J. S. Afr. Inst. Min. Metall., vol. 84, no. 6.
Jun. 1984. pp. 153–158.

The effect of consumer specifications on the planning and operation of a coal mine

by N. T. HALGREEN*

SYNOPSIS

The use of coal for combustion, carbonization, and the production of synthetic fuel is discussed briefly, highlighting the effect of certain physical and chemical properties of coal on these processes. The effect of consumer specifications of properties such as calorific value, ash content, moisture content, and size consist on the planning and operation of a mine are discussed, including the influence of coal degradation through time or mechanical means. The effects of various mining methods on these parameters and on the utilization of coal reserves are discussed.

SAMEVATTING

Die gebruik van steenkool vir verbranding, verkooksing en die produksie van sintetiese brandstof word kortliks bespreek met die klem op die uitwerking van sekere fisiese en chemiese eienskappe van steenkool op hierdie prosesse. Die uitwerking van verbruikerspesifikasies wat betref eienskappe soos kaloriewaarde, asinhoud, voginhoud en groottesamestelling op die beplanning en bedryf van 'n myn word bespreek, insluitende die invloed van die degradering van steenkool deur verloop van tyd of meganiese effekte. Verder word die uitwerking van verskillende mynboumetodes op hierdie parameters en op die benutting van steenkoolreserwes ook bespreek.

Introduction

Carbon plays such an overwhelmingly important role in life that its relative scarcity may come as a surprise. It accounts for only 0,04 per cent of the total mass of the earth, and a mere 0,02 per cent of the carbon in the earth's crust to a depth of 5 km occurs in a form that can react with oxygen, the rest being in the form of carbonates, carbon dioxide, etc. Most of this reactive carbon occurs in very concentrated form in fossil fuels (peat, lignite, coal oil, and natural gas), and the known reserves of coal represent by far the largest proportion.

Fossil fuels are today not only the main source of energy but also the basis of many manufacturing processes (plastics, pharmaceutical products, iron and steel, aluminium, and many other materials in daily use). Some of these products are currently manufactured by the use of carbon derived from coal, but there is almost unanimity in the opinion that the production of oil will peak towards the end of the century and then decline, thereby increasing our dependence on coal for reactive carbon.

Coal is therefore a very important natural resource, and much effort has been expended (and is still being expended) on making the best of it. This obviously includes present and future consumers of coal and their specifications for the required product, since these could influence the planning and layout of any new mine, the methods to be applied, and the utilization of the coal reserves.

Since coal is mostly used as a heating and steam-raising fuel, or is carbonized to form cokes, chars, and related byproducts, or is converted into synthetic gaseous and liquid hydrocarbons, its most important chemical and physical properties, for practical purposes, are those that determine its response to oxidation and reduction. When heated, most coals evolve tarry vapours, gas, and moisture, and some coals soften and fuse into coke residue. In the presence of air, the combustible products burn. The tarry vapours normally burn with a smoky flame, the gases burn with a non-smoky flame, and the solid residue glows, leaving ash derived from the mineral matter.

Characteristics and Utilization

A brief look at the most important uses of coal will indicate some of the parameters that affect the consumer.

Combustion

Combustion of coal is by far the most important method of coal consumption in this country, and can be defined as the oxidation of carbon and hydrocarbons to carbon dioxide and water, with the accompanying release of heat.

What kind of coal is burnt in any particular combustion appliance is ultimately decided by availability and cost. Some of the more important characteristics that affect the operation of such combustion appliances are calorific value, moisture content, relative hardness, content of volatile matter, ash content, abrasive index, and ash characteristics. The calorific value determines the heat produced per unit input of coal. The moisture content, particularly the surface moisture, affects the flowability of the coal through a coal-handling system, the flame stability, and the combustion efficiency. In addition to moisture content and size of fuel fed to a mill, ease of pulverization, as determined by the grindability index, is an important factor affecting mill capacity. Ultimately, the degree of hardness influences the fineness of the coal supplied to a furnace. The abrasive index of a coal is an indication of the amount of wear that it will cause in a mill and on other components. The volatile matter affects ignition and flame patterns, and influences the relationship between primary and secondary air. As well as contributing heavily to objectionable stack emissions, coal ash and inorganic volatile material generated by thermal alteration of the mineral matter in coal will not

* Mine Manager, Middelbult Colliery, P.O. Box 5236, Secunda, 2302 Transvaal.

SA ISSN 0038–223X/$3.00 + 0.00.

only adversely affect heat-transfer processes by fouling heat-absorbing and -radiating surfaces, but also threaten the integrity of a combustion system by causing corrosion and, in certain circumstances, erosion.

Carbonization

The coke industry undoubtedly has the most stringent standards of all the major coal-consuming industries, and coals used in the manufacture of coke must be carefully selected. Furthermore, the proper preparation of coals before carbonization is essential for the production of high-quality coke. If a coal is to be satisfactory for use in the production of metallurgical coke, it must first have sufficient coking ability to yield a coherent coke alone or in blends with other coals. Secondly, it must be possible to carbonize the coals or blends without damage to ovens or difficult operating problems. Lastly, the coal must be low in ash and sulphur. However, it is not enough that a coal possesses these attributes as an average; it must possess them consistently. Therefore, although the main purpose in the cleaning of coals is to reduce ash and sulphur, it also serves another important function: because coal varies to some extent in different areas of a mine, preparation yields a coke with uniform chemical and physical properties.

Gasification

The gasification process at present employed in this country requires coal of a limited size range, since the Lurgi-type gasifiers in use have a fixed bed. Ideally, the ratio between the top and bottom size should be no more than 6 : 1. It is imperative that the range of size distribution, as well as of ash melting-point, of the coals to be fed to this process should be established during the exploration stage. A low ash melting-point results in the formation of clinkers inside the gasifier.

The main technical difficulties in gasification do not arise from the chemistry of the process, but from the nature of coal. In principle, any process must achieve efficient contact between the solid carbon surface and the reacting gases, and this is affected by the size distribution of the coal particles in the system. Extreme fines (smaller than 3 mm) cannot be used in Lurgi-type gasifiers. However, since the gasification process requires large quantities of process steam, the fines are normally used for the generation of steam. Here the problems of coal quality are essentially the same as discussed earlier under *Combustion*.

Liquefaction

Although there are not yet any commercial liquefaction plants in operation, large-scale pilot tests have indicated that this could be a viable long-term alternative. Unlike gasification, which does not require clean coals, the technology of coal liquefaction is so complex that it can best be applied to washed coals of uniform quality. The feed coals should be limited to 10 per cent mineral matter, but preferably less than 4 per cent. Washing the coal reduces the extraneous ash content.

Meeting Consumer Specifications during Mining

When planning a coal mine, the coal producer should bear in mind the several measures that can be adopted during the production process to meet consumer specifications. These relate to selective mining, control of impurities during mining, and control of size consist, weathering, and moisture.

Selective Mining

Depending upon the particular geographical location or seam characteristics, modern practices of raw-coal preparation can be used to obtain improved product quality and uniformity. Nevertheless, certain coal markets may require only marginal quality while others may require very high quality, and these objectives can be sought by the starting of the 'preparation' of coal underground at the working face. Underground preparation involves the selection of those portions of the seam which already meet the specifications or can be cleaned to satisfy predetermined market requirements involving:

- maintenance of uniformity in chemical quality,
- elimination of removable impurities,
- control of sizes and size ratios, and
- control of moisture.

The methods employed to attain these objectives vary widely with the seam under development, the mining equipment available, and the changing trends in consumer markets.

When a mine is opened and development progresses into various areas, the petrography of the coal in the seam does not remain uniform, the character of the roof and the floor are subject to change, and the character and prevalence of the mineral impurities are subject to considerable variation.

The quality of coal marketed from any mine depends upon intelligent foresight, planning, execution, and supervision. Mining becomes a highly technical art.

The quality of coal as determined by chemical and petrographic analysis is without question one of the most important considerations in the development and life of any coal mine. Variations in such properties as volatile matter, ash, sulphur, calorific value, ash melting-point ranges, reactivity of the coal, and petrography are of considerable interest, and to a limited extent also such properties as phosphorus content, free swelling index, plasticity, hardness, and ash composition. The maximum and minimum specifications of these characteristics as established by competitive market conditions place definite limits on the marketability of a coal.

There are few coal seams that do not show wide variations in such characteristics as calorific value, and ash and sulphur contents throughout the geographical area in which they occur. These variations exist not only over the bedding plane of a seam but also along the columnar sections. Close scrutiny and evaluation of the data derived from sampling and exploration are necessary in the determination of the optimum mining and preparation methods required to yield a given quality of product. Selective mining over the bedding plane can be achieved by the production of coal from mine sections containing the desired quality, and control of the distribution and mining intensity of the sections.

For the close control of selective mining, it may be desirable for the exploratory data to be supplemented by systematic sampling of the working faces in both entry and room development at preselected intervals. The identification of quality areas by the plotting of sampling results on mine maps is essential in providing guidance to mine management and allowing the correlation of control projections. Planning, development, and supervision of tonnage assignments from given mine areas to meet definite production-control schedules constitute a function that must be co-ordinated with sales or consumer requirements.

Control of Impurities during Mining

The occurrence of impurities in coal affects most other important parameters. Any part of a seam containing coal of an unacceptable quality can be regarded as an 'impurity' in the coal seam and, although reference is made here mainly to impurities, any other parameter, such as calorific value, can be handled in very much the same way.

Impurities may occur as distinct partings that vary in thickness, brightness, hardness, and regularity. They may consist of prominent and irregularly occurring clay veins, sulphur balls, pyrite, or pockets and streaks of hard coal. The secondary source of impurity is the medium surrounding the seam, i.e. the roof and the floor. The problem of preventing contamination of the coal at the working face during mining is greatly increased if the roof and floor material is soft or irregular. It is frequently necessary for part of the seam to be left at the top to form a coal roof and part of the seam at the bottom to serve as a floor. This practice may coincide with the elimination of an undersirable portion of the seam, as well as being a desirable safety precaution.

Care and uniformity in the application of conventional or continuous mining equipment govern the successful elimination of roof or floor impurities. The coalcutter used in conventional mining may be employed to cut out an undesirable section of coal at any point in the seam, but more often the cut is made above or below undesirable coal. Carelessness in the operation of conventional loading machinery can readily result in contamination by machine cuttings that are loaded out with face coal. Systematic checking of the thickness of roof and bottom coal can be employed to improve selectivity. Where wide variations in quality occur between two distinct sections of a seam, the method of loading out coal can result in intimate and uniform mixing, or uncontrolled and erratic quality.

In thin seams, where the working height is limited and where conventional and continuous mining machines are commonly employed, the elimination of inferior top and bottom coal becomes a more difficult problem.

Since coal mining is a destructive process, the breaking or rending loose of the coal from the solid necessarily has a shattering effect on embedded impurities and on roof and bottom shales. Definite and attainable standards, or goals as determined by mine management, coupled with effective, competent supervision of the production, will provide the degree of uniformity in the quality of the raw coal that can realistically be expected.

Of the modern mechanical mining systems, conventional mechanized mining is perhaps the most nearly ideal means by which selectivity at a given coal face can be reasonably successful in eliminating undesirable seam contaminants.

Where a continuous mining system is employed using a continuous miner or longwall shearer, selectivity at the face is often appreciably minimized. With these systems, mining is usually non-selective and practised over the full seam.

Differences in the quality of the coal produced by the conventional and continuous mining systems are often very pronounced.

An appreciation of the effect of impurities on the quality of coal loaded for a preparation plant can be gained if it is considered that the presence of 0,5 t of 100 per cent ash material will raise the ash content of the raw coal contained in one 56 t capacity railroad car by 1 per cent. Since the heavier impurities found in and with coal beds vary from 60 to 80 per cent in extraneous ash content that might be removable with more selective mining, a considerable quantity of extraneous impurities can generally be found in raw coal that can cause it to increase two or more percentage points in ash content.

In mining systems utilizing the continuous miner, the control of extraneous impurities depends largely on the skill and attentiveness of the machine operator. Inexperienced or inattentive operators may allow continuous mining machinery to penetrate into the floor or into the roof, introducing needless and undesirable impurities. Some measure of the seriousness of the introduction of roof and floor material into raw coal as a result of poor practice is evidenced by the fact that attention is at present being given to the development of probes and sensors for mining machinery that will shut down the equipment if it is operated outside the desired coal limits. This could also result in considerable cost savings due to cutting elements not being damaged by the cutting of roof or floor material.

With the longwall shearer, the opportunity for the limitation of extraneous dirt largely exists in the correct selection of the design, style, and type of machinery so that a minimum of undesirable top and floor material will result from any given mine and working place.

In systems using the continuous miner or longwall shearer, success in controlling the introduction of impurities was typically confined to the seam areas immediately adjacent to the roof and the floor. Since both these systems are generally applied as full-seam mining systems, it is impracticable to exclude thin partings and other impurities within the coal seam from the mined product. Roof and bottom rock are the sources of contamination that do not require seam pre-preparation. Shale, if present, can be removed either before or after the broken coal is loaded. Many seams show a thin layer of shale between coal and roof that tends to crumble and separate from the roof within a few hours after the coal has been removed. Unless taken down, these layers tend to drop off and mix with powdery cuttings located with the broken coal at the face, or they tend to fall into the materials-handling system during and after loading.

In pillar extraction, continuous miners often cut through ribs into falls of roof or goaf, dragging varying quantities of waste back into the cut to mix with the cuttings.

Perhaps the most overlooked type of extraneous material, which can cause needless and costly plant downtime, is foreign material consisting of discarded steel of all kinds, pieces of wood of all sizes, detonator and blasting-cap wires, used tamping, occasional explosives and exploders, roof bolts, and pieces of brick and blocks. This material is introduced into the raw coal largely through carelessness or indifference of the mine organization.

The most common items of discarded steel are machine bits, some broken off as a result of faulty tempering during sharpening and some pulled out of the equipment during operation. Roof bolts, bolt plates, and cable hangers constitute another major cause of contaminant material, particularly where the mining system is a retreat, or pillar-recovery, system utilizing continuous miners. Where face conveyors are used, chain parts and flights are misplaced frequently near the face while extensions are being made.

It is not an uncommon occurrence for supervisory employees at coal-utilizing plants to be able to associate a single piece of roof-support timber or bolt as the source of plant downtime, or as the cause of major damage to equipment amounting to thousands of rands.

Control of Size Consist

According to the mining system in use, characteristics of structure and hardness inherent in the coal seams are initially responsible for influencing the percentage of sizes produced. Low-volatile coals in the bituminous group are universally softer and weaker in structure than higher-volatile coals. Hardness and density of structure also increase with inherent ash content. Even within a seam, individual benches and stratified layers show widely varying characteristics of structure and hardness. In some seams that are mined conventionally, machine cuts are made in the softer parts. Some seams show marked lines of cleavage, which must be taken into consideration when mine projections are established. Some sections of individual mines may even show weaker structures than others, yielding friable coal that could ultimately change the percentage ratios of material sent to the coarse and fine sections of a cleaning plant. Plant systems can be seriously overloaded to the extent that plant efficiencies deteriorate markedly, and may require the construction of costly and unplanned auxiliary cleaning or screening facilities.

In addition to natural handicaps in maintaining a minimum of degradation, many operating factors are detrimental. However, these can be controlled with the exercise of care and supervision. In most well-regulated mines, standard entry and room widths, as well as centres, are established, subject to changing conditions of overburden, more to conform with mining systems, roof control, and productive capacity than with any consideration of their effect on the size of the product. Nevertheless, wide entries show a higher ratio of large and coarse sizes than do narrow entries.

Where development and pillar extraction are concurrent and continuous, the effect of roof pressure on the structure of the coal is negligible. Where pillars left between rooms are too narrow to support the overburden, or too large an area is developed at once and there is too much time delay in advance and retreat, pillar coal may tend to yield a significantly different size consist than that obtainable in the solid coal. This change in the size of raw coal as mining progresses from solid coal to pillar coal results from pressure-caused pillar fractures, which, when subsequently mined by the continuous mining system, yield coarser coal.

Conventional Mechanized Mining

In the conventional mining system, the successive processes of cutting, drilling, blasting, and loading at the face have a pronounced effect on the production of sizes, depending on whether or not the practice follows certain well-established principles. Cutting and drilling produce an abundance of fines, while blasting produces large lumps and some fines. As the product is loaded and conveyed outside, further degradation occurs. If the amount of fines produced from each of the four major phases of conventional mining can be minimized, the resulting coarser product offers more preparation flexibility, since the coal size can be reduced more effectively through controlled crushing and screening to yield an optimum size distribution for subsequent concentration.

The influences upon the production of fines by the cutting phase of conventional mining are numerous, involving both the design of the cutting machine and the application of the machine to the face.

The coal cutter employs a chain-lacing design that allows some bits to tear out longitudinal grooves in the coal, while others break out the intervening cores or walls between the grooves. The type of chain lacing employed and the number of bits used have a marked effect on the particle size of the resultant cuttings. Indeed, various chain-lacing patterns are possible, and it is always advisable to experiment with a number of patterns to see which gives the best results.

Cutting bits vary widely, and many styles, shapes, and forms are available. Many factors influence the selection of bits, some of these being the inherent coal grindability indices, the seam characteristics, the degree, type, and location of impurities present in the seam, the cleavage characteristics of the coal, the abrasion characteristics, and the economics of bit replacement and maintenance. The ultimate selection of a bit for a given mining area should be based on extensive experimentation. The choice should strongly favour a bit style that promotes chipping and fracturing and minimizes a grinding type of penetration, thus producing less fines.

The drilling of holes can be done by regular drilling crews using electric drills or by special mobile drilling units. It is important, with any of these methods, that no holes are drilled in advance of cutting.

Drilling-hole patterns are almost as numerous as are coal mines. The method to be used in the drilling and blasting of the working places in any mine can best be found by tests underground. The number of holes, and their spacing, location, and distance from the sidewall, cannot be determined in any other manner, although experience in the mining field can be used as a guide.

One basic principle that should be emphasized in the selection of a drilling pattern is that each hole and resultant blast should 'relieve' the next. A second is that the burden on each hole should be adjusted to the maximum charge that can be loaded, although this maximum must remain within the legal maximum. Consequently, a common pattern is a row of holes in the top in thin coal, or in the top and middle in thicker coal, with the centre hole blasted first in the bottom row in two-row faces, and in the top in one-row faces.

Blasting for the prepreparation of size is frequently inadequate for the following reasons:

(a) indifference or lack of experience on the part of the miners,
(b) incorrect tamping and blasting of holes simultaneously, and
(c) failure to clean out cuttings from the cut-and-drill holes.

Continuous Mining

Continuous miners combine, in a single unit, the functions of dislodging and loading the coal into an initial unit of the mine transportation system.

Size consist is affected to some degree by the specific type of continuous miner used and upon its application underground. It is known that operators reduce the size of coal further while waiting for shuttle cars by allowing the machine bits to crush the product already cut.

In longwall mining, a shearer is used to break the coal from the solid. The selection and its effect upon size consist, the presence of impurities, and the operational techniques are subject to a number of variables, each of which requires considerable study and evaluation. Typical variables to be examined primarily include the following:

(i) seam hardness, thickness, and height;
(ii) the presence, location, and thickness of rock partings;
(iii) the presence and degree of concentration of rolls, clay veins, faults, and sulphury concentrates; and
(iv) roof and floor characteristics.

Difference in Size Consist between Conventional and Continuous Mining

Differences in the size consist of coal produced by conventional mechanized mining as compared with that produced by continuous miners are more pronounced in the coarser size ranges than in the fine ranges. Under most circumstances, there are only slight differences in the minus 6 mm size fractions produced by each mining method.

Generally, the continuous miner produces a substantially smaller amount of plus 50 mm sizes than in conventionally produced coal.

Weathering

Weathering is the tendency of coals to break apart when they are exposed to atmospheric conditions. It is well known that nearly all coals in contact with the atmosphere sooner or later show signs of weathering, which usually adversely affects the calorific values and coking properties.

Low-rank coals show a pronounced tendency to disintegrate or slack on being exposed to the weather, particularly when they are wetted and dried alternately or are subjected to hot sunshine.

Coals that slack readily contain relatively large amounts of moisture. When exposed to the weather, such coals lose moisture rapidly. As the coal loses moisture at the surface, the moisture from the interior of the piece gradually drifts outwards to the surface. If the loss of moisture at the surface proceeds at a faster rate than that at which it is replaced by moisture from the interior of the piece, shrinkage at the surface is greater than that in the interior; consequently, stresses are generated in the coal surface, and the coal cracks and disintegrates. Likewise, when air-dried coal is wetted by rain, the exposed surface of the piece gains moisture more rapidly than the interior, causing greater expansion in the coal surface and further breakage.

Slacking, as in the handling of a friable coal, causes the formation of an excessive amount of fine material at the expense of the coarser sizes, thus decreasing the value of the coal for most uses. Moreover, storage of coals that slack readily is unsatisfactory, not only because of the loss of the more valuable coarse sizes, but also because slacking increases the tendency of coal to ignite spontaneously owing to the increased surface area exposed to oxidation. These coals can be stored with comparatively little trouble from slacking only when the loss of moisture is retarded.

Control of Moisture

The moisture content of raw coal can vary over an extremely wide range, the amount present often being determined by a number of factors. Some of these are as follows:

(1) inherent moisture,
(2) effectiveness of the mine drainage systems,
(3) the natural mine drainage as affected by the mining plans,
(4) the use and effectiveness of water applied at the face to suppress dust,
(5) the addition of moisture during transportation and/or open stockpiling, and
(6) the inflow of water into the strata.

The undesirable effects of excess moisture in raw coal are numerous. Such moisture often increases transportation and shipping costs, since the costing is sometimes based on the total mass of the raw coal, including all the non-combustibles present. The presence of excess water creates material-handling problems at transfer points, chutes, feeders, and bins as a result of the sticky nature of wet raw coal. Such coal has a deterrent effect in the preparation plant, particularly in the crushing and dry-screening operations. In addition, other phases of the preparation process can be seriously hampered when wet raw coal is present in the plant feed.

Any unnecessary addition of water to the coal at the face or later should therefore be avoided. Adequate drainage systems should be provided and maintained to direct water away from the working face, especially in areas where mining is proceeding on the dip. Since dust control at the face is usually maintained by the use of sprays during cutting or continuous-mining operations, care should be exercised not to over-wet the face with spray water. Wetting agents can be used to reduce the amount of spray water required, as well as to provide more effective dust control. The addition of moisture during transportation and/or open stockpiling can be reduced by the scheduling of transportation, handling, and inventory to provide minimum retention times between mine and plant. Stockpiles and stocking areas should be designed to provide adequate natural drainage and disposal of surface run-off.

Combination of Mining Methods

As indicated throughout, various mining methods have a pronounced effect on certain parameters that are specified by the consumer. At present there is a tendency with the newer mines to attempt a balance in output from conventional mechanized mining, continuous mining operations, and longwall mining.

Depending on the depth below surface, the use of conventional mechanized mining results in a utilization of coal reserves varing between 30 and 75 per cent. Longwall mining must be used in conjunction with continuous miners. This results in a higher average percentage extraction, but is considerably more limited in its application. In terms of coal utilization, continuous mining has the widest scope in that it can be applied on bord-and-pillar mining, pillar extraction, and rib-pillar extraction. This would result in a percentage extraction comparable with that in longwall mining, but with the added advantage that fewer limitations are imposed on the system.

Should circumstances favour the use of longwall mining, the stockpiling capacity and the choice of stockpiling method and equipment are also affected. Provision has to be made to augment the coal supply from stockpiles while a longwall face is being moved from one location to another.

Depending on the coal demand of the consumer, problems can be experienced if additional coal is supplied from a live stockpile, since the stockpile would have to be large enough to supply additional coal at a high rate for several weeks, thereby exposing coal in the stockpile to the effect of weathering.

Conclusion

It has been shown that the quality of mined coal is determined by the nature of the deposit, the layout, supervision, and operation of the mining process, and developments in mining engineering.

As regards further developments in coal 'preparation' to meet consumer specifications, it is expected that the average surface moisture of coal will rise because considerably more water is added to the coal in the process of longwall mining, pillar extraction, and rib-pillar extraction. These mining methods result in a higher percentage extraction, and it is foreseen that the use of these methods will increase.

The mining of lower-quality coal seams in the future would lead to an increase in the dirt content. The rising dirt content will further increase the proportion of fines in the raw coal and the amount of ash in the fine size range. Meeting these demands will pose an ever-increasing challenge to the mining men of tomorrow.

Bibliography

BERKOWITZ, N. *An introduction to coal technology.* London, Academic Press, 1979.

BETHE, W. P. Impact of changing raw coal properties and market trends on coal preparation. Fifth International Conference on Coal Research, Sep. 1980.

GORBATY, M. L., LARSEN, J. W., and WENDER, I. *Coal science.* London, Academic Press, 1982. vol. 1.

GURUSWAMY, S. Resistance of coal to breakage. *J. Sci. Indus. Res.*, 1951.

LA GRANGE, C. C. Pretoria, Fuel Research Institute, *Report* no. 28, 1951.

MIKHAIL, M. W., and PATCHING, T. H. Size degradation of bituminous coal from Western Canada. Canadian Institute, May 1980.

MOODIE, B. Pretoria, Fuel Research Institute, *Report* no. 8, 1975.

PITT, G. J., and MILLWARD, G. R. *Coal and modern coal processing.* London, Academic Press, 1979.

RAAB, G. A. Pretoria, Fuel Research Institute, *Report* nos. 59 (1972), 35 (1973), 48 (1973), 54 (1973), 11 (1974), 26 (1974).

SZENDI-HORVATH, G. On the fracture toughness of coal. *Austral. J. Coal Min. Techn. Res.*, no. 2. 1982.

VAN KREVELEN, D. W. Coal and its properties related to conversion. Plenary lecture at the International Conference on Coal Conversion, Pretoria, Aug. 1982.

Furnaces

Furnaces '84 Exhibition, organized by Fuel & Metallurgical Journals Ltd, is to be held in Birmingham (England) on 26th and 27th September, 1984. It will provide an opportunity for interested people to view a complete range of plant, equipment, and services central to the thermal-processing industries.

Accompanying the exhibition will be two major international conferences on the theme of 'Furnaces in Thermal Processing into the 80's'.

The first, on 26th September, emphasizes 'Progress in Furnace Equipment Technology' and will be organized by Fuel & Metallurgical Journals Ltd. It will deal specifically with the heat treatment and reheating of metals, particularly from the viewpoint of the equipment user. A wide-ranging programme of papers is scheduled, which has already attracted a great deal of interest from metal thermal-processing sectors.

On 27th September, the Wolfson Heat Treatment Centre, University of Aston in Birmingham, will be organizing a conference on 'Advances in Heat Treatment Processes', and will look at developments aimed at improving the efficiency, cost, and quality aspects of industrial heat-treatment processing.

For full details of the Exhibition and Conference, please contact Mr Colin Robinson, Exhibition Manager, Fuel & Metallurgical Journals Ltd, Queensway House, 2 Queensway, Redhill, Surrey, RH1 1QS. Tel.: 0737 68611. Telex: 948669 TOPJNL G.