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COAL MINING IN CANADA

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COAL MINING IN CANADA

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ABSTRACT

The current Canadian coal production is approximately 43×10^6 tonnes per annum. Two-thirds of this output is classified as thermal coal and one-third as coking or metallurgical coal. The three western provinces produce 92 percent of the total, the remainder is produced by the provinces of Nova Scotia and New Brunswick on the eastern coast of Canada.

The geological conditions in the western coalfields are markedly different from those in eastern Canada. The bulk of the coal in the western provinces is mined by surface mining methods whereas in eastern Canada underground mining predominates.

This paper provides an overview of the Canadian coal mining, reviewing the general state of the industry with emphasis on current and projected mining techniques.

EXPLOITATION MINIÈRE AU CANADA

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RÉSUMÉ

La production canadienne de charbon est actuellement d'environ 43×10^6 tonnes par année. Les deux tiers de cette production font partie de la catégorie du charbon thermique et un tiers de la catégorie du charbon à coke ou charbon métallurgique. Les trois provinces de l'ouest fournissent 92 % de cette production et le reste provient de la côte est du Canada, soit des provinces de la Nouvelle-Écosse et du Nouveau-Brunswick.

La situation géologique des champs houillers de l'ouest est très différente de celle des houillères de l'est du Canada. Dans les provinces de l'ouest, l'extraction du charbon se fait surtout à ciel ouvert tandis que dans l'est, on procède par extraction souterraine.

Le présent résumé donne un aperçu de l'industrie canadienne d'exploitation du charbon et fait le point sur la situation générale de l'industrie en soulignant les techniques actuelles ou futures d'extraction du charbon.

INTRODUCTION

In terms of the world's recoverable coal reserves Canada stands in eighth place providing 0.6% of the world's total (Fig. 1). In comparison her neighbour, the United States, is in the first place with 27.8% followed by the U.S.S.R. with 24.1%.

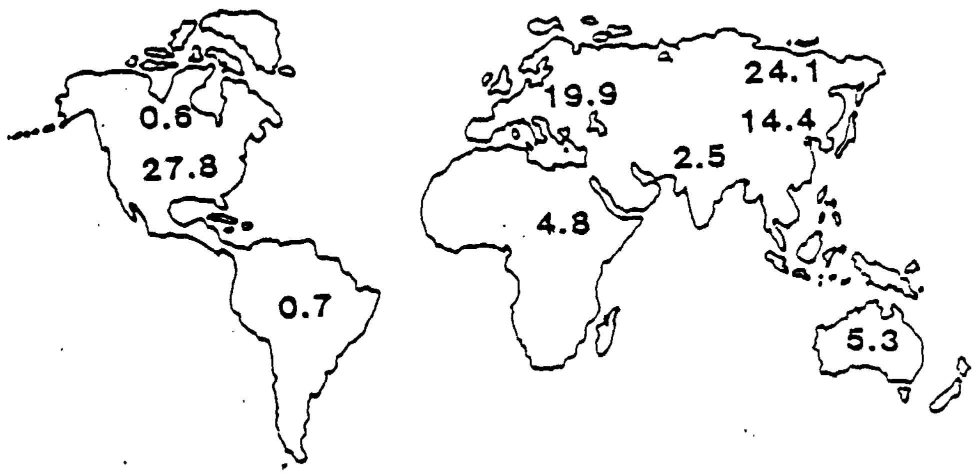

Fig. 1 Distribution of World Recoverable Coal Reserves (in Percentages)

Fig. (2) shows the occurrences of coal in Canada by rank. While several provinces contain coal deposits, by far the largest deposits are found in the three western provinces of Alberta, British Columbia and Saskatchewan. As a conservative estimate 90 percent of the lignitic, 80 percent of high volatile bituminous and nearly 100 percent of sub-bituminous, and low and medium volatile bituminous coals are located in the three western provinces.

During the past decade Canadian coal production of all types increased from a 18.8 x 10^6 tonnes in 1972 to 25.3 x 10^6 tonnes in 1975 to 42.8 x 10^6 tonnes in 1982. Of this total bituminous coals accounted for 52%, sub-bituminous 30% and lignite 18%. Approximately two thirds of this output (29 x 10^6 tonnes) was classified as thermal coal and one third (14 x 10^6 tonnes) as coking or metallurgical coal.

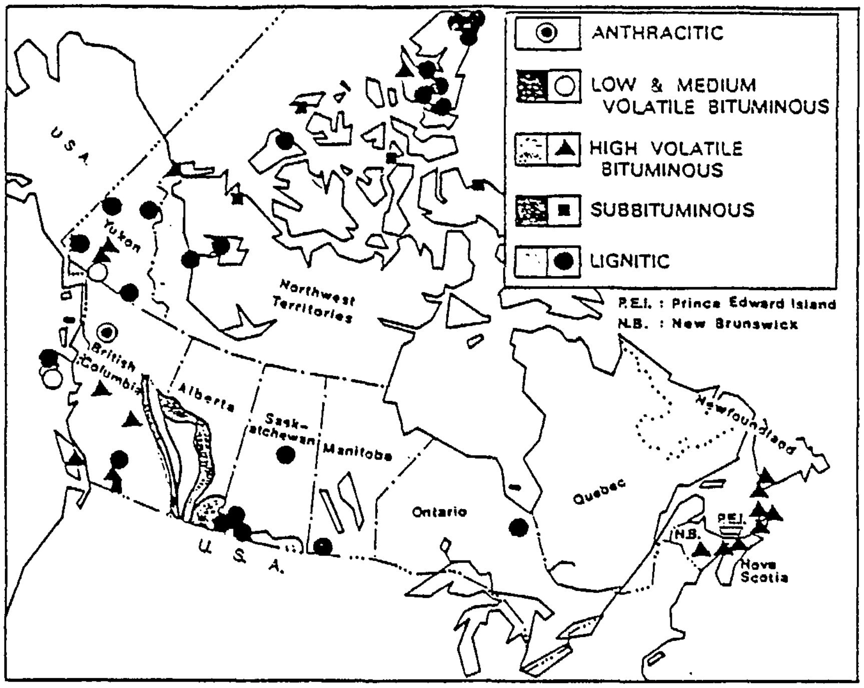

Fig. 2 Coal In Canada

The three western provinces currently produce 39.3 x 10^6 tonnes of coal - 92% of the total; the remainder - 3.3 x 10^6 tonnes (8%) is produced by the provinces of Nova Scotia and New Brunswick on the eastern coast of Canada - some 5500 kms away from the centre of the western coal-fields. The bulk of the west Canadian coal (96%) is produced by surface mining methods, whereas on the east coast mining is predominantly underground and only a small portion (15%) of the total is produced by surface mining.

In 1982 approximately as much coal was imported into Canada as was exported. A total of 15.8 x 10^6 tonnes of coal were imported, mostly from the eastern United States, primarily for use in the provinces of Ontario and Quebec. Almost two thirds of the imported coal was thermal with the remaining third metallurgical coal for the steel industry. It is cheaper to import coal into central and eastern Canada from the eastern United States rather than from western Canada due to high transportation costs.

The 1982 coal exports from Canada totalled 16 x 10^6 tonnes. Metallurgical coal accounted for 81%, thermal coal - 19%. Japan was the largest buyer with 10.8 x 10^6 tonnes or 67% of the total exports. This was followed by Korea's 2.3 x 10^6 tonnes and Germany's 0.95 x 10^6 tonnes. Smaller quantities of thermal coal were shipped to Europe, South America and the United States.

Canadian consumption of coal during 1982 totalled 41.5 x 10^6 tonnes. The electric power industry accounted for 33.7 x 10^6 tonnes, steel industry 5.6 x 10^6 tonnes and others 2.2 x 10^6 tonnes.

Table (1) provides salient statistics on Canadian coal production, imports, exports and production by provinces.

TABLE (1) CANADIAN COAL STATISTICS X10^6 TONNES

	1975	1979	1980	1981	1982
World Production	3 614.9	4 074.0	4 130.0	4 350.0	4 389.0*
Canadian Production	25.3	33.0	36.7	40.1	42.8
Canadian Consumption	25.6	34.8	37.2	38.4	41.5
Imports	15.8	17.5	15.9	14.8	15.8
Exports	11.4	13.7	15.3	15.7	16.0
Net Imports	4.4	3.8	1.6	(0.9)	(0.2)

PROVINCIAL PRODUCTION

	1983*		1982	
Nova Scotia	3.0		3.0	
New Brunswick	0.55		0.5	
Saskatchewan (lignite)	7.5		7.5	
Alberta (sub-bituminous)	14.2	21.4	13.1	20.0
(bituminous)	7.2		6.9	
British Columbia	11.3		12.3	
TOTAL CANADA	44.25		42.8	

Note: Production and exports do not equal consumption and imports due to industrial stockpiling.
Source: Energy Statistics Section EMR.
*Preliminary

MINING METHODS

Mining methods adopted for the development of coal seams in a particular area largely depend upon the geological setting. Geology can simplify or add complexities to mining directly affecting the economics of an operation.

In western Canada, particularly in the Mountain Region, (Fig. 3) the coal bearing strata are highly folded and faulted causing considerable tectonic thickening and thinning of coal seams in certain locations. There are numerous coal seams present of varying thicknesses (up to 20 m thick) at gradients varying from 0° to almost vertical. Coals are friable in nature. The coal seams in the Foothills and Plains Region of Alberta and lignite deposits of Saskatchewan are almost flat lying.

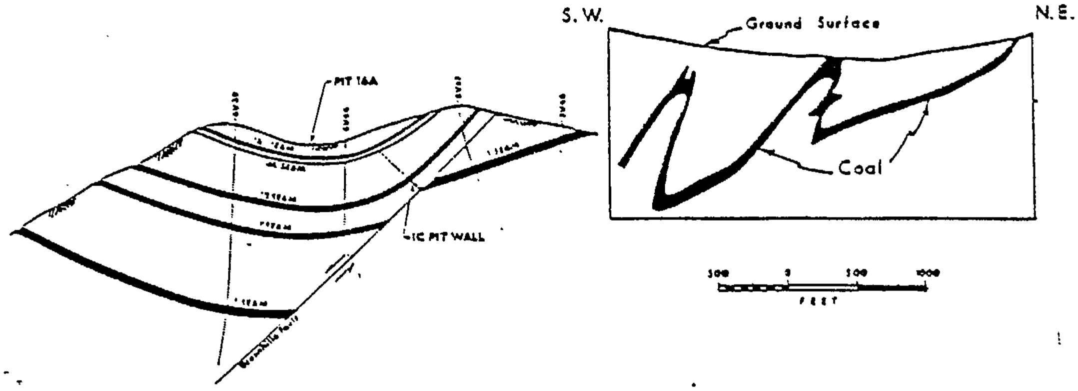

Fig. 3 Typical Geological Sections: Coalfields of British Columbia and Alberta

In Nova Scotia, in the Sydney Coalfield which supplies almost all of the coal in this province, coal seams are gently dipping (10-12° seaward), are of a thickness between 1.7 to 3.5 m and are free of geological abnormalities such as faults and folds that are encountered in the provinces of Alberta and British Columbia. Only a small part of this coalfield is on land; the greater portion is beneath the Atlantic Ocean.

As stated earlier 96% of the total coal production from the western Canadian provinces is by surface mining. The remainder 4% is from underground operations. On the east coast 85% of all coal is produced by underground mining methods. It is proposed to briefly review the methods of mining under three sub-headings:
Surface mining in western Canada
Underground mining in western Canada
Underground mining in eastern Canada

SURFACE MINING IN WESTERN CANADA

In the provinces of British Columbia and Alberta most surface coal mines are open pit terrace operations. The operations use typical truck shovel methods extracting multiple coal seams from several multi-bench work faces. Only one coal operator in the Mountainous Region uses a dragline. Several draglines are being used on coal projects in the Foothills and Plains Region of Alberta. Saskatchewan lignite is also mined with high capacity long boom draglines.

The top soil and unconsolidated material is removed by a variety of equipment including scrapers, front-end loaders and hydraulic shovels; hard, consolidated overburden is drilled and blasted. Blast holes are drilled with rotary crawler mounted rigs using bits in the 22 cm to 31 cm diameter range - for a 12 m high bench a typical hole will be 14.6 m in depth including the sub-grade drilling of 2.6 m.

The primary explosive used for blasting is ANFO. Wet holes which cannot be dewatered are loaded with a water gel slurry. In harder rock, e.g. sandstone, aluminized ANFO containing 3 to 7 percent of Al is used.

Overburden is excavated mostly by cable shovels and front-end loaders; recently the hydraulic shovel has gained considerable acceptance. Electric cable shovels with 11, 19 and 23 m^3 rock dippers form the major excavation unit.

Overbruden is hauled to waste dumps either in the pit or outside of it in rock-body trucks. The most popular size is 154 tonnes but trucks of 90 tonnes, 110 tonnes, 180 tonnes and in one case even 315 tonnes are being used.

As has been noted western Canadian coals are friable and do not require drilling and blasting. Coal is usually loaded by the front-end loaders and/or hydraulic shovels into coal body trucks. Front-end loaders and hydraulic shovels of up to 19 m^3 bucket capacity are currently in use.

The majority of bench heights in western Canadian pits are 12 to 15 m. Overall pit slopes are 45° to 50° with some localized steeper slopes. In moderately dipping seams the footwall is often followed. In seams dipping greater than 30° benching of the footwall, to create safety berms, may be necessary. In some cases dewatering has been necessary to relieve artesian pressure and stabilize the pit walls, in others rock bolting of the footwall has been utilized.

Haulage road widths determined by the size of the equipment in use are 25-30 m wide and grade between 6 to 10%. In the mountainous topography switchback haulage roads are provided in some pits. Safety ramps for stopping runaway trucks are provided and considerable research has been undertaken into vehicular braking systems.

Depending upon the topography at the mine site end tipping or area dumping (dumping in layers) of the overburden is carried out. In the mountainous region end tipping is frequently used. End tipping normally does not permit compaction of the disposed material and thus results in line dumps and occasional dump failures. Waste dumps are usually terraced and settle to the angle of repose of the waste material between 35 to 37°.

Guidelines and government regulations exist relating to the reclamation of mined out pits, waste areas and other areas disturbed by the mining activity. Waste dumps are required to be sloped to an overall maximum of 27° for reclamation. Backfilling of the pit is usually carried out as soon as space is available. In almost all cases overburden is deposited externally to the pit for the first few years.

UNDERGROUND MINING IN WESTERN CANADA

The two operators in western Canada producing coal by underground mining methods are Smoky River (formerly McIntyre Mines Ltd.) and Westar Mining (formerly B.C. Coal Ltd.). The combined annual production from the two collieries is approximately 1.5 million tonnes.

The Smoky River mine had tried conventional retreat longwall mining on a limited scale in the early 1970's but without success. A decade later, with the availability of more sophisticated mining equipment, longwall mining is being reconsidered. At present, however, all coal is produced by variations of room and pillar methods.

A typical layout has a 5.5 m wide three-entry development on 25 m centers with angled crosscuts on 30 m centers. Rooms are 55 to 60 m long. When pillaring the pillars are split in two directions parallel to the rooms and crosscuts. The slices are taken to left and right. More recently McIntyre have introduced a five-entry development system.

The equipment in use consists of the standard drum type continuous miners (Lee Norse & Joy) and cable reel shuttle cars that dump through crawler-mounted feeder breakers onto the belt conveyors. Twin boom, electric roof bolting machines are used to install mechanical roof bolts with mesh screen on a square pattern. Sides are supported by wodden props, lagging boards and resin set wooden dowels. Junctions are supported by steel beams on wooden chocks.

The coal recovery with the room and pillar system averages 50-55%.

At Westar Mining room and pillar method has been used on a small scale to mine the flatter (4-11°) portions of the No. 10 coal seam. The No. 10 seam provides all of the underground coal mined by Westar.

The equipment used has been similar to that used at Smoky River consisting of a combination of a continuous miner, shuttle car and belt conveyor with roof support being achieved with roof bolts.

The steeper sections (10-55°) of this thick seam (16-18 m) are being extracted by hydraulic mining.

This technique was first introduced by Westar at their Balmer South mine in 1969. A paper on Westar's hydraulic mining operations was presented to the 9th World Mining Congress held in Dusseldorf (1976). Since then several other papers on this subject have appeared in the technical press. For this reason only a brief reference to this technique is made.

In this method a jet of water is used to cut, load and transport the coal from the face into a gravity fluming system. Entries and sub-levels are driven by continuous miners fitted with an "aquachute" used to transfer all the coal from the development workings into the flume system.

Pillar extraction is done by water discharged under high pressure through the monitors. The actual pressure at the monitor varies depending on its height and the position relative to the high pressure pump on the surface. At the pump the pressure is about 15.8 MPa (2300 psi) and the flow is 95-100 litres per sec (1500-1600 USGPM).

Until recently all coal mined at Westar has been above drainage and has been transported to the surface entirely by flumes. More recently a panel (No. 6) has been developed which is below the drainage level; therefore, the coal has to be lifted to the surface. An underground dewatering station screens out the +5 mm (0.2 in) size coal for conveyor transport. The fines in the slurry form are transported to the surface dewatering facilities.

An estimated coal recovery of between 50 to 60% is achieved at Westar's hydraulic mine.

UNDERGROUND MINING IN EASTERN CANADA

Large scale underground coal mining operations in eastern Canada are limited to three producing collieries on Cape Breton Island, Nova Scotia, in the Sydney Coalfield. The mines are operated by the Cape Breton Development Corporation (CBDC), a Government of Canada Corporation.

The CBDC produces approximately 3 million tonnes of thermal and metallurgical coal from these three operating mines - No. 26, Lingan and Prince Colliery. Lingan produces twice as much as each of the others. Lingan and Prince are 'slope' mines whereas No. 26 is served by two shafts sunk in 1923. It is the oldest underground coal mine in Canada still operational.

Although room and pillar mining has been practised at shallow depth in the past all the existing mines currently employ the longwall system of extraction. Lingan and No. 26 Collieries employ the typical advancing longwall whereas Prince has converted to shortwall retreat mining from a room and pillar operation.

Only one seam is extracted at each of the mines. All of the present workings are submarine. Further development in each of the mines will extend the mine operations even further under the ocean-floor. Stipulations with respect to minimum thickness of cover between the sea and mine workings are followed. Mining design is based upon a calculated maximum tensile strain of 8.5 millimeters per meter (mm/m) at the seabed.

A typical advancing longwall face at No. 26 and Lingan Collieries is 200-220 m long. A 60-75 m wide coal pillar is left between adjacent units for roadway protection. In addition a coal pillar, 65 m wide, is left between the face start line and the nearest main deep. This configuration of layout gives a resource extraction of 60 to 65%.

The longwalls are fully mechanized and are equipped with powered supports, double ended ranging drum shearers and armoured face conveyors. Roadways are driven by roadheaders such as the Dosco's Mk11A and the Anderson Strathclyde's RH22 with a wet cutting head.

At Prince Colliery mining has progressed from a small scale strip mine operation to room and pillar to retreat longwalling. It is the shallowest of the three mines operated by CBDC - 190 m below the sea level compared with

500-750 m for the Lingan and No. 26 Colliery. Due to the shallow depth and the stipulation of maintaining the sea-bed tensile strain to within the prescribed CBDC limit of 8.5 mm/m, it was decided to open two shortwall faces to be mined on the retreat.

The first retreating shortwall face was introduced in May 1980. The face was 60 m long and equipped with standard face equipment comprising of powered supports, armoured face conveyor and a double-ended ranging drum shearer. A face output per man-shift (O.M.S.) of 37.2 tonnes was achieved. Since then several shortwall faces have been mined.

The benefits of retreat mining, where it can be successfully applied, are fully recognised. For practical reasons advance longwalling will continue for some years at Lingan and No. 26 Colliery. Studies are in progress to develop procedures to convert the advancing longwall to retreat in the existing mines. For new projects now in the design stage a typical full-scale retreat mining and its many variations such as alternate advance/retreat (Fig. 4) are being considered.

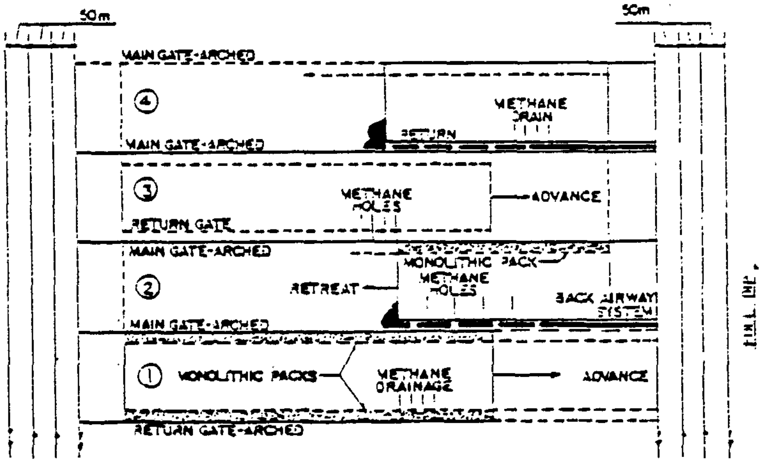

Fig. 4 An Alternate Advance/Retreat System for CBDC Mines

The mines in the Sydney Coalfield are gassy with a methane release approaching 60 m^3/tonne of coal mined. Systematic methane drainage is carried out at all existing mines. Comprehensive methane extraction and collection plans have been developed for the new mines.

An additional item of interest is the computer-based environmental monitoring. Such a system has been operational at No. 26 Colliery for some time. A second system is due for installation shortly in Lingan Colliery. Fig. (5) depicts a layout of the main components of the overall system.

RESOURCE CONSERVATION AND PRODUCTIVITY IMPROVEMENT

In the surface mining of coal particularly in mountainous region of western Canada due to the difficult geological environment problems are faced in recovering in situ coal. Mining losses and dilution are high.

Some 80 to 90 percent of coal is recovered from major seams dipping to up to 30° and not unduly disturbed by geology. From seams sandwiched between the distorted and broken strata, depending on the seam thickness, recoveries of 40 to 50 percent are obtained. In such cases dilution is very high. In case of thinner seams which are in close proximity to major seams recoveries can be as low as 20 percent to nothing.

New methods and techniques are being continually sought to improve in situ recovery and to minimize dilution. The approach taken has been two prong.

First, greater degree of in-pit supervision has been introduced to ensure that the top coal is not removed with overburden and the bottom coal is not left in place. With metallurgical coal selling at $70-80/tonne incentive to establish such supervision is high.

The second approach has been not to use methods and machines which might cause further pulverization of naturally occurring coal. The greater the quantity of fines in the coal, the higher the processing cost is since the flow sheet to treat such coals becomes more complex. A typical west Canadian process plant will incorporate three cleaning circuits, e.g. dense medium, hydrocyclones and froth flotation. Hydrocyclones and froth flotation sections are added to clean fine coal - two stage hydrocyclones will process 0.5 mm x 0.2 mm size coal and froth flotation - 0.2 mm x 0.

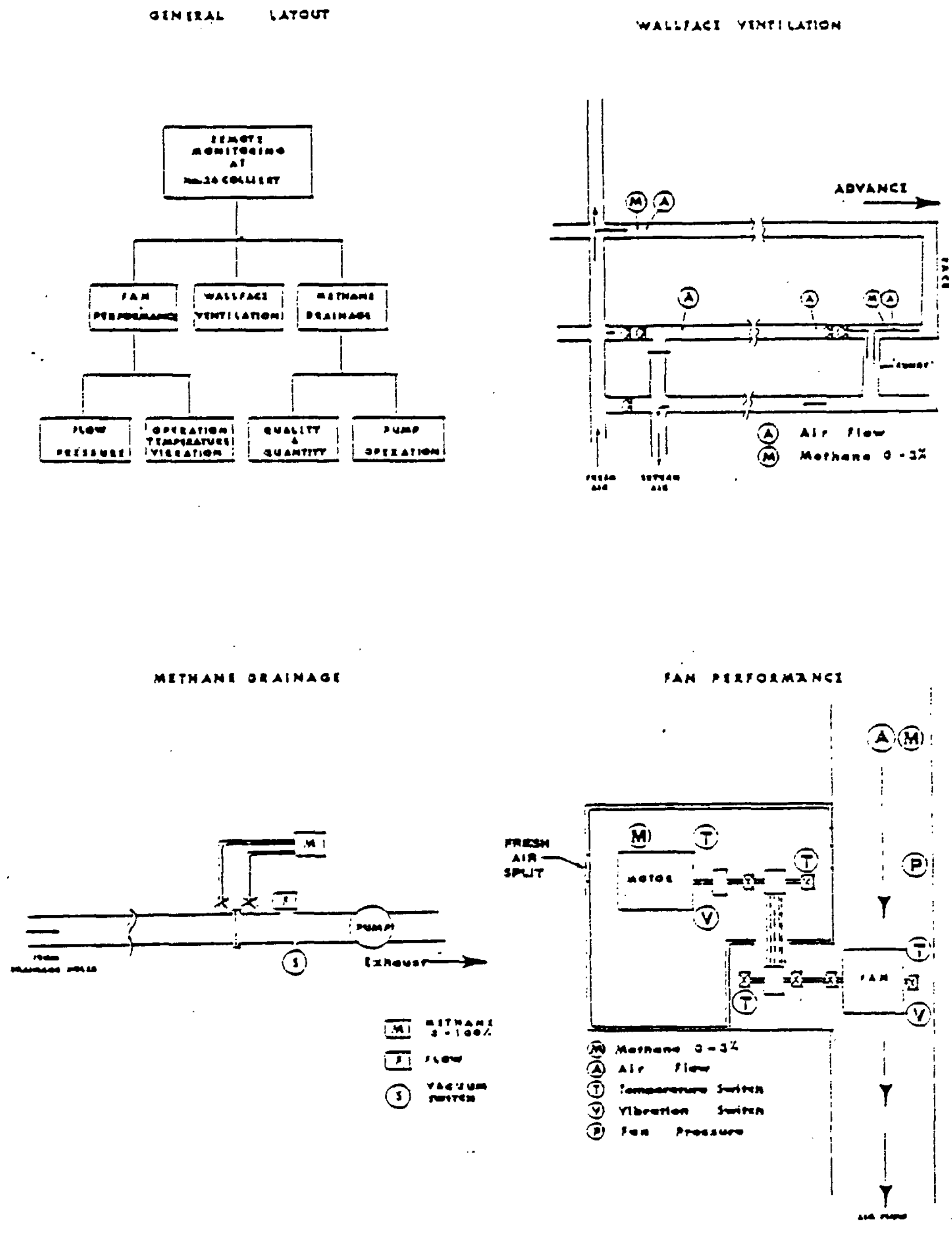

Fig. 5 Main Components of Computer Based Environmental Monitoring System at No. 26 Colliery

For this reason equipment such as hydraulic shovels and backhoes are used. High breakout force and capacity for selective mining thereby providing better separation between coal and waste at the coalface, has contributed to remarkable acceptance of this type of machine.

The surface mines of western Canada are highly mechanized and use the most modern of mining equipment. On several projects high capacity draglines are in use. Longer boom draglines are used to mine deeper overburden. The largest dragline working in Canada is with the Saskatchewan Power Corporation operating in its lignite operation. The dragline has a 121.9 m long boom and a 69 m^3 bucket.

Although not yet operational for high capacity thermal coal projects producing 6-10 million tonnes of coal per annum, various equipment combinations such as dragline/conveyors, bucket wheel/conveyors, stacker/reclaimers and cross pit conveyors etc. are being considered and their application and economics evaluated. For long distance transportation high capacity, high speed (1000 fpm) belt conveyors have been installed on several new coal mining projects. Greater application of belt conveyor systems is foreseen in Canadian coal mining.

Motivated with a desire to conserve resources and improve in situ coal recovery the west Canadian underground mine operations are seriously considering the application of longwall mining where applicable. Overall coal recoveries of 80-85% are considered feasible compared with the best recoveries of 50-60% in room and pillar and hydraulic mining.

Developments of the past few years in longwall technology have expanded the application of this method such that it has been applied in thin and thick seams, inclined seams and at much shallower depths than hitherto considered possible.

Hydraulic mining is versatile and will continue to be used, and find increasing application in thick and irregular seams as well as in seams which are very gassy, dusty and prone to outbursts. Combinations of schemes such as the cutting of coal with a shearer loader or plough equipped with a water jet assisted cutting mechanism and the transportation of cut material from the face in the form of slurries are being examined, particularly for harder coals where seams are gassy and the incidence of frictional ignitions on the coalface exists.

In Nova Scotia, schemes to improve the recovery of in situ coal by redesigning the conventional longwall layouts are being evaluated. It is considered that resource recovery could be increased by another 20% by eliminating pillars of coal left between the panels (to protect gateroads). In this regard the possibility of reusing gateroads to serve two adjacent longwall faces is being considered. In new projects such schemes have been incorporated in mine design. Particularly in retreat mining reusing of roadways will reduce the amount of development work necessary.

In another situation significant, developed coal reserves in existing and planned collieries are sterilized due to their shallow depth of solid cover to the seabed. These coal blocks cannot be mined by conventional longwall caving techniques due to the inherent danger of creating excessive (>8.5 mm/m) seabed tensile strain.

In the past such blocks of coal have been mined by room and pillar methods. Due to poor roof conditions only limited success was achieved.

It is considered that a greater portion of these reserves can be exploited with smaller scale selective mining methods (e.g. retreating shortwalls). Plans along these lines are currently being developed.

Future mining calls for the recovery of coal from depths of up to 1200 m and from workings extending up to 13 km from the coastline. As the mine workings extend deeper many problems associated with deep mining particularly in gassy seams, are manifesting themselves.

The first and most significant is the problem of gas outbursts. At No. 26 Colliery which is currently 770 m below sea level there have been a number of incidents of gas outbursts. Other problems relating to depth are expected to arise due to increased ventilation requirements and roof pressures. There is no local experience in multiple seam longwalling. Sequence of extraction can help alleviate the problem of higher roof pressures. Studies are in progress to develop first-stage guidelines utilizing the prevailing experiences in other countries longwalling under similar geological environment.

A serious problem faced in Nova Scotia arises from the presence of sandstone channels within the coal seam which can result in frictional ignition on the coalface when struck by the picks of a shearer loader. In 1979 such a frictional ignition caused an explosion at No. 26 Colliery resulting in fatalities. Since then an applied research program has been initiated with the aim of controlling such ignitions.

Methods of predicting the existence of rock intrusions ahead of mining are being evaluated. An underground demonstration program has been initiated to test thru-flush pick and sintered synthetic diamond inserts for the shearer drums. Success of these demonstration projects will lead to a reduction in frictional ignition hazard, eliminate or reduce dust concentration on the face, prolong bit life and improve economics by use of long-life picks. Studies have also been initiated to evaluate the existing and upcoming technology, such as the water jet-assisted cutting, to mine coal on the face in place of the conventional shearer loaders.

Together with the steps taken for resource conservation, measures have been taken to improve productivity. This has been achieved in part with greater degree of various forms of mechanization, increased use of available equipment, by improving ancillary services and in part through various schemes relating to improved industrial relations.

As has been described, all production faces are equipped with modern longwall equipment. Much of it is imported although consideration is being given to manufacture some components locally. Hemscheidt shield supports are manufactured in Sydney, Nova Scotia under a licensing agreement.

Monorail systems have been introduced for the recovery and transportation of heavy equipment. In the recent past a G.M.T. (GYRO Mining Transportation Ltd. U.K.) high speed manriding train was installed at the Prince Mine. Currently studies are in progress to identify suitable systems for rapid transport of personnel and materials for the existing and new generation of CBDC mines.

Undersea mining places serious constraints on the transportation routes. The workings extend farther and farther from the land based portals/shafts increasing the distance to be travelled by personnel, materials and mineral. Therefore the incentive to find a suitable mode of transportation remains very high.

A Canadian built tunnel boring machine has recently started excavating a series of 3.5 km long parallel access tunnels at the Donkin-Morien coal project of CBDC. Designated as M-300, the machine is a first for Canada in terms of its size and usage underground in a coal mine. This 7.6 m diameter machine weighs 350 t, and has a total horsepower of 2050 kw. It is a hybrid that incorporated the shielded construction style common in earth borers with a rock cutting head. (Fig. 6)

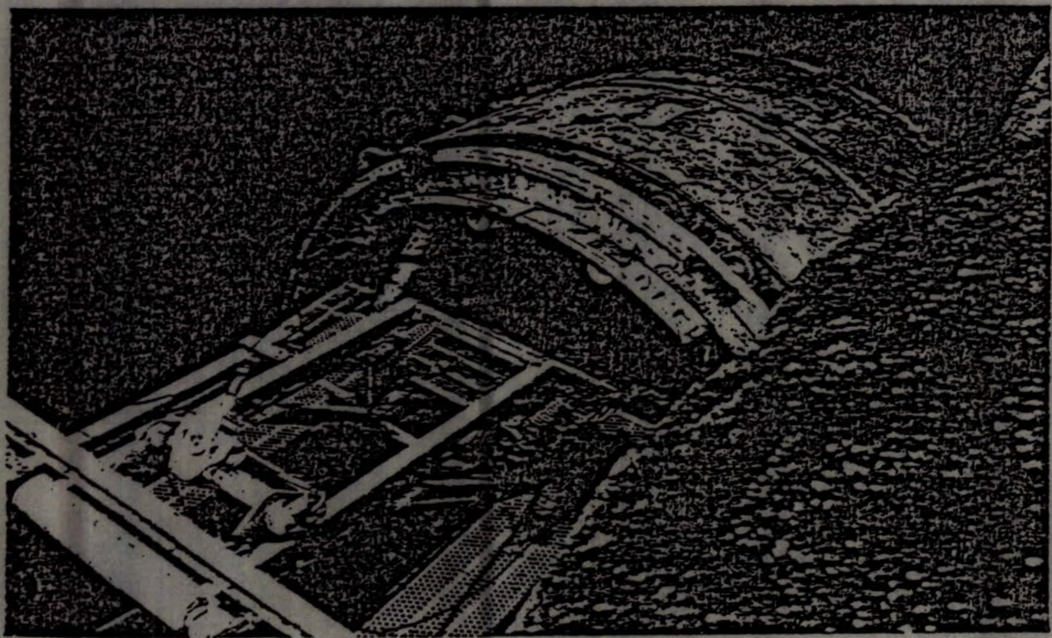

Fig. 6 Canadian built tunnel boring machine operating at the Donkin-Morien Coal Project of CBDC

CONCLUDING REMARKS

The Canadian coal industry, like the coal industries in some other industrialized nations have gone through a cycle of ups and downs. Coal lost ground during the 1950's and 1960's because of the competition from oil and gas. The oil crisis of the early 1970's provided a shot in the arm improving the fortunes of the coal industry. Since then the Canadian coal industry has continued to expand providing coal for domestic use and export. The current world wide recession and stable oil prices have dampened somewhat the plans for a further growth of this industry - albeit temporarily.

Although Canadian coal production is small compared to the world leaders such as the United States and U.S.S.R., modern technology is used in its production and processing. Recently renewed emphasis has been placed on applied research in these two areas carried out through the research laboratories of the Canada Centre for Mineral and Energy Technology (CANMET) - a federal government department.

The application of modern technology has maintained the competitive position of Canadian coal in the world market. The production costs of Canadian mines are competitive with comparable mines elsewhere in the world. The cost coupled with the relatively stable labour force providing security of supply and a desire of overseas buyers to diversify their sources has given Canada good leverage in the coal export trade. None the less in today's export market Canada faces stiff competition from other exporters. The past few years have seen huge capital investments to improve the overall economics of shipping coal. This has been achieved by expanding and improving the infrastructure from the exporting mines to the coastal ports.

The port capacity has been increased by expanding the existing facilities and by building a new port at Prince Rupert to serve mainly the coal exports from north-east British Columbia. Almost all export coal from the western mines to the port is carried by unit trains a distance of approximately 1100 kms. Sizeable investments have been made in increasing rail capacity by improving railway track, double tracking and route diversion to reduce severe track gradients met on difficult mountainous terrain.

ACKNOWLEDGEMENTS

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