a faster and more complete combustion process. If necessary, flue gas scrubbing could be used to further clean the gases prior to exhausting them to the atmosphere. The thermal energy of the hot flue gases could be used in a conventional boiler or other heat exchanger prior to exhausting to the gases.

ALBRIGHT COAL WASTE BANK FIRE PROJECT[3]

Waste Bank Site

Figure 1 is a diagram of the Burnout Control system initially designed for the burning coal waste bank near the town of Albright, WV. The site

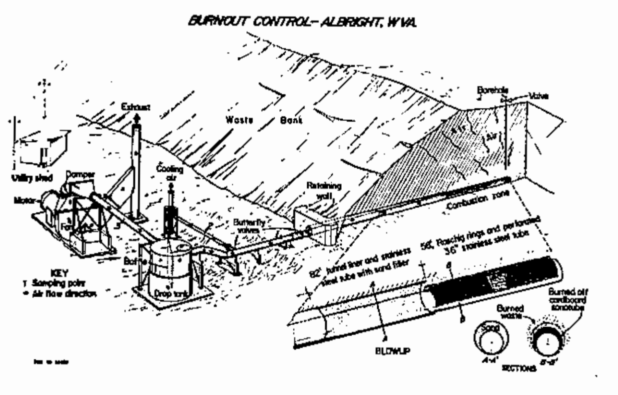

Fig. 1. Artist Rendition of Burnout Control System at Albright, WV.

itself is situated along the west bank of the Cheat River about 1 mi north of the town and directly across the river from the village of Ruthbelle. The waste pile (approximately 1700-ft long, 200-ft wide, 40-ft high) contains about 300,000 yd^3 of coal waste with fly-ash and other refuse typical of older dump sites in the bituminous mining region mixed in. Samples taken at different depths from seven cased boreholes located over a top surface area of 0.75 acre (the planned fire zone) indicated the waste to have an elemental composition corresponding to $CH_{1.033}O_{0.200}N_{0.013}S_{0.024}(ASH)_{0.33}$ with an average heating value of 5,800 Btu/lb or 50% of that of bituminous coal. Permeability tests made by exhausting air from the same seven boreholes, indicated an air permeability which generally decreased with depth, having an average value of about 200 D (or 20% of that of dry sand) near the base of the pile. Porous flow calculations (see Chaiken 1987) indicated that this permeability would support a 6,600 std.ft^3/min exhaust flow with a 5-ft diameter pipe at a vacuum level of 55 in H_2O. At an expected gas temperature of 1,750° F, the exhaust would correspond to a thermal output of 5 MW which could convert to 1 to 1.25 MW of electrical power. During the Albright field trial, no effort was made to utilize the thermal power generated.

Burnout Control System Design

Configuration of the burnout control system (Green International Inc. 1986) is shown in figures 1 and 2. The combustion manifold inserted into the bank was a 3/16 inch wall duct of 309 stainless steel, 138 ft long and 3 ft in diameter. The last 10 feet of the manifold tube consisted of a half-round section surrounded by a 48-inch cardboard sonotube filled with rashing rings and charcoal to assist in obtaining an initial uniform fire zone. Forty feet of the duct was perforated with about 300 2 1/2" holes and surrounded by a web thickness of up to 1.0 ft of 3-in refractory rashing rings held in place by the sonotube, which would burn away to result in a 4-ft-diameter, 50-ft-long, essentially uniform vacuum zone inside the pile into which combustion products would be drawn. A 5-ft-diameter steel tunnel liner, which served as a construction tool for inserting the combustion manifold, surrounded the unperforated length of the manifold. The annular space between the tunnel liner and the combustion manifold was filled with sand and stopped with a steel barrier constructed at a point where both ducts emerged from the pile. The combustion manifold outside the bank was connected to the fan through an expansion joint, a main shut-off valve, additional ducting, and a drop-out tank to remove any large particles from the exhaust. In this first field trial, there was no intent to utilize the heat produced, therefore the exhaust gases were simply emitted to the atmosphere after they were cooled by dilution with cold air which was drawn into the hot exhaust duct at a point before the drop-out tank (fig. 1, 2). However, the system design did allow for retrofit of an air pollution control system, if needed. As will be described in the next section, an alkali wet scrubber was eventually installed to control the exhaust emissions.

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[3]The assistance of Patriot Coal Co., Morgantown, WV, and the WV Department of Energy in making possible the use of the Albright site is gratefully acknowledged.

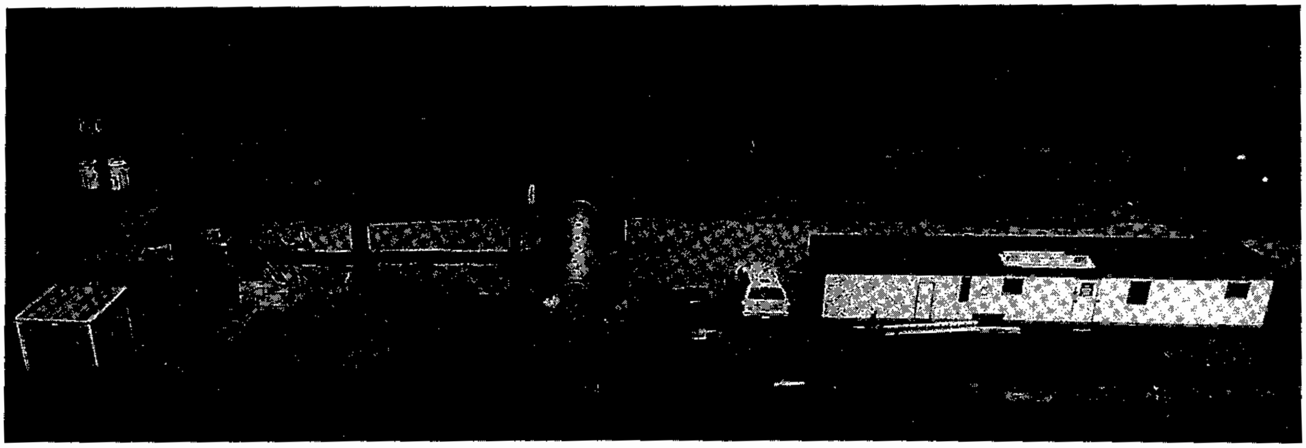

Fig. 2. View of Burnout Control System from Top of Coal Waste Bank. (prior to installation of alkali wet scrubber)

An 8-in-diameter auxiliary air inlet pipe was installed from the top of the pile to a point near the rashing rings (fig. 1). This pipe was to supply additional air for several possible purposes: 1) For igniting the waste immediately surrounding the manifold; 2) for cooling the combustion manifold if gas temperatures exceeded the working limit (1,800° F) of the 309 stainless steel; and 3) for afterburning the hot exhaust, if the gas mixture was fuel rich. As it turned out, this auxiliary air pipe never functioned properly, to the detriment of the third purpose, which during the burnout operations became most important. A new auxiliary air pipe eventually had to be installed from the backside of the waste pile (not shown in fig. 1 or 2). The exhaust fan was a centrifugal type, 1,700 rpm blower with corrosion resistant blades. Powered by a 400-hp, 2,300-V drive motor, it was designed to pull 40,000 std.ft^3/min. at 600° F, while maintaining a 50-in H_2O pressure drop. The extra capacity of the fan (20,000 scfm) was required to handle the dilution air used for cooling the exhaust.

The vacuum applied to the waste bank could be controlled by altering the position of the cold air inlet valve on the dilution air duct (in parallel with the manifold), and/or varying the damper opening to the fan inlet. It was also possible to completely stop the main flow from the combustion manifold at any time by closing the 36-in butterfly valve just downstream of the expansion joint and adjusting the vacuum at that point to zero. This was done routinely on numerous occasions during the burnout operations.

Instrumentation (direct reading and/or online for remote sensing and recording) was available to monitor pressures, flows, temperatures, valve positions, motor condition, and gas composition. A primary online instrument station (station #1) was located at the manifold where the high temperature exhaust exited the waste bank. Another online station (station #3), located in the duct leading to the fan inlet from the drop-out tank, yielded data on the cooled exhaust emitted to the atmosphere.

Burnout Control Operations

Around-the-clock operation of Burnout Control began in May 1986 and continued into the following months with the testing of equipment, instruments, and procedures. During this period, considerable burning took place in the waste around the combustion manifold which apparently had ignited spontaneously; however, the burning took place mostly under conditions of inadequate oxygen and exhaust temperature. Despite thermal outputs as high as 2.5 MW and exhaust temperatures as high as 450° C, low levels of oxygen prevented the complete combustion of the fuel gases present in the exhaust. The failure of the auxiliary air pipe to function properly contributed to the problem of a fuel rich stoichiometry. Under these conditions, the stack emissions contained low levels of odoriferous H_2S and unburnt hydrocarbons which in turn led to complaints from nearby residents. Fan operations were temporarily shutdown in order to install a flue gas scrubber for eliminating the nuisance odors, which occur only under the conditions of poor reaction stoichiometry.

A wet scrubber system based on a spray of sodium hydroxide solution was designed and built into the drop-out tank. In addition, a 5 MW capacity tube-in-shell hot water heat exchanger was installed in the duct leading to the drop-out tank. The heat exchanger was necessary in order to dissipate a major portion of the sensible heat of the exhaust prior to contact with the sodium hydroxide spray solution to prevent excessive evaporation of the solution. The modified Burnout Control system was startedup again in September and operated mostly intermittently due to a number of reasons: 1) The need to winterize the site; 2) the need for parts replacement and maintenance related to corrosion induced by the scrubber system; and 3) the need to insert a new auxiliary air inlet pipe into the waste bank for achieving an increase of oxygen into the hot manifold exhaust for more complete and cleaner combustion.

By January 1987, clean burning conditions were achieved, and through March 1987 it was possible to produce controlled thermal outputs of up to 5 MW and temperatures as high as 930° C (1,700° F)- the original maximum design level. It was observed that with exhaust temperatures exceeding 600° C (1,100° F) and oxygen levels exceeding 0.5 to 1.0% in the exhaust, all nuisance odors disappeared. Carbon monoxide in the exhaust was generally 140 to 200 ppm indicating essentially complete combustion, and sulfur dioxide stack emissions were only 200 to 400 ppm within air pollution requirements for the local area.

During an elevated vacuum test in March 1987, the temperature of the stainless steel duct inside the waste pile apparently exceeded its maximum working temperature (980° C or 1,800° F) for useful wall strength. Thus the 36-in diameter stainless steel pipe was sucked closed at a point about 30 ft into the pile, which terminated the field trial.

Output Data

Figures 3 to 8 depict some data-time plots encompassing the last 5 days of the field trial[4]. Figure 3 shows the vacuum level at station #1 on the combustion manifold which was varied from 25 to 50 in H_2O. The increase in vacuum after day 1 was an attempt to compensate for the observed decrease in flow (fig. 5). Normally, the vacuum and flow at station #1 follow each other quite closely. At the time however, the operator did not realize the decrease in flow was due to the collapsing combustion manifold. The exhaust temperature at this time (fig. 4) was at its measured peak of 930° C (1,700° F), with a corresponding thermal output of 5 MW (fig. 6). Even after collapse of the manifold, sufficient hot gas was exhausted to yield a thermal power level between 2 and 3 MW.

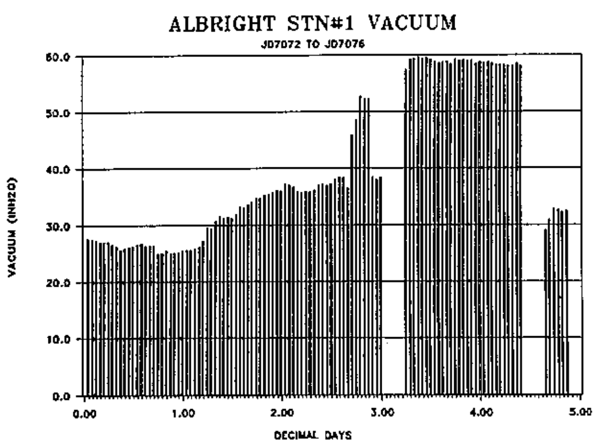

Fig. 3. Applied Vacuum at Station #1.

[4]The absence of data for part of the time in figures 3 to 8 is due to the fact that either the fan was turned off or the appropriate instrumentation was not functioning at the time.

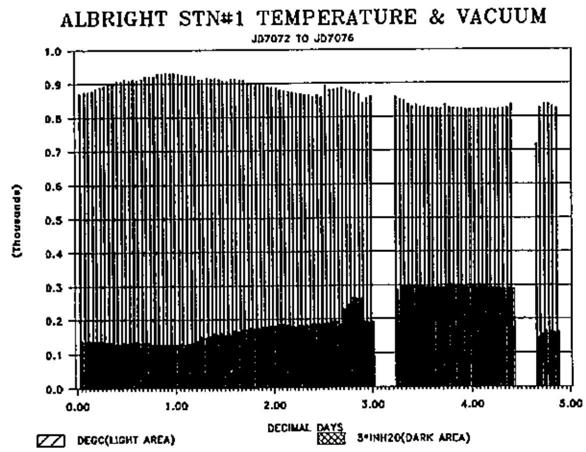

Fig. 4. Exhaust Gas Temperature at Station #1.

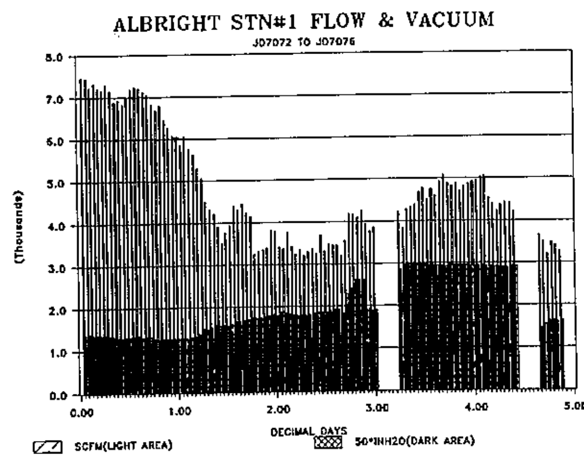

Fig. 5. Exhaust Gas Flow at Station #1.

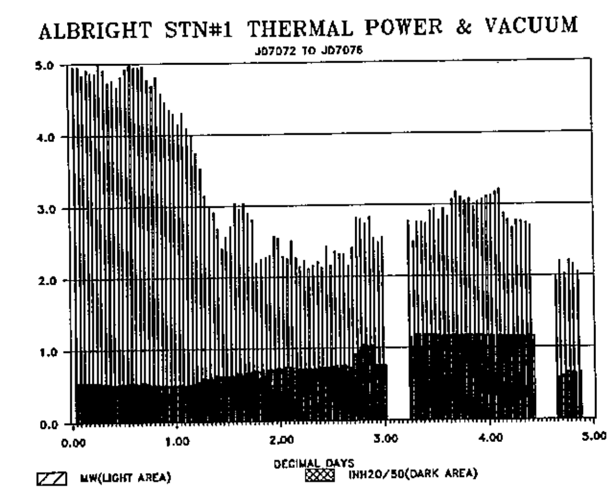

Fig. 6. Thermal Power Level of Exhaust at Station #1.

Figure 7 shows the effective energy gain by the Burnout Control process during the last 5 days of operation. This gain is essentially the amount of energy produced by burning relative to the amount of energy consumed by operation of the Burnout Control system. It is given here as the ratio of exhaust thermal power to fan motor consumption power after correcting for the amount of fan power used to pull in cooling dilution air and water vapor. Because the fan uses most of the electricity consumed during Burnout Control operations, the energy gain factor is a good indication of the economical viability of the process. The observed gains shown in figure 7 are about a factor of 50, and consistent with previous predictions (Chaiken 1980, 1987).

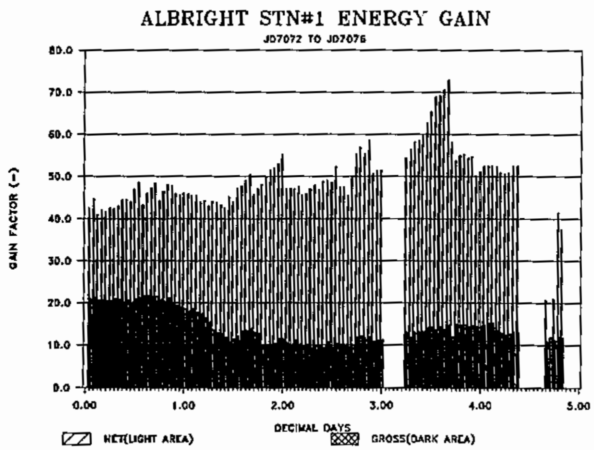

Fig. 7. Energy Gain Factor in Exhaust Gas at Station #1.

Figure 8 depicts the 5-day time plot of SOx emissions as determined from on-line gas sampling from the duct leading to the fan, i.e., after scrubbing. The levels of SOx shown here (140 to 240 ppm) are relatively small and probably acceptable in this locale. Future process designs may well have more efficient SO_x scrubbers that could reduce the SO_x emissions to even lower levels.

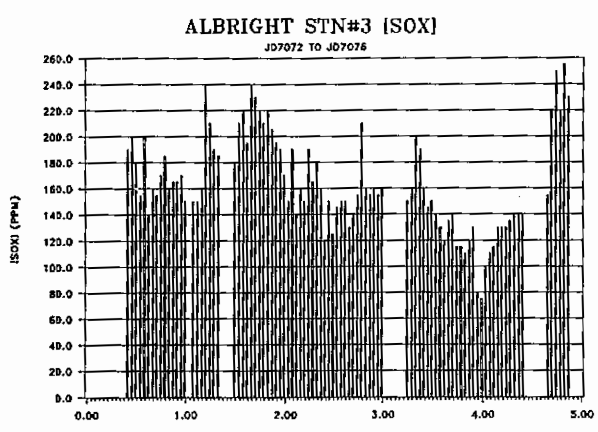

Fig. 8. SOX Emissions to Atmosphere. (measured at Station #3)

CONCLUSIONS

Work is still underway to analyse in detail the data and observations accumulated over the 1 year of the field trial at Albright. Meanwhile several significant results are already apparent:

1. The basic Burnout Control process is applicable to burning coal waste piles. An estimated 2,000 tons of waste were consumed during the trial.

2. Designed output levels of hot gas flow, temperature, and gas composition were achieved; however there are needed improvements in engineering design, especially for the khigh-temperature exhaust manifold and the exhaust gas scrubber.

3. Essential data were provided on what process controls are needed for optimum output.

4. Essential experience was obtained on controlling emissions and moderating flows.

Further data analyses are expected to reveal additional useful results - particularly on the propagation of the combustion zone within the bank, and the treatment and control of subsidence. Although this information is still forthcoming, it is clear that the work at Albright has already brought us a big step forward in establishing a viable means for controlling AML coal fires, and for converting smoldering coal wastes to an energy resource.

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